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TITLE:

**Theory-Based Motives for the Impasse in Counterspace Weapons Regulation**

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# Abstract

Taking into account the profound global utility of near-earth space, and the increasing threat posed to it by orbital debris, this thesis attempts to explain why a seemingly well-established system of international governance has failed to deter the testing, and genuine considerations for operational employment, of counterspace (CS) weapons. In doing so, it seeks to identify motives based in fundamental international relations (IR) theory. While recognizing the criticality of a U.S. commitment to any effective CS weapons regulation, it is hypothesized that the nation's well-established opposition to such legislation can be explained using constructivist principles.

Structure is added through the application of specific research objectives (SROs). These include describing the physical and operational complexities of the space environment, the nature of CS weapons and their employment considerations, and the orbital debris problem (SRO 1), conducting an analysis of applicable IR forums, existing international space law, and pertinent historical events as they pertain to shaping modern foreign policy positions (SRO 2), and formulating realistic proposals for advancing the conduct of responsible behavior in space by curtailing the employment of CS weapons (SRO 3).

While the pursuit of SRO 1 provides context, SRO 2 directly addresses the research question. A review of regulatory instruments confirms their inadequacy in providing enforceable guidelines. However, it also establishes that normative standards of behavior have been explicitly defined. A subsequent analysis of recent events indicates a blatant disregard for these standards by Russia and China, validating modern U.S. policy and strategy positions. From a constructivist point of view, this partially validates the research hypothesis. Aspects of realist theory, specifically Power Transition Theory, are also necessary to account for the actions of Russia and China as strategic competitors. Finally, in addressing SRO 3 the thesis provides a starting point for subsequent research and debate.

# Acronyms

| | |
|---|---|
| ABM | Anti-Ballistic Missile |
| ADAC | Attitude Determination and Control |
| ASAT | Anti-Satellite |
| ASI | Italian Space Agency |
| BLOS | Beyond Line-of-Sight |
| C2 | Command and Control |
| CD | Conference on Disarmament |
| CNES | French National Center for Space Studies |
| CNSA | Chinese National Space Administration |
| COPUOS | Committee on the Peaceful Use of Outer Space |
| COTS | Commercial-Off-the-Shelf |
| CPLA | Committee, Policy and Legal Affairs Section |
| CS | Counterspace |
| CSA | Canadian Space Agency |
| CSOC | Combined Space Operations Center |
| CSSI | Center for Space Standards and Innovation |
| CSTD | Commission on Science and Technology Development |
| DIA | Defense Intelligence Agency |
| DLR | German Space Agency |
| DoC | Department of Commerce |
| DoD | Department of Defense |
| DoS | Department of State |
| DoT | Department of Transportation |
| DRDO | Defense Research and Development Office |
| DSS | Defense Space Strategy |
| E.U. | European Union |
| ECOSOC | United Nations Economic and Social Council |
| EM | Electromagnetic |
| EMP | Electromagnetic Pulse |
| ESA | European Space Agency |
| EW | Electronic Warfare |
| FAA | Federal Aviation Administration |
| FCC | Federal Communications Commission |
| FoV | Field of View |
| GB | Great Britain |
| GEO | Geostationary Earth Orbit |
| GGE | Group of Governmental Experts |
| GLONASS | Global Navigation Satellite System |
| GMT | Greenwich Mean Time |
| GPS | Global Positioning System |
| HEO | Highly Elliptical Orbit |
| HPM | High-power Microwave |
| ICBM | Intercontinental Ballistic Missile |
| IADC | Inter-Agency Space Debris Coordination Committee |
| IR | International Relations |

| | |
|---|---|
| ISR | Intelligence Surveillance and Reconnaissance |
| ISRO | Indian Space Research Organization |
| ISS | International Space Station |
| ITAR | International Trafficking in Arms Regulations |
| ITU - | International Telecommunications Union |
| JAXA | Japanese Aerospace Exploration Agency |
| JPL | Jet Propulsion Laboratory |
| JSPOC | Joint Space Operations Center |
| JTF | Joint Task Force |
| KARI | Korean Aerospace Research Institute |
| KKV | Kinetic Kill Vehicle |
| LEGEND | LEO-to-GEO Environmental Debris Model |
| LEO | Low Earth Orbit |
| LOE | Lines of Effort |
| LSC | Legal Subcommittee |
| MEO | Medium Earth Orbit |
| METOC | Meteorological and Oceanographic |
| MIT | Massachusetts Institute of Technology |
| NASA | National Air and Space Administration |
| NDS | National Defense Strategy |
| New START | New Strategic Arms Reduction Treaty |
| NSfS | National Strategy for Space |
| NSS | National Security Strategy |
| NTM | National Technical Means |
| NWG | Nuclear Working Group |
| ODMSPs | Orbital Debris Mitigation Standard Practices |
| ODPO | Orbital Debris Program Office |
| ORDEM | Orbital Debris Engineering Model |
| OSWG | Outer Space Working Group |
| PAROS | Prevention of an Arms Race in Outer Space |
| PMD | Post Mission Disposal |
| PNT | Position Navigation and Timing |
| PRC | People’s Republic of China |
| PTBT | Partial Nuclear Test Ban Treaty |
| ROSCOSMOS | Russian State Cooperation for Space Activities |
| RPO | Remote Proximity Operations |
| SAS | Space Applications Section |
| SATCOM | Satellite Communications |
| SLR | Satellite Laser Ranging |
| SM-3 | Standard Missile 3 |
| SRO | Specific Research Objective |
| SSA | Space Situational Awareness |
| SSAU | State Space Agency of the Ukraine |
| SSN | Space Surveillance Network |
| STEM | Science, Technology, Engineering and Math |
| STSC | Scientific and Technical Subcommittee |

| | |
|---|---|
| TCBM | Transparency and Confidence-Building Measure |
| TEL | Transporter Erector Launcher |
| U.S. | United States |
| UKSA | United Kingdom Space Agency |
| UN | United Nations |
| UNDC | United Nations Disarmament Commission |
| UNODA | United Nations Office for Disarmament Affairs |
| UNOOSA | United Nations for Outer Space Affairs |
| USSR | Union of Soviet Socialist Republics |
| WMD | Weapon of Mass Destruction |

**I. <u>Introduction</u>.** Space is becoming increasingly congested, contested and competitive (DOD, 2011, Pg1; Johnson-Freese, 2017, Pg26-55). Recent events indicate that the number of international actors striving to display power and relevancy through kinetic actions in the international space domain is growing (Harrison, et al., 2019). As of March 2019, India is the latest actor to have successfully demonstrated a kinetic anti-satellite (ASAT) capability (Langbroek, 2019). Others are working meticulously to acquire or improve weapons systems of a similar nature (Harrison, et al., 2019; Panda, 2018A; Panda, 2018B). In the absence of discrete law and policy guidance, the weaponization of space is well underway (Matignon, 2019; UN, 2002; Weeden & Samson, 2019).

Although kinetic ASAT weapons have not been used as part of an offensive attack on another country's space assets (Moltz, 2014, Pg1), it has become common-place to demonstrate such capability by destroying an organic space asset (Langbroek, 2019; Moltz, 2014, Pg8; Oberg, 2008; Zissis, 2007). Even when carefully planned and calculated, these types of demonstrations generate considerable amounts of orbital debris (Langbroek, 2019; Zissis, 2007). Depending on altitude, this debris may remain in orbit for minutes / hours / days (best-case) to months / years / decades (worst-case) and poses a significant risk to other space systems in similar orbits (Moltz, 2014, Pg24; Moltz, 2019, Pg53). At extremely high altitudes, the presence of orbital debris can impose nearly permanent environmentally degradative effects.

Ultimately, experts fear that if not managed appropriately, the use of counterspace (CS) weapons with permanent physical effects, regardless of pretext, could contribute to the initiation of a cascading chain reaction (the Kessler Syndrome) that would leave entire orbital regimes unusable (Drmola & Hubik, 2018; Moltz, 2014, Pg25). As such, the primary intent of this thesis is to answer the question: **Why has the system of international space governance failed to deter the testing, and genuine considerations for operational employment, of such weapons systems?**

In order to adequately address the research question identified above, this paper aims to identify verifiable motives based in fundamental international relations (IR) theory. Because of the complex nature of the material being discussed, a number of specific research objectives (SROs) will aid in providing context and pragmatic structure to the document. These include describing the unique environmental, and operational complexities of the international space domain, the nature of CS weapons and their theoretical employment considerations, and the orbital debris problem (SRO 1), conducting a detailed analysis of applicable IR forums, existing international space law, and pertinent historical events as they pertain to shaping modern foreign policy positions (SRO 2), and formulating realistic proposals for advancing the conduct of responsible behavior in space by curtailing the employment of CS weapons (SRO 3).

Using foundational IR theory as a frame of reference, this thesis employs qualitative methods to evaluate the shaping functions of a modern system of international space governance that continues to permit the testing and employment of CS weapons. United States (U.S.) governmental policy, doctrine, and strategy documents, as well as international guidelines and legal instruments serve as primary source materials. Secondary source materials include books and publications by leading space policy experts, scientific studies and journal articles, threat assessments, pertinent news and current events, and academic text pertaining to IR philosophy. **All source material is strictly unclassified and available for review by the general public.**

The document is structured in such a manner as to facilitate reading by non-space professionals and novice IR students. Along with fundamental IR concepts, readers will gain insight into the physical, environmental and operational factors that, by their very nature, shape IR in the space domain. The relation between CS weapons and orbital debris is clarified to highlight the seriousness of the problem at hand. Then, existing international regulatory institutions and devices are analyzed for effectiveness, highlighting gaps pertaining to CS weapons regulation. Taking into account the still unsurpassed leadership of the U.S. in space, a review of recent historical events serves to explain aggressive foreign policy positions and a continued reluctance to support efforts aimed at addressing these legislative shortfalls. Ultimately, a coherent understanding of the status-quo is applied to develop realistic proposals for advancing responsible behavior in space and maintaining the legitimacy of near-earth orbital regimes.

Assumptions and proposals made throughout this document aim to facilitate progress in a clearly deficient category of international law. They shall, however, be considered purely academic in nature and do not reflect the view of the university or the governments of the U.S. or Colombia. Their sole intention is to facilitate productive discussion in the IR and space policy community.

**II. <u>Theoretical Perspectives on Space Governance</u>.** This chapter will explore fundamental IR concepts that will later be used to explain the actions of critical actors in the space domain. As alluded to by the title of this paper, specific emphasis will be placed on associating discrete and well-developed IR theories with individual foreign policy positions. A range of these theories will be made available for consideration. Consequent chapters will identify the most applicable.

The study of IR is facilitated through a number of theoretical perspectives known as IR paradigms. These should be considered viewpoints or lenses that assist in conceptualizing the environment and manner in which international actors interact. They may also aid in formulating the fundamental reasoning behind their respective policy positions and character. IR paradigms are plentiful in nature and their individual efficacy remains hotly debated amongst academics. Most contain a number of sub-schools (i.e. evolved variations) that aim to improve upon previous outlooks by taking into account additional factors or emerging concepts (Wholforth, 2008, Pg131). Each of these sub-schools, in-turn, may host a number of specific theories that add exponentially increasing factors of complexity and variance in the name of analytical fidelity (Wholforth, 2008, Pg141). This blurs the lines between ideological perspectives and makes it almost impossible to clearly distinguish between paradigm boundaries.

For the purposes of this thesis, this chapter will define three of the most commonly utilized IR paradigms. Related sub-schools and individual theories thought to be most applicable to IR in space will then be explored. Every effort will be made to explain these concepts in a manner that allows even the most novice of IR students to recognize the utility of each viewpoint. Ultimately, the practical application of these ideas, along with an understanding of CS weapons and their impact on the space environment, will aid in providing context for the status-quo. That being, an international system of space governance that has failed to constrain the testing, and considerations for operational employment, of debris-producing CS weapons. Theory-based approaches may also assist in shaping the spectrum of potential solutions for this problem.

**a. Applicable International Relations Paradigms.** A review of prominent IR literature suggests a substantial amount of subjectivity in the interpretation of IR paradigms. This trend is exacerbated further when diving into associated sub-schools. It appears difficult to find extensive commonality in the definitions of even the most fundamental IR concepts. The point of this section is not to get caught up in these discrepancies. This thesis by no means argues for or against the accuracy and/or utility of a particular paradigm. Nor does it attempt to make ground-braking advancements in the development and application of new (or uniquely conglomerated) IR concepts. Instead, it seeks simply to apply existing analytical tools in the search of an explanation for the absence of pragmatic international space legislation.

The three paradigms most relevant to the study of IR in space include Realism, Liberalism and Constructivism. Figure 2.1 attempts to provide a synopsis of the principal notions, both shared and discrepant, that shape each manner of IR analysis. Subsequent sections aim to explain the concepts in further detail. The figure should make apparent that, while sharing a relatively common view of the nature of the international environment and the principle actors operating therein, each manner of behavioral analysis differs in its definition of primary objectives, fundamental behavioral causes, and methods for shaping IR.

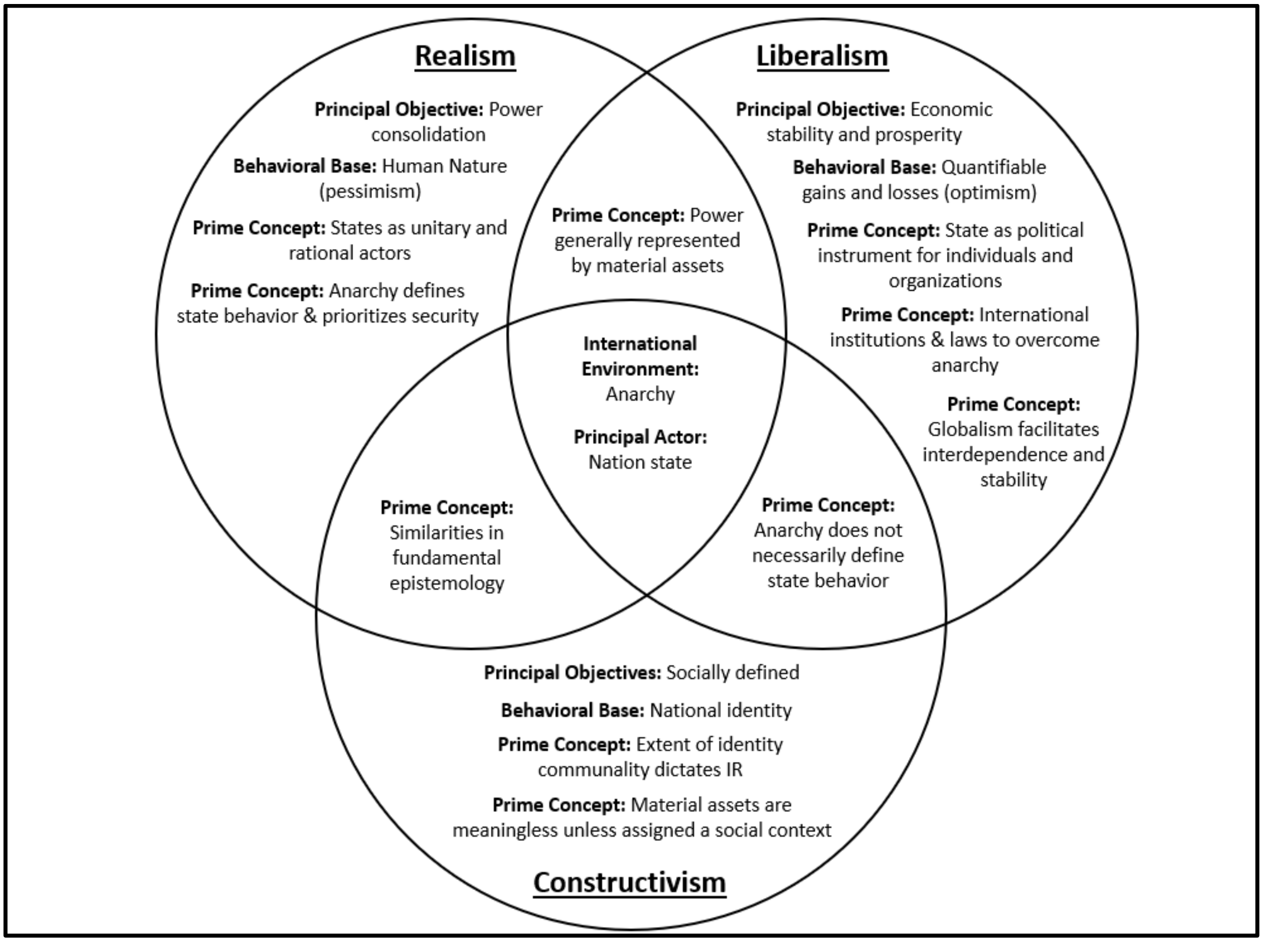


**Figure 2.1. Comparison of Prominent IR Paradigms**

Realism serves as the foundation for all subsequent IR philosophies (Wholforth, 2008, Pg131-132). While accepting the notion of varied international actors, albeit with limited power and influence, it identifies the nation state as the single most important entity (Antunes, et al. 2018, Pg1). Nation states are said to operate as unitary actors in an anarchical environment. More specifically, in the absence of any truly effective form of international governance. As such, nationalistic tendencies, driven by self-interest, dominate formal decision-making processes and political engagements. Classical Realism pessimistically links this behavior to a human nature, arguing that the consolidation of national power logically drives the actions of pragmatic decision makers with any form of specific national identity (Morgenthau, 1948, Pg7). Realism also imposes a notion of unavoidable conflict. Naturally, when held by planners and politicians, this type of mindset can lead to exceedingly aggressive policies.

A subsequently developed sub-school, titled Neorealism, maintains the fundamental tenets of Classical Realism (a societal construct of anarchy and the primary objective of individual actors to consolidate power), but argues that instead of being based entirely in human nature, the decision-making process of each nation is influenced by its relative power (Antunes, et al. 2018, Pg2). Taking into consideration empirically measurable features such as population and territory size, economic and financial resources, military strength, and political capacity, Neorealism aims to impose increased scientific and analytical rigor on IR analysis (Waltz, 1979, Pg69). Something which Classical Realism does not necessarily allow.

Neoclassical Realism adds more variables by taking into consideration unique influences such as internal socio-political pressures and leadership personalities (Omar, 2013, Pg2). In this manner, supporters aim to facilitate a more accurate explanation of discrete, country and event specific, foreign policy positions that both Classical Realism and Neorealism are unable to provide (Omar, 2013, Pg3).

In a general sense, Liberalism builds upon Classical Realism by introducing a further developed set of roles to international actors and defining philosophical objectives that exceed power consolidation. The nation state continues to be the primary international actor. However, emphasis is placed on its role as a political instrument rather than an independent entity, working on behalf of individuals and groups to reach desired objectives (Moravcsik, 2008, Pg237). These objectives, in turn, are most frequently rooted in a desire for economic stability and prosperity.

A second major difference is associated with the shared perception of the international environment. While Realism is established on the solitary construct of anarchy, liberal theorists add the belief of compelling systematic order via international law and the construction of state interdependence. This interdependence is facilitated by globalization, a core tenet in liberal philosophy based on maximizing mutual benefits through economic and cultural interactions (Moravcsik, 2008, Pg239). By systematically structuring and incentivizing globalization, international institutions such as the United Nations (UN) and the European Union (E.U.) aim to pursue their principal objectives (Meiser, 2018, Pg2). Ultimately, the level of collective interdependence is believed to be directly proportional to the propensity for inter-state conflict. Specifically, the more globalized a set of actors, the less likely they are to engage in inappropriate behavior.

Like Realism, Liberalism has a number of sub-schools that take into account philosophical developments and discrete IR theories. Neoliberalism places further emphasis on exploiting the economic benefits of globalization by reducing governmental controls and promoting free-trade to the maximum extent possible. More specifically, neoliberals are of the opinion that unregulated capitalism alleviates economic and social inequalities by maximizing individual liberty and opportunity (Wikan, 2015, Pg1). This specific philosophy has played a significant role in shaping western society and is frequently referred to as the moral standard in the conduct of IR. Traumatic events such as the 2008 financial crisis, however, suggest that excessive private-sector deregulation can actually increase societal vulnerability.

Like realists and liberals, constructivists maintain the notion of nation states serving as principle agents in an international environment defined by anarchy. However, to an even further extent than Liberalism, constructivist philosophy emphasizes the role of subordinate actors, specifically social groups. That is, ideals shared by these actors literally “construct” national identities and define principal objectives pursued in the conduct of IR (Hurd, 2008, Pg302-303).

Constructivists see analytical procedures employed by realists and liberals as intrinsically bound to material constraints, most commonly military and economic resources seen as constituting power (Hurd, 2008, Pg300). As such, they argue that social and ideological variables are not accurately accounted for. A commonly quoted example of this disparity, developed by Alexander Wendt in his 1995 article titled Constructing International Politics, states that while both the United Kingdom and North Korea possess nuclear weapons (i.e. material assets constituting military power), their relationship with the U.S. is fundamentally different. That being amity in the case of the United Kingdom and enmity in case of North Korea. Wendt argues that this phenomenon can only be accurately explained by taking into account each country's national identity, which is fundamentally tied to internally shared social values (Pg73). Ultimately, it is believed that material representations of power do not have any meaning unless social context is provided (Theys, 2018, Pg1).

Because constructivists reason that national identities are associated with societal values (Katzenstein, 1996, Pg5), it is said that states can maintain multiple identities. Each subsequently shapes their relationship with idealistically aligned or non-aligned counterparts (Theys, 2018, Pg2). This aids in explaining foreign policy discrepancies. For example, the U.S. maintains a generally friendly and supportive relationship with countries that also promote democratic and capitalist values. Its stance towards strategic competitors, communist regimes and suppressive dictatorships, on the other hand, is much more hostile. As indicated by this paper's research hypothesis, it is expected that Constructivism plays an important role in explaining the tone of and nature of individual space policy positions, especially in the U.S.

**b. Applicable International Relations Theories.** Generally speaking, individual IR theories attempt to leverage historical tendencies in predicting whether or not the international environment will be characterized by conflict. Naturally, realist theories tend to imply that conflict is fundamentally unavoidable, amplifying on various logical pathways to this end-state. Liberal theories, on the other hand, suggest that conflict can be avoided by imposing stability on the international system. While this paper does not intend to predict the propensity for conflict in space, an understanding of the following concepts will allow us to understand the reasoning behind specific foreign policy positions and actions by prominent space actors. Depending on the readers favored IR paradigm, they may also serve useful in evaluating the effectiveness of proposed lines of effort (LOEs) for advancing CS weapons regulation and responsible behavior in space. As such, the Balance of Power, Balance of Threat, Hegemonic Stability, Power Transition, Complex Interdependence, and Social Norms Theory are briefly examined.

Balance of Power is a realist theory. It suggests that in an anarchical international environment, a state is free to use power, generally in the form of military capabilities, to pursue its individual objectives (Wohlforth, 2008, Pg141). Counterparts, in turn, are naturally disposed to develop their own capabilities in order to address a perceived power imbalance. They may also team up, either with or against the protagonist (Walt, 1987). These notions are further refined through the addition of empirical rigor in the Balance of Threat Theory. Here, instead of taking actions purely to counteract power imbalances, states take action according to perceived threat. That being, a composition of more quantifiable factors pertaining to ideology and intent, military and economic capabilities, and geography (Wohlforth, 2008, Pg142).

Such threat balancing, has the potential of resulting in what IR theorists refer to as a Security Dilemma. That being, in the process of arming itself for self-defense, a state may actually (albeit unintentionally) reduce the overall security situation further by causing counterparts to seek re-establishing the previously apparent competitive advantage (Wohlforth, 2008, Pg142). The result is a perpetual cycle competition and heightening of tensions. Historically, this concept is frequently associated with Cold War studies, specifically when addressing the unintended second and third-order effects of pursuing anti-ballistic missile (ABM) capabilities.

The realist Theory of Hegemonic Stability proposes that order is imposed on the anarchic international system when a single dominant entity, with overwhelming power and a willingness to assume the requisite responsibilities, assumes a global leadership role. While predominantly applied in the context of analyzing the global economy, this paper argues that stabilizing effects imposed by hegemonic leadership are also evident in aspects of space operations.

The Power Transition Theory amplifies on the concept of hegemonic stability by suggesting that states in a leadership role will work to maintain their position. Reasonably empowered counterparts, on the other hand, will work to contest the central leadership figure. As challengers build their own capacities, the extent to which the hegemonic leader is defied will increase (Wohlforth, 2008, Pg143). This notion is frequently applied in analyzing scenarios of increasing tension between the U.S. and the Russian Federation and/or China.

Within the space and IR community, the term Thucydides Trap has become frequently associated with Power Transition Theory, specifically when analyzing the U.S. vs. China scenario. Devised by former Assistant Secretary of Defense for Policy and Plans (and political scientist) Graham Allison, Thucydides Trap references the view held by the eponymous Athenian general and historian that the Peloponnesian War was directly linked to a power transition scenario between

Athens and Sparta (Allison, 2015). Allison advocates that an analysis of 16 power transition scenarios in the last 500 years suggests a 75% chance of violent conflict in future cases (Allison, 2015). According to this prediction, the strategic competition between the U.S. and China may, therefore, very well result in war that extends into the international space domain.

As mentioned previously, complex interdependence is a precept of the liberal paradigm and its various sub-schools. The Complex Interdependence Theory suggests that mutual dependence between international actors, most prominently facilitated through globalization, imposes stabilizing effects on the international system. By constructing an interdependent global economy (for example), individual actors are by default less apt to follow self-serving impulses. As will be explained in subsequent sections, this paper argues that the fundamental nature of the space environment (i.e. the physical principals of orbital dynamics and the global of utility space-based capabilities) makes the understanding of Complex Interdependence Theory a prerequisite for analyzing IR in space.

Social Norms Theory is associated with the constructivist paradigm and attempts to explain how shared values ultimately manifest themselves in politics (Theys, 2018). Within the international system, compliance (or non-compliance) with certain behavioral norms defines the discrete value-set of an international actor. Compliances with a regulative norm, for example, would indicate a shared understanding of non-appropriateness as it pertains to the behavior in question, even if such a norm has not been captured in legally binding instruments. This thesis maintains that social construction is naturally more prominent in democratic societies. Conversely, the behavior of autocratic societies is likely better explained by reverting to realist principles.

**c. The Relation to Space Governance.** In today's international system, space governance is imposed either through legally binding agreements or voluntary guidelines and standards of behavior. In the absence of a realistic alternative, the UN serves as the principal international governing body and, as we will see later in this thesis, its respective IR forums have served to facilitate the implementation of nearly every piece of international space legislation to date. Ultimately, international space law, both legally binding and voluntary, informs the applicable national regulatory institutions of spacefaring nations. These, in turn, dictate the system design and operational employment of space system architectures managed by both governmental and commercial entities under their jurisdiction. The notion that this international system of governance was able to successfully prevent open conflict in space, at least until now, may appeal to advocates of the liberal paradigm.

Certainly, Cold War era treaties were successful at providing an initial framework for stability in the international space domain. However, this paper argues that since then, unchallenged U.S. leadership, combined with the physical and fiscal challenges of participating in space operations, has served as the principal stabilizing function. In the decade following the fall of the Union of Soviet Socialist Republics (USSR), there simply was no perceived need for the U.S. to advance space legislation, particularly CS weapons regulation, as the U.S. reigned supreme.

Following the terrorist attacks on September 11th, 2001, U.S. foreign policy positions have been entirely dominated by the aggressive preservation of national security. The subsequent Global War on Terror provided significant opportunities for the reemergence of strategic competitors. While the U.S. was occupied in Iraq and Afghanistan, Russia and China have pointedly advanced their CS weapons portfolios under the presumption that such capability may provide a strategic advantage. The provocative testing of such technologies has since soured U.S. willingness to support any meaningful advances in international space legislation.

Taking into account that the hegemonic leadership exercised by the U.S. in a post-Cold War environment (while facilitating provisional stability) did little to advance international space governance, the recent actions of increasingly influential international actors seem to further inhibit progress. **Specifically, it is hypothesized that the neoconservative nature of modern U.S. space policy, accounting for the untrustworthiness of strategic competitors, has prohibited national consent to the implementation of legally binding CS weapons regulation. The formation these policy positions is thought to be best explained using constructivist principles.** In other words, the historically bellicose, violative, and hypocritical behavior of Russia and China has made elected leaders in the executive and legislative branches of the U.S. government (representing the will and values of the American people) entirely resistant, on grounds of projected ineffectiveness, to any form of binding international agreement. Because of the prominent leadership role of the U.S. in both space and international governance, truly effective CS weapons regulation would rely entirely on such a commitment. Consequently, the seemingly unconstrained testing and operational employment of CS weapons technology continues to threaten the viability of tremendously important orbital regimes.

**III. <u>The Space Environment</u>.** Any entity with a presence in space, is by default forced to conduct IR. This is dictated by the fundamental laws of physics and nature of the space environment. Therefore, in line with SRO 1, a coherent understanding of foundational scientific principles and environmental factors is required to judiciously analyze space policy positions.

**a. Utility, Congestion, and the Tyranny of Distance.** The natural global utility of space emphasizes its international nature. As technological developments make entering the space domain more feasible, the number of participants grows concurrently. According to a database maintained by the UN Office for Outer Space Affairs (UNOOSA), 284 objects were launched into space in 2019 alone, bringing the total number of active satellites in earth-orbit to more than 4,987 (2019). This number represents hundreds of state and non-state entities and is predicted to grow exponentially (Moltz, 2014, Pg7). Reaching the lowest of sustainable orbits, however, can impose launch cost exceeding $10,000 dollars per pound. Additionally, once deployed, there is no way to conduct maintenance activities on a spacecraft. Operational lifespans are therefore entirely dependent to sound engineering principles, reliable components, system redundancy and fuel reserves. Should a spacecraft become defunct, it cannot be recovered.

**b. Environmental Factors.** Space is not an empty, black, vacuum. Instead it comprises a unique and complex operating environment shaped by a number of factors. These include radiation, extreme temperatures, orbital debris and (since we are talking about space operations in near-earth orbital regimes) atmospheric effects imposed by the outermost layers of the earth's thermosphere and exosphere. For the purposes of this thesis, orbital debris will be discussed in its own chapter.

The sun is by far the most dominant source of environmental factors in our solar system. The immense gravitational force imposed by this celestial body shapes the orbit of every planet, from Mercury to Neptune and beyond. In the context of near-earth space operations, the tremendous amounts of solar radiation, emitted continuously and omnidirectionally into the surrounding space environment, are tremendously impactful. This solar radiation, frequently referred to by space professionals as "space weather," shapes the technical design of space systems, dictates discrete orbital characteristics (depending on sensor type), and frequently plays a factor in equipment malfunctions (i.e. system anomalies). There are, of course, a variety of other sources of space radiation. However, for our purposes, their impact is almost negligible. Solar radiation is best categorized into two types: Electromagnetic (EM) radiation and charged particle radiation.

EM radiation is composed of elementary particles called photons (Mahan, 2009, Pg244). These photon particles are massless, chargeless and propagate through space at specific, inversely related, frequencies and wavelengths that vary depending on type (Mahan, 2009, Pg244). EM radiation types are classified by wavelength (measured in microns [µm]) to form a universally accepted scale of reference titled the EM Spectrum. Generally speaking, the known EM Spectrum begins with wavelengths of around $10^{-7}$ µm (e.g. cosmic rays) and terminates at wavelengths of around $10^{8}$ µm (e.g. TV & radio waves). Of note, the visible portion of the EM Spectrum (0.4-0.7 microns) only comprises two percent of known EM wavelengths (Lanphear & Medina, 2009, Pg116).

The sun continuously emits EM radiation across the entire spectrum. This is most impactful on space system sensor design. Photon receptors in electrooptical imaging sensors (for example) are specifically configured to capture EM radiation, in the visible spectrum, being reflected off of objects on the earth's surface. In other applications such as infrared or radar imaging, naturally occurring EM solar radiation may present itself as background noise that can significantly reduce the quality of products available to end-users, thus shaping orbital profile considerations and electronic filter requirements.

For our purposes, charged particle radiation is best described as the product of either atomic and/or sub-atomic particle collisions or natural radioactive decay (Lanphear & Medina, 2009, Pg116). In each case, charged particles are physically projected into the surrounding environment carrying both mass and energy. The specific particle type is commonly used to identify the type of radiation being discussed. Alpha radiation (α-radiation/α-rays), for example, is composed of protons and neutrons while beta radiation (β-radiation/β-rays) is composed of electrons or positrons (USNRC, 2017).

The hydrogen fusion process taking place at the center of the sun is responsible for a majority of the charged particle radiation found in our solar system (Lanphear & Medina, 2009, Pg116). This phenomenon of charged solar particle propagation is frequently referred to as solar wind (Lanphear & Medina, 2009, Pg115). Just like EM radiation, naturally occurring charged particle radiation has a significant impact on space system design and operation. Most prominently, it calls for the hardening of critical electronic components and almost always has a negative impact on mission duration. Charged particle radiation has been known to cause anomalies that include sensor faults, temporary and permanent disruptions of mission essential hardware, and accelerated solar panel decay.

Periodic surges in solar activity (in the form of solar flares and/or coronal mass ejections) can dramatically alter space weather conditions by exponentially increasing the amount of both EM and charged particle radiation (Lanphear & Medina, 2009 Pg117). While the earth's magnetic field usually prevents a majority of this radiation from entering our atmosphere, space systems in near-earth orbits are left vulnerable to its effects. Prolonged studies, trend analysis and specialized sensor equipment has allowed the scientific community to inject a sense of predictability into space weather patterns. This allows critical systems and/or sensors to be turned off or repositioned in an effort to minimize irreparable damage. However, a substantial aspect of vulnerability remains.

As previously mentioned, the shape and nature of earth's magnetic field serves to deflect a vast majority of the charged particle radiation direct at earth. However, due to the presence of intersecting magnetic field lines, a small amount of solar radiation is captured to form what scientists and space professionals refer to as the Van Allen Radiation Belts. These belts are composed of two toroid-shaped regions of radiation with maximum flux (i.e. spatial particle density) at altitudes of around 5,000km and 18,000km respectively (Lanphear & Medina, 2009, Pg188). The fundamental impact presented by charged particles trapped in the Van Allen Radiation Belts does not change. As such, space systems operating in Medium-Earth Orbits (e.g. Global Positioning System [GPS]) are particularly susceptible to their effects and often require especially hardened components and additional failsafe devices to guarantee survivability. The localized and predictable nature of these radiation belts, however, allows scientists and engineers to map them and properly account for their undesired effects.

The space environment imposes temperature extremes on spacecraft that far exceed anything found under the protective layers of earth's atmosphere. Spacecraft orbiting the earth at lower altitudes experience regular periods of darkness as their orbital regime dictates that the earth, at times, blocks the line-of-sight between the spacecraft and the sun. Consequently, spacecraft in low-earth orbits may experience extreme highs and lows in temperature that exceed -170$^{o}$C during periods of darkness, and 123ºC during periods of direct sunlight (Miracle, 2017). This forces scientists and engineers to consider the effects of heat-cycling during system design. Spacecraft operating at higher altitudes, on the other hand, may never experience darkness. While continuous sunlight has its advantages when it comes to solar power generation, the extreme heat imposed on space system components calls for the use of temperature regulating sub-systems (e.g. radiators and heat-syncs) to maintain operating efficiencies.

Contrary to popular belief, the effects of earth's atmosphere remain considerable on orbiting space systems even at relatively high altitudes of up to 1,000km (Lanphear & Medina, 2009, Pg129). More specifically, frictional drag decreases the velocity of orbital objects (Moltz, 2014, Pg24). For active space systems, this may contribute to errors in the accuracy of mathematical orbital positioning predictions and often calls for the application of orbital maintenance maneuvers by using liquid propellant motors to increase velocity along the principal thrust vector. At low altitudes, if left unaddressed, frictional drag can reduce the velocity of orbiting objects enough to cause re-entry. Periods of intense solar activity can heat up the outer layers of the ionosphere (through EM radiation and charged particle bombardment) resulting in atmospheric expansion and consequential drag effects on space systems at higher altitudes (Lanphear & Medina, 2009, Pg129).

Ultraviolet EM radiation from the sun also interacts with molecular oxygen in the outer layers of the earth's atmosphere to form a corrosive substance called atomic oxygen (NASA, 1995, Pg2). Atomic oxygen has been proven to oxidize exposed spacecraft components (NASA, 1995, Pg2). This frequently causes accelerated solar panel degradation in space systems operating at lower orbits. Since the function and efficiency of photovoltaic cells is critical to keeping on-board batteries charged, their deterioration can shorten mission duration.

**c. Orbital Mechanics.** The international nature of the space environment is dictated (above all else) by the fundamentals of orbital mechanics. A spacecraft does not simply hover over the country that deployed it. Instead, imagine it falling continuously around the earth, forming a rotating orbit defined by a specific set of parameters. Depending on the nature of these orbital parameters, a satellite may pass over every continent on earth multiple times every day. Now imagine thousands of satellites in orbit around the earth at the same time! Add to this the complexities imposed by conflicting foreign policies, military competition and man-made orbital debris and you quickly come to realize why both coordination and regulation is required.

**1. Fundamental Laws.** Orbital mechanics are defined by a set of physical principles that include Johannes Kepler's Laws of Planetary Motion and Sir Isaac Newton's Laws of Motion. These fundamental physical laws (along with the Theory of Conservation of Mass and Energy) can be used to explain not only planetary motion, but also the motion of man-made spacecraft and satellites.

The characteristics of orbital planetary motion were first accurately defined by Johannes Kepler in the mid seventeenth century. This German astronomer and mathematician developed a set of mathematically supported theories (later accepted as factual) to explain the motion of planets in our solar system. A 1964 article in *The British Journal for the History of Science* titled Kepler's Law of Planetary Motion: 1609-1666, describes these concepts in a fashion that allows even non-space professionals to understand them with ease:

> (1) Planets travel around the sun in elliptical orbits, with the sun at one focus. The moon in the same way, travels in an ellipse around the earth (Pg2).
>
> (2) The velocity of a planet varies with its distance from the sun in such a way that a line joining the planet with the sun sweeps out equal areas in equal times (Pg2).
>
> (3) The square of the time taken by any plane to make a complete orbit is proportional to the cube of its mean distance from the sun (Pg2).

The Laws of Motion, defined by English physicist Sir Isaac Newton, explain the forces at work during Kepler's observations (Lanphear & Medina, 2009, Pg95). Neil deGrasse Tyson and his co-authors summarize these laws concisely in their 2016 book titled *Welcome to the Universe: An Astrophysical Tour*:

> (1) An object that is at rest will remain at rest unless acted upon by an external force. Furthermore, an object with uniform velocity will remain at that uniform velocity unless acted upon by an external force (Pg43).
>
> (2) The force required to impose deviation from an objects uniform velocity (i.e. acceleration) is equal to the product of the object's mass and the desired acceleration (Pg44).
>
> (3) Force exerted on an object is met by an equal and opposite reaction (Pg44).

Newton also developed the Law of Universal Gravitation which states that every particle in the universe attracts every other particle in the universe with a force that is proportional to the product of the masses and inversely proportional to the square of the distances between the particles (Lanphear & Medina, 2009, Pg96).

Ultimately, Newtonian physics and Kepler's Laws (along with other principles such as the conservation of mass and energy) allowed scientists to calculate the escape velocity required for an object to fall continuously around the earth (i.e. satellite in an earth orbit). More advanced applications now facilitate the placement of space systems in specifically designed earth orbits, enabling discrete sensor applications, that are predictable and sustainable with only minor orbital adjustment necessary to overcome natural perturbations. The most extreme applications of these scientific principles have facilitated deep space exploration missions by allowing scientists and mission planners to conduct gravity-assist maneuvers, using the gravitational force of other planets in our solar system to literally sling-shot their spacecraft towards the desired destination.

**2. Orbital Elements.** The orbit of every satellite is defined by a discrete set of parameters commonly referred to as the classical orbital elements. Table 3.1 provides a brief description of these orbital elements along with the associated symbology. Later figures will allow the reader to visualize defining orbital characteristics using two and three-dimensional frames of reference.

| Element | Name | Description | Definition |
|---|---|---|---|
| a | Semimajor Axis | orbit size | half the long axis of the ellipse |
| $e$ | Eccentricity | orbit shape | ration of half the foci separation (c) to the semimajor axis (a) |
| $i$ | Inclination | orbital plane's tilt | angle between the orbital and equatorial plane |
| $\Omega$ | Right Ascension of the Ascending Node | orbital plane's rotation about the earth | angle, measured eastward, from vernal equinox to the ascending node |
| $\omega$ | Argument of Perigee | orbit's orientation in the orbital plane | angle, measured in the direction of satellite motion, from the ascending node to perigee |
| $v$ | True Anomaly | satellite's location in its orbit | angle, measured in the direction of satellite motion, from point of perigee to satellite location |

**Table 3.1. Classical Orbital Elements (Chatters, et al., 2009, Pg104)**

Figure 3.1 depicts the components of a standard elliptical earth orbit in a two-dimensional plane. Apogee and Perigee are generally defined as the furthest and closest points (respectively) to earth in a satellite's orbit. Eccentricity (*e*) is a ratio commonly employed by space professionals to define the shape of an orbit (Chatters, et al., 2009, Pg101). The higher the *e* value, the more elliptical the orbit. Specifically, an orbit with an *e* value of 0 is circular and the degree of ellipsis increase as *e* reaches a maximum value of 0.95. True Anomaly (*v*) is an angular measure of satellite location from the point of perigee (Chatters, et al., 2009, Pg104). A *v* value of 0º indicates that the satellite is currently located at Perigee while a *v* value of 180º indicates that the satellite is located at Apogee. A velocity vector is frequently used to display orbital velocity (km/sec) at a specific angular *v* value. A satellite in an elliptical orbit will reach its highest orbital velocity at Perigee. Orbital velocity then decreases, in direct relation to an increase in *v* value, until reaching a minimum at Apogee.

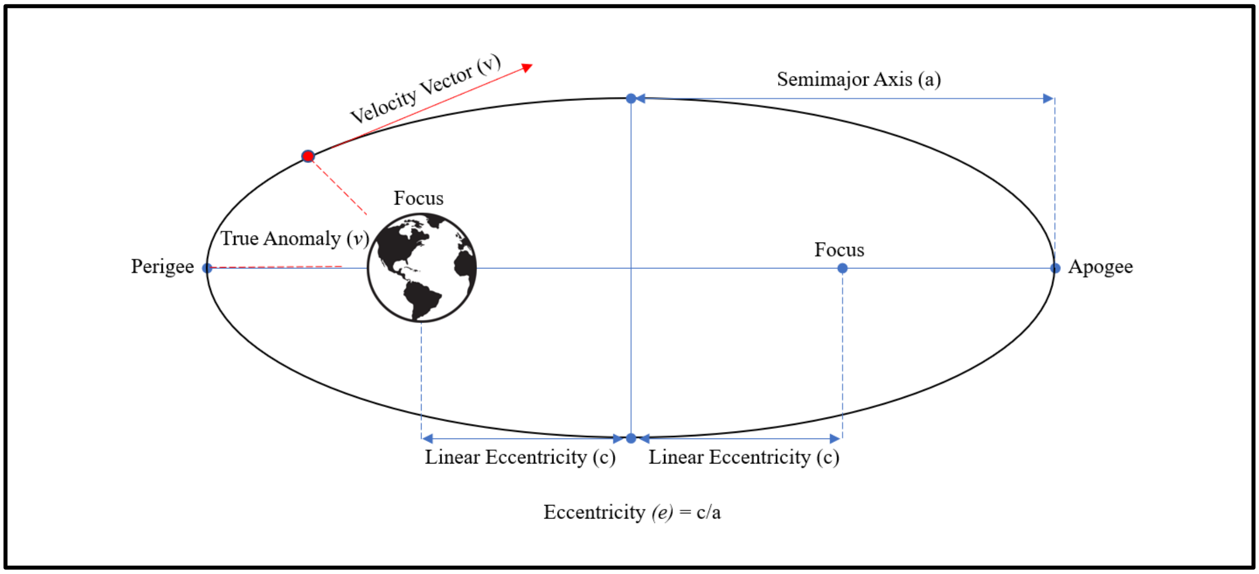


**Figure 3.1. Characteristics of the Standard Elliptical Orbit**

Figure 3.2 allows the reader to visualize additional orbital characteristics using a three-dimensional frame of reference. Orbital Inclination (*i*) is an angular measure of an orbit's tilt relative to the equatorial plane (Chatters, et al., 2009, Pg102). Consequently, an orbit with an *i* value of 0º is commonly referred to as an equatorial orbit. Polar orbits have an *i* value of 90º and retrograde orbits have *i* values exceeding 90º. The term Ascending Node is used to define the point at which the orbit of a spacecraft breaks the equatorial plane with a velocity vector pointing into the northern hemisphere. Naturally, the descending node implies the opposite, that being the crossing of the equatorial plane with a velocity vector pointing into the southern hemisphere. Because the earth is continuously rotating below the spacecraft, you can imagine (for most typical orbital configurations) the ascending node as traveling eastward along the equatorial plane over time. The location of the ascending node is measured from a standardized point of reference (vernal equinox) to establish an angular unit of reference called the Right Ascension of the Ascending Node (Ω). Given enough time, the transient nature of Ω associated with most typical orbits, dictates that a spacecraft will literally pass over every point on earth.

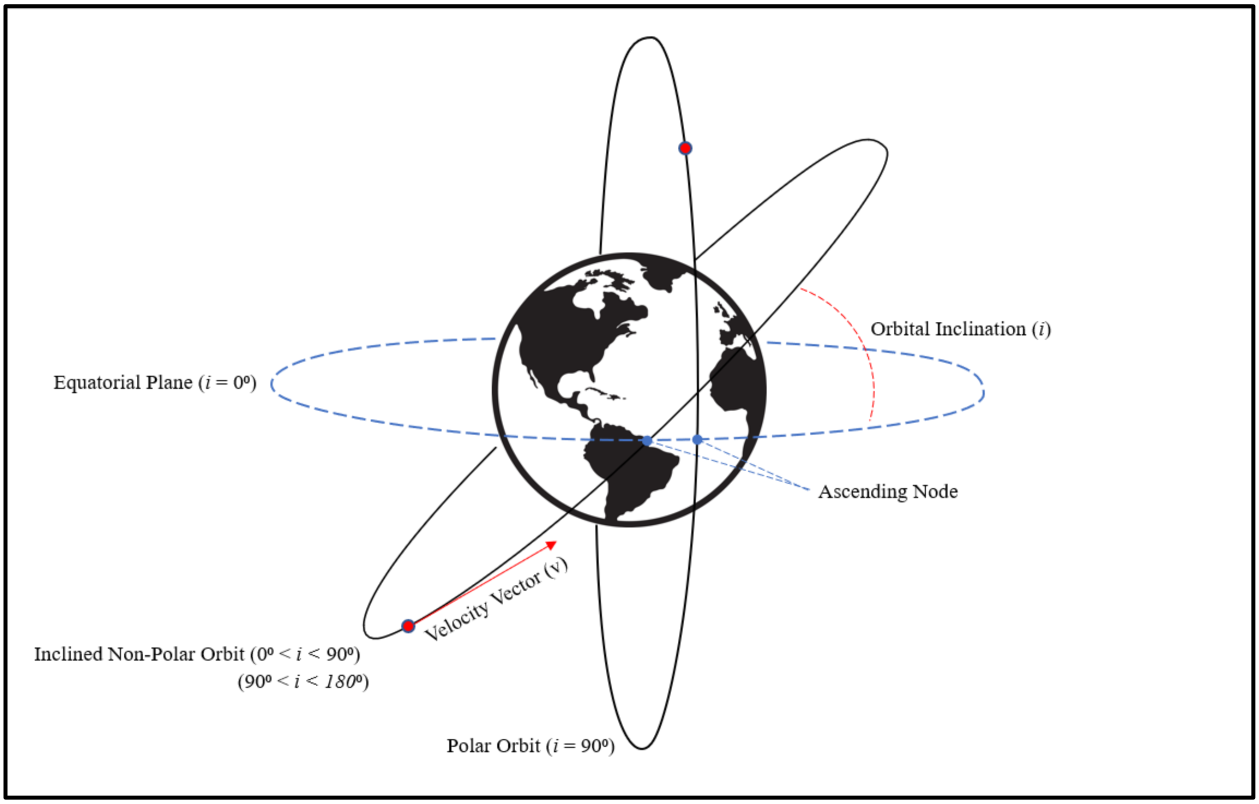


**Figure 3.2. Orbital Inclination and the Ascending Node**

**d. Orbital Regimes.** Depending on the spacecraft payload or sensor being employed, discrete sets of orbital characteristics facilitate specific mission types. The current sensor resolution limitation associated with optical imaging satellites, for example, is a prominent factor (amongst a number of others) for their frequent employment at relatively low altitudes. When more persistent sensor coverage is required, higher orbital altitudes or eccentricities may be of value. Ultimately, satellites in a variety of orbital regimes facilitate functions ranging from communications, broadcasting and navigation to intelligence collection, global monitoring and scientific research. Some of the more diverse system architectures even employ satellites in multiple orbital regimes to maximize end-user utility. Generally speaking, the most prominent near-earth orbital regimes can be classified according to orbital altitude, ranging from Low Earth Orbit (LEO) to Medium Earth Orbit (MEO) and Geostationary Earth Orbit (GEO). LEO and GEO arguably provide the greatest utility and are therefore the most utilized. A brief synopsis of pertinent characteristics relating to each orbit type follows.

LEO describes orbital regimes with an altitude between 160 and 1,200 miles (Moltz, 2014, Pg21). This translates into orbital periods (the time it takes to complete one revolution of the earth) of around 90 minutes. This orbital regime is most commonly utilized to facilitate intelligence collection and earth imaging, developmental space sciences (the International Space Station [ISS] operates in LEO), and narrow-band satellite communications (SATCOM) services such as Iridium (Moltz, 2014, Pg21). The relative proximity to earth makes LEO orbits more accessible, but also more susceptible to various types of threats.

MEO describes orbital regimes with an altitude between 1,200 and 22,300 miles (Moltz, 2014, Pg21). This translates into orbital periods between 2 and just under 24 hours. This orbital regime is most commonly utilized to facilitate position, navigation and timing (PNT) systems such as GPS, the Russian Global Navigation Satellite System (GLONASS) and the Chinese BeiDou System (Moltz, 2014, Pg21). All of these operate in orbits with periods of around 12 hours. Of note, the ambient space environment in this region is extremely hostile. The previously described Van Allen Radiation Belts call for increased system redundancy and shielding, adding programmatic complexity and cost.

GEO describes orbital regimes with an altitude of around 22,300 miles (Moltz, 2014, Pg21). This translates into orbital periods of exactly 24 hours and allows space-systems to be "parked" in specific orbital slots that match the earth's rotational rate. I.e. for spacecraft in GEO with an $i$ value of $0^o$, **Ω** matches the earths rotational rate along the equatorial plane, allowing for persistent sensor coverage. This makes GEO especially useful for wideband SATCOM, intelligence collection and missile defense missions (Moltz, 2014, Pg21).

The high altitude of GEO makes it particularly susceptible to the effects of man-made orbital debris. Failed systems and/or particles generated by collisions or CS weapons do not experience the same velocity reducing atmospheric effects as in lower orbital regimes. Thus, orbital debris in GEO can almost be considered permanent. This, combined with the extreme utility of individual GEO slots, and tremendous spacecraft cost (some the size of school buses and with production values exceeding one billion dollars), makes the management and preservation of the GEO environment a top priority.

A number of other orbital regimes, are at times used to facilitate specialized requirements and sensor functions. Highly Elliptical Orbits (HEO) utilizing *i* values above 45°, place orbital apogee at high latitudes in the northern hemisphere. This allows the spacecraft to "hang" over their target area for a majority of their orbital period, before "sling-shotting" around the southern hemisphere at extremely high velocities. Prominent space actors have historically used HEO regimes to project communications and ballistic missile detection capabilities into latitudes that are not accessible from GEO.

Another type of specialized orbit is the sun-synchronous orbit. Typically utilized by electrooptical imaging spacecraft in LEO, a sun-synchronous orbit has an *i* value of around 98°. This allows for photos to be taken with consistent lighting angles during every spacecraft revolution and enhances the productivity and accuracy of image analysts by allowing them to assume constant shadow effects.

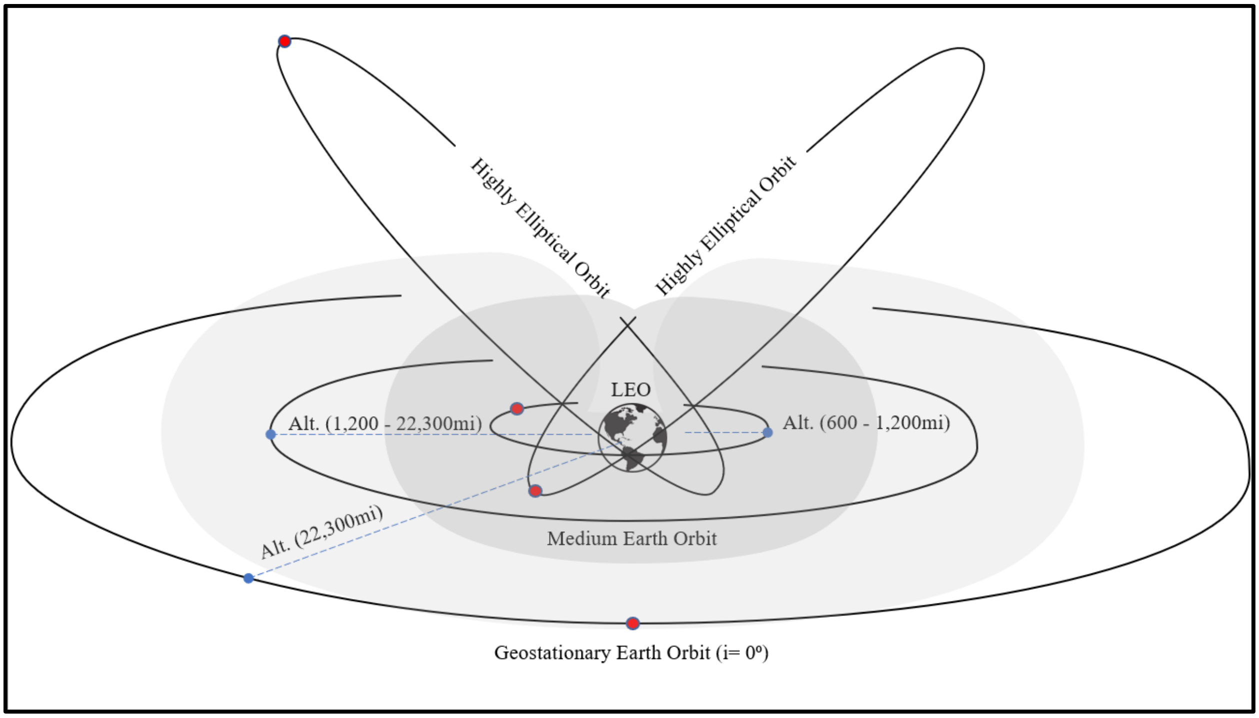


**Figure 3.3. Principle Near-Earth Orbital Regimes**

Figure 3.3 allows for a visual depiction of the most prominent orbital regimes. Whereas LEO and MEO are generalized zones of space system employment, GEO refers to a discrete orbital altitude and inclination where the benefits of geostationary positioning take effect.

**IV. <u>Principles of Space Operations</u>.** Now that we have strengthened our understanding of the space environment and the foundational principles of orbital mechanics, let us briefly analyze (in continued pursuit of SRO 1) the principal functional areas and actors involved in modern space operations. An understanding of these factors is fundamental in grasping the seriousness of the problem at. Specifically, in allowing for a contextualizing of the global utility of near-earth space and a visualization of the possible consequences to orbital debris accumulation.

**a. Space Operations Functional Areas.** A U.S. government publication titled Joint *Publication 3-14, Space Operations*, describes how Department of Defense (DoD) space operations capabilities are used to enhance the joint force and support military operations at the strategic, operational and tactical level. Some of these capabilities are easily translated into general "functional areas" applicable to both military and civilian end-users. These functional areas are key to understanding exactly why the space domain is so important and include PNT, Space-Based Intelligence, Surveillance and Reconnaissance (ISR), SATCOM, Environmental Monitoring, and Missile Warning and Nuclear Detonation Detection.

PNT services provided by space-based assets influence nearly every aspect of our daily lives. Constellations such as GPS, GLONASS and BeiDou provide extremely accurate geographic location and synchronized timing signals to end-users. Depending on the signal type being utilized, GPS can provide sub-meter position location accuracy. This facilitates precision navigation, guided weapons employment, communications security protocols based on frequency hopping techniques, and much more. To bring the scope of modern PNT dependency into perspective, nearly every modern cellular device, smart watch, automobile, or automatic teller machine is enabled by space based PNT systems. At this time, the provision of PNT services remain a state sponsored activity.

Spaced based ISR assets enjoy a discrete set of advantages. The most significant being access to denied areas where little to no data can be collected by ground-based, sea-based or airborne sensors (JCS, 2018, Pg30). The fundamental nature of orbital mechanics guarantees (depending on orbital parameters) persistent overflight of designated target areas for the collection of various types of imagery and signals intelligence. As such, the orbital parameters associated with space-based ISR collection assets are often specifically designed to favor (in addition to sensor characteristics) the type, nature and location of specific target areas. Because international law does not extend state sovereignty into the space environment, ISR collection activities proceed relatively unhindered. State sponsored ISR collection activity from space has a long history dating back to the Cold War years. These days, it is becoming increasingly commercialized. Companies such as Digital Globe and European Space Imaging GmbH provide high-resolution imagery to both civilian and government clientele alike.

SATCOM architectures provide beyond-line-of-sight (BLOS) connectivity to users without access to terrestrial communications infrastructure (JCS, 2018, Pg31). In many cases, SATCOM capabilities are also used to supplement terrestrial networks. At the strategic level, DoD sponsored SATCOM systems allow national leadership to maintain situational awareness and convey their intent to subordinate commanders (JCS, 2018, Pg31). At the operational and tactical levels, SATCOM allows disadvantaged or highly-mobile end-users to execute and coordinate mission critical tasks. Commercial SATCOM providers enable everything from satellite phone networks to high-bandwidth, global, data sharing. There are many types of SATCOM systems and support architectures. Their employment considerations and orbital parameters are shaped primarily by signal frequency. Like ISR, SATCOM concepts were initially employed by government entities during the Cold War. Today, while a number of secured strategic systems are still maintained, it is becoming more and more common for these same government entities to lease bandwidth from commercial providers. For the purposes of this thesis, we can also include satellite TV and radio in this functional area.

The same advantages that facilitate space-based ISR activities also enable effective environmental monitoring. Space-based environmental monitoring systems are used to examine both the space and terrestrial environment. Terrestrial monitoring allows for the collection of meteorological and oceanographic (METOC) data that informs a large variety of end-users with everything from weather forecasts to swell conditions (JCS, 2018, Pg32). Space environment monitoring activities are aimed at providing space system operators, and end-users, with advanced notice of space-weather events to minimize negative impacts on service quality or potentials for physical damage to space systems. This is accomplished by closely monitoring solar activity and the directly associated radiation environment in near-earth orbital regimes. Space-based environmental monitoring activities are actively being conducted by both military and civilian government entities as well as commercial and educational organizations.

By its nature, Missile Warning and Nuclear Detonation Detection is specific to strategic military end-users and has little utility in the commercial sector. Space-based assets in GEO and HEO permit persistent sensor coverage over target areas. Frequently, cryogenically cooled infrared sensors are used to identify heat sources associated with the booster phases of ballistic missiles. This information is then passed to intelligence professionals and decision makers for action. These same principles are also used to detect and classify (by location and yield) nuclear detonations (JCS, 2018, Pg33). Missile warning and nuclear detonation detection activities have played a critical role in maintaining a relatively stable global security environment since their inception in the late 1960s.

**b. The Space and Ground Segments.** Each functional area described above, regardless of whether carried out by a government entity or commercial provider, requires a complex systems architecture to guarantee effective sensor tasking, spacecraft command and control (C2), data processing, and ultimately end-user support. Within this systems architecture, space professionals frequently delineate between space and ground segments to provide additional specificity. *Joint Publication 3-14*, identifies the Space Segment as consisting of the operational spacecraft carrying out their designated functions in the common space domain (Pg17). These spacecraft do not typically facilitate on-board data processing or autonomous C2. Instead, only mission critical sensors and supporting sub-systems are brought into space to maximize fiscal efficiencies and reliability.

Generally speaking, the size and complexity of a comprehensive system architecture's Space Segment is determined by global coverage requirements and available fiscal / technological resourcing. A satellite constellation such as Iridium, for example, has been purposely designed and resourced to facilitate persistent global coverage, from LEO, for end-users requiring satellite telephone services. As such, the commercial provider maintains 66 active spacecraft. Other capability providers, operating in the same orbital regime, may only require intermittent, regional, sensor coverage and can therefore get away with far less spacecraft. Naturally, as orbital altitude increases, so does the associated sensor coverage. A single wideband communications satellite in GEO, for example, may cover over nearly one quarter of the globe.

The Ground Segment consists of terrestrial facilities that support spacecraft C2, information processing, and data storage (JCS, 2018, Pg16). Since only mission critical sensors and support systems are brought into space, raw data is down-linked to processing centers where, depending on functional area, analysts and/or automated algorithms generate products for end-users. Conversely, C2 inputs are up-linked to conduct station keeping, provide sensor tasking and update firmware.

The size and complexity of space and ground segments are directly proportional. A constellation of wideband communications or missile warning satellites in GEO, providing persistent coverage over a specified region, requires C2 and data processing stations within the field of view (FoV) of each satellite. A miniature cube-sat operated by a local university, on the other hand, may only require a single ground station, composed of a laptop, a transponder, and an antenna, to maintain situational awareness and conduct intermittent checks of critical systems.

**c. Prominent Space Actors.** The numbers of actors utilizing the space domain, to carry out tasks within the previously defined functional areas, is immense and ranges from powerful nation states to commercial and educative entities of all sizes. As innovative approaches continue to drive down the costs of entering and operating in space, this number will grow.

China, Russia and the U.S. are by far the most prominent state actors in space. Each has a rich, and in the case of China rapidly developing, history of space exploration and space systems development. Intense Cold War competition between the USSR and the U.S. expedited technology development to unprecedented levels, setting the stage for a "space race" and historic events such as the first earth-orbiting satellite (Sputnik, 1957, USSR), the first human in space (Yuri Gagarin, 1961, USSR), the first human spacewalk (Alexei Leonov, 1965, USSR), and the moon landing (Apollo 11, 1969, USA). Since then, both entities have developed comprehensive space system architectures that facilitate the full range of functional areas discussed previously. In more recent years, China, in an effort to bolster its reputation as a global and regional influence, has developed a remarkable number of organic space capabilities, both in the context of human space exploration and military applications.

Many more state actors are deciding to enter the space domain, or further develop existing capabilities. Japan, the E.U. and (interestingly enough) Brazil are frequently mentioned by space policy experts as increasingly powerful stakeholders (Moltz, 2015). Many of these emerging entities have only local or regional coverage requirements. Many more only require limited capability in discrete functional areas. As such, while growing in influence, their status is not expected to surpass that of traditional hegemons. Others, without the requisite aptitude or resourcing to develop organic space capabilities are choosing strategic partnerships that facilitate cost sharing or the leasing of services. Coordination and cost sharing between state actors has facilitated success stories such as the ISS and a variety of other deep-space exploration mission. Given the immense costs associated with these types of undertakings, international partnerships will likely continue to be the norm.

Although associated with a considerable amount of risk, the space domain has proven to be a hugely profitable investment opportunity for a large number of commercial entities ranging from privately owned business ventures to transnational companies. Commercially owned and operated spacecraft are present in every near-earth orbital regime. Many commercial operators lease payload space and/or bandwidth to a multinational customer base that often includes both government and civilian entities. From an IR perspective, this adds a significant amount of complexity, and interdependence (frequently associated stability) to the space domain.

Because profit margins in the traditional space industry favor specialization, industry giants like Boeing, Lockheed Martin and Raytheon (other than facilitating comprehensive projects of national strategic importance for the U.S. government) have led the way in discrete sector development, providing a wide range of specific services for their customer base. These include launch operations, satellite bus construction and payload integration, C2 and systems architecture maintenance, and technical support. Depending on factors such as organic capability and resourcing, customers may choose to outsource some or all of the aforementioned activities.

Other commercial actors have chosen instead to maintain a predominantly organic systems architecture in order to provide specialized products and services (e.g. high-resolution electrooptical satellite imagery or narrowband SATCOM) to their customers. Of note, the component-based nature of modern spacecraft prescribes that specific subsystems are almost always purchased from specialized third-party entities. Furthermore, the immense cost associated with launch operations dictates that this task is almost always outsourced, even by companies maintaining control of a majority of their space and ground segments. Emerging revolutionaries such as SpaceX, Blue Origin and Bigelow Aerospace are reducing these costs by introducing concepts such as organic supply chains and re-usable rocket boosters.

For the purposes of this thesis, commercial entities that only conduct sensor, spacecraft subsystem, or component design activities are not considered critical stakeholders. Instead, emphasis is placed on actors actively investing in or operating space segment components in support of tasks aligned with the previously defined functional areas.

Nontraditional actors and academic institutions are becoming increasingly involved in the space domain. Miniaturized spacecraft called CubeSats, 10cm x 10cm units constructed using commercial-off-the-shelf (COTS) components, are actively being designed and constructed at nearly every major university specializing in science, technology, engineering and math (STEM) activities. They frequently hitch rides to space as third parties on launch systems already scheduled to place traditional payloads into orbit. A CubeSat program sponsored by Universidad Sergio Arboleda in Bogotá, added Colombia to the list of space-faring nations when it facilitated the 2007 launch of Libertad-1 into a sun-synchronous LEO orbit from the Baikonur Cosmodrome in Kazakhstan (Universidad Sergio Arboleda, 2007). Although the capabilities of CubeSats are growing, these satellites typically have an extremely short life-span and lack the attitude determination and control (ADAC) sub-systems found in larger spacecraft. When combined with their still somewhat unregulated nature, this leaves many space professionals worried that they are contributing to the orbital debris problem.

**V. Counterspace Weapons.** So, what exactly are CS weapons and how are they categorized? In answering these questions, this chapter continues to address SRO 1 and provides the necessary context to facilitate a subsequent review of international space law and historical events (SRO 2). This, in turn, is required to address the primary research question and propose solutions to advance the status-quo (SRO 3), which seems to present inadequacies in CS weapons regulation.

The 2019 Space Threat Assessment classifies contemporary CS weapons into four categories: Kinetic Physical, Non-Kinetic Physical, Electronic and Cyber (Harrison, et al., 2019, Pg2). Before expanding on each it is important to note that CS weapons are not solely intended to target assets in the Space Segment of a systems architecture. Ground segment components such as control stations, data processing centers and networking infrastructure also make easily identifiable and vulnerable targets for malicious actors.

**a. Kinetic Physical Counterspace Weapons.** Kinetic physical CS weapons attempt to strike directly, or detonate a warhead near, a space-based system or ground station with the intent of causing catastrophic and irreversible damage (Harrison, et al., 2019, Pg3). The result of effective weapons employment usually entails complete system failure and (if targeting space-based assets) the generation of orbital debris that may significantly degrade the associated orbital regime. These weapons can be further categorized into direct-ascent and co-orbital systems. Direct-ascent weapons lack the terminal velocity to enter an earth-orbit and therefore rely on a ballistic flight path to make impact with their target (Harrison, et al., 2019, Pg3). Co-orbital CS weapons, on the other hand, are placed into earth-orbits that closely match those of their targets. Here, they can lay in wait for years before employment (Harrison, et al., 2019, Pg3).

Figure 5.1 provides a visual depiction of two (completely theoretical) kinetic physical CS weapon employment scenarios. The first scenario shows a direct ascent ASAT being used to target an electrooptical imaging satellite in a polar orbit. Ultimately, a warhead or kinetic kill vehicle (KKV) is launched towards the target satellite, on some form of rocket booster, with the intention of physically intercepting it in orbit. This requires extremely precise target sensing and guidance systems. The warhead or KKV does not reach orbital velocity and therefore maintains a ballistic trajectory. A successful proximity warhead detonation, or KKV intercept, physically destroys the target satellite, creating thousands of pieces of orbital debris that remain in orbit along the general direction of the satellite's previous velocity vector.

The second scenario shows a co-orbital ASAT being used to target a satellite in a prograde orbit with an inclination of around 45º. The ASAT device was launched previously into an orbital regime whose elements closely match those of its target. The ASAT device may then lie in wait for an undetermined amount of time before closing with its target and conducting some form of physical attack aimed at critically damaging or destroying the target system. This physical attack will likely also create significant amounts of orbital debris that remains in orbit along the general direction of the satellite's previous velocity vector. As mentioned in preceding chapters, orbital altitude and local environmental factors would dictate the rate at which this debris will de-orbit. Naturally, a capable space surveillance network (SSN) could identify the object and alarm the owner of the target system of a possible threat. But what if such a capability is disguised as a harmless science instrument? This is where the concept of dual-use technology comes into play.

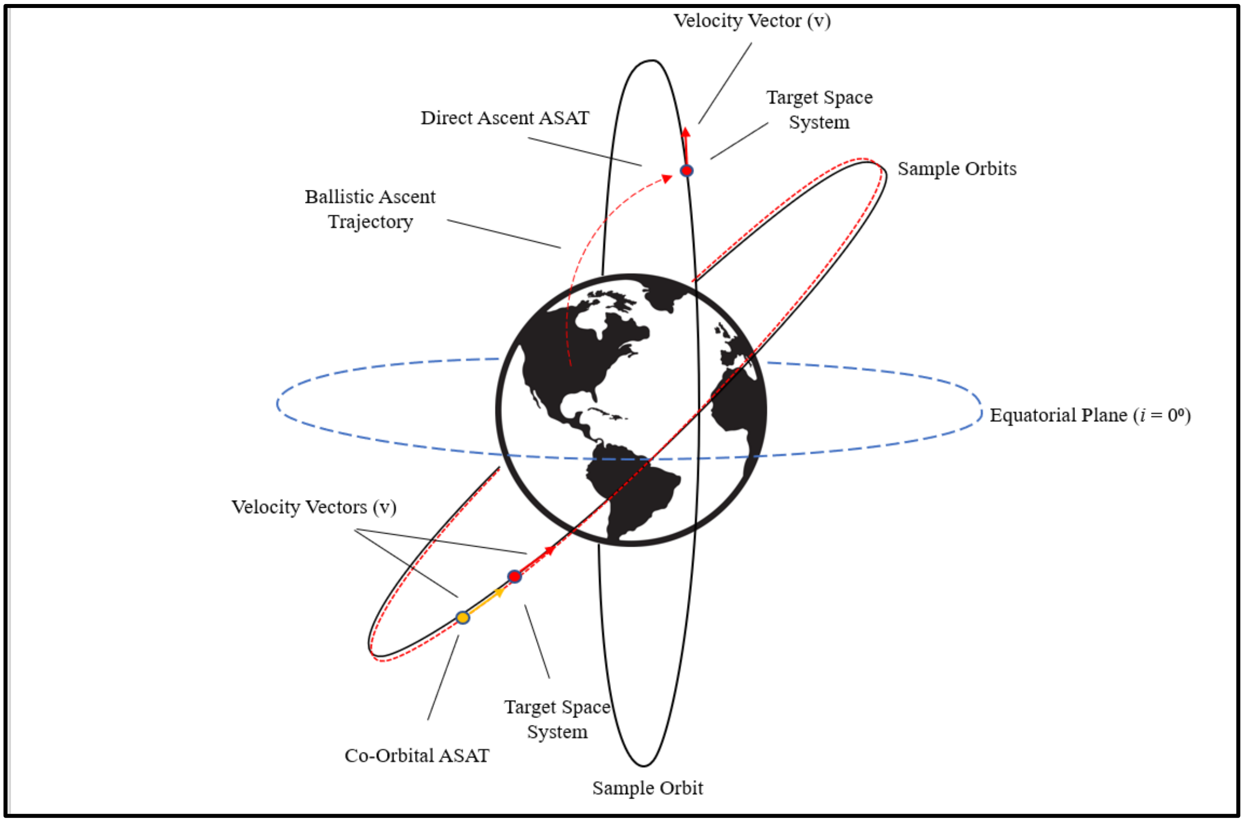


**Figure 5.1. Theoretical Employment of Kinetic Physical CS Weapons**

**b. Non-Kinetic Physical Counterspace Weapons.** Non-kinetic physical CS weapons are designed to cause physical effects on satellites and/or their associated ground stations without the use of physical contact (Harrison, et al., 2019, Pg3). Examples of non-kinetic physical CS weapons include lasers, electromagnetic pulse (EMP), and high-power microwave (HPM) generating ordnance (Harrison, et al., 2019, Pg3). The results of effective weapons employment differ significantly depending on the type and strength of the CS weapon utilized but may range from temporary sensor faults to catastrophic and irreversible system failure. Although generally not associated with the complete physical destruction of a space system, the loss of critical sub-systems (especially ADAC systems) may turn the satellite itself into orbital debris.

Figure 5.2 provides a visual depiction of another theoretical attack scenario, this time by a non-kinetic physical ASAT system. The same electrooptical imaging satellite from Figure 5.1 is carrying out designated sensor tasking over a specific geographic area (the FoV of the imaging sensor is depicted by a yellow oval). A malicious actor, with the intention of hiding strategic assets or making a political statement, decides to blind the imaging sensor using a targeted, high intensity, laser beam. Depending on a variety of factors, the results of this attack may range from a simple degradation in image quality to permanent sensor loss. Hypothetically, a space system could be targeted by a laser powerful enough to cause physical destruction. However, current technological limitations pertaining to power generation and overcoming the effects of atmospheric scintillation make this unrealistic for the time being.

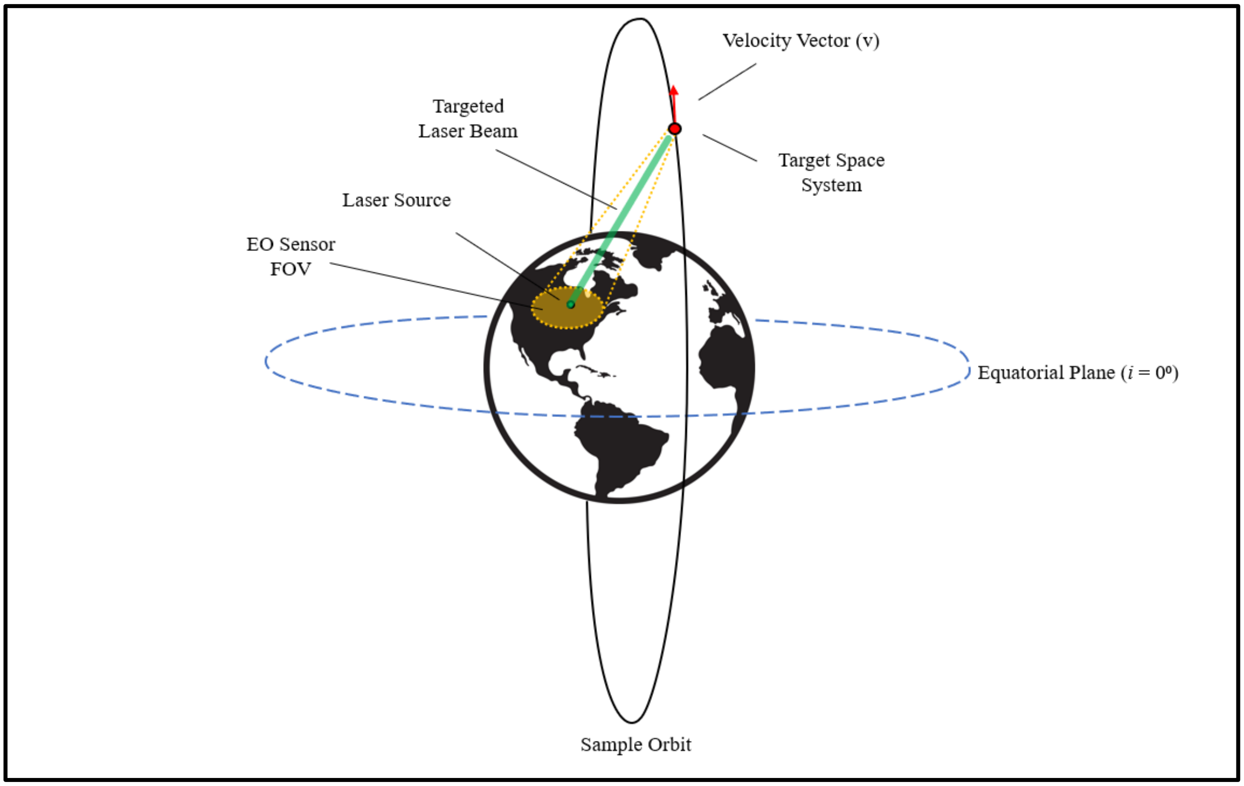


**Figure 5.2. Theoretical Employment of Non-Kinetic Physical CS Weapons**

**c. Electronic Counterspace Weapons.** Electronic CS weapons are designed to attack satellites and/or their associated ground stations via the EM frequency spectrum (Harrison, et al., 2019, Pg4). These attacks can be further characterized into jamming or spoofing. Jamming generally entails overpowering a sending or receiving antenna with a high-power signal that falls within the systems operational band (Harrison, et al., 2019, Pg3). Spoofing on the other hand entails tricking a receiver with a fake or re-transmitted signal to corrupt the data provided to end-users. The result of effective weapons employment is usually reversible in nature and therefore, although problematic, does not significantly contribute to the generation of orbital debris.

Figure 5.3 provides a visual depiction of a theoretical attack scenario where electronic CS weapons are employed to deny critical BLOS communications capabilities to a strategic adversary. The figure displays a constellation of five SATCOM assets operating in GEO. The proposed system architecture, via its comprehensive space and ground segments, provides global access to wideband data services for the end-user. The uplink antenna coverage of the target satellite is depicted by a yellow oval. Within this coverage area, a malicious actor directs a targeted jamming signal at the satellite. Because this jamming signal encompasses the same operating frequency as other uplink signals, it is able to overpower genuine ground segment entities attempting to pass mission critical C2 inputs. This type of electronic attack is called uplink jamming. Its effects are usually temporary in nature and do not create orbital debris.

The same electronic warfare principles can be used to target the systems ground segment. By overpowering downlink antennas, a malicious actor may prevent end-users from effectively utilizing the functional signal being sent by a space-based asset. Because downlink jamming generally targets receiving terminals within the terrestrial FoV of the malicious actor, it requires much less power. The jamming source may also be harder to identify and geo-locate. In many tactical scenarios, end-users may not even realize they are actively being jammed, instead blaming service interruptions on cryptographic security protocol mismatches or basic user error. Downlink jamming is also temporary in nature and does not generally implicate permanent physical damage to the associated functional equipment.

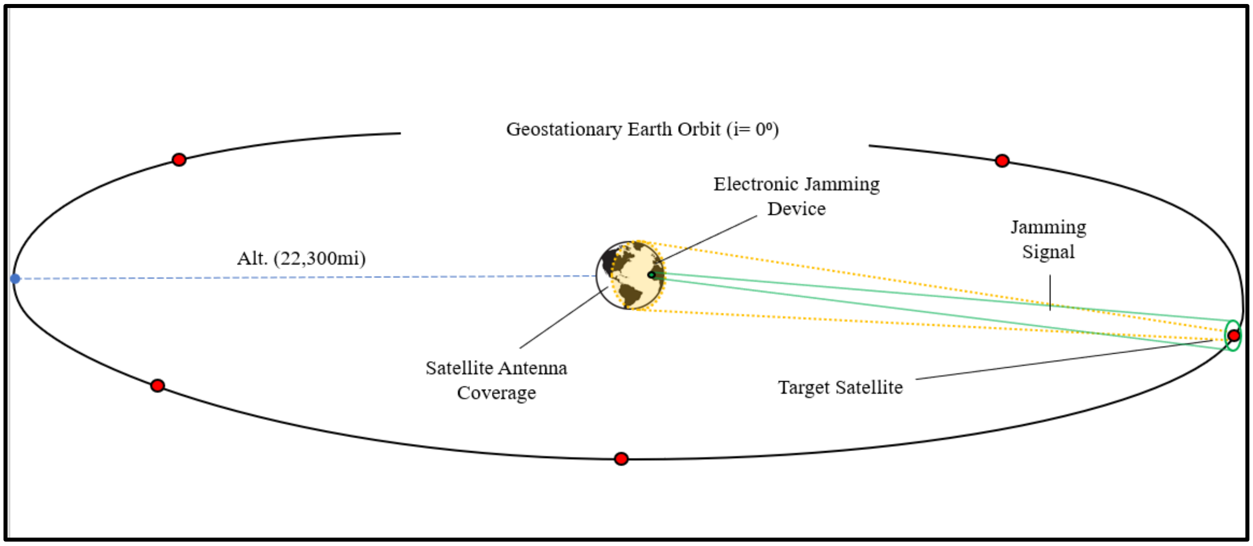


Figure 5.3. Theoretical Employment of Electronic CS Weapons

**d. Cyber Capabilities with Counterspace Effects.** The cyber domain may be leveraged for CS purposes by targeting the data utilized by space systems and their corresponding ground stations (Harrison, et al., 2019, Pg5). These types of attacks are typically utilized to monitor data / metadata or to insert corrupt data sets for spoofing purposes (Harrison, et al., 2019, Pg5). The results of effective cyber-attacks are typically reversible and may range from the compromise of sensitive information to temporary systems failure. However, unbound access to critical systems (specifically those intended for ADAC) may allow an attacker to go as far as altering orbital parameters and/or purging fuel reserves necessary for orbital station-keeping (Harrison, et al., 2019, Pg5). This, in turn, could lead to a spacecraft going defunct.

Figure 5.4 provides a visual depiction of such an extreme scenario. Here, the theoretical network infrastructure of a spacecraft's ground segment has been infiltrated by a malicious actor. The actor gains access to critical data that may facilitate intelligence collection activities. He then decides to execute malicious C2 functions (perhaps after unsuccessfully attempting to extort the system's owner), changing the spacecraft's orbital parameters and depleting all onboard fuel reserves. Since station-keeping maneuvers will eventually be required, the target satellite is now essentially a fully functional piece of debris with orbital parameters that may or may not still facilitate effective sensor employment.

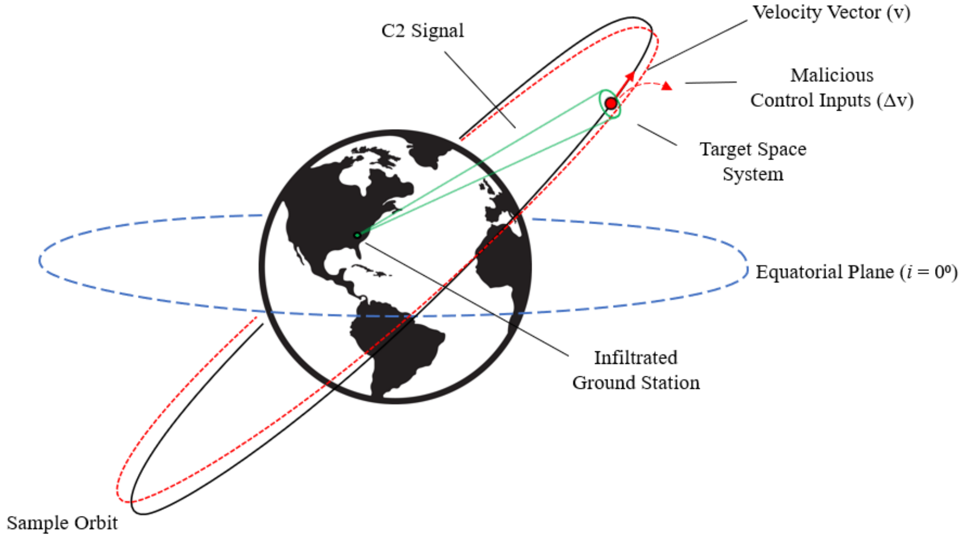


**Figure 5.4. Theoretical Employment of Cyberspace Capabilities**

**e. The Dual-Use Dilemma.** The dual-use nature of some space technologies imposes difficulties in differentiating between benign and malicious intentions. This often causes distrust amongst prominent international actors and makes the space domain particularly susceptible to security dilemmas as commonly defined by IR scholars (Johnson-Freese, 2017). While classifying ASAT capabilities into discrete functional categories is rather forthright, determining whether or not a space technology should be considered a weapon at all is complicated by what space professionals refer to as the Dual-Use Dilemma.

Within the military technology spectrum for example, a modern intercontinental ballistic missile (ICBM), developed with the purpose of delivering a nuclear weapon to a target on the other side of the globe, is likely also capable (with slight modification) of placing a co-orbital ASAT into space. Likewise, an ICBM interceptor such as the Standard Missile 3 (SM-3), is also capable of being employed as a direct ascent ASAT weapon to destroy a satellite in LEO. As such, some policymakers argue that any entity with these capabilities is automatically to be considered a threat to assured freedom of action in the space domain.

The dual-use concept extends into nearly every aspect of space operations. If there is a realistically feasible concept of employing a space and/or ground segment capability against an adversary, someone has likely thought of it and used it to support a political talking point. Even the space shuttle, by virtue of having had a mechanical arm capable of capturing and manipulating a spacecraft in orbit, has been critiqued by various conspiracy theorists as being a possible CS weapon. In recent year, technology demonstrations and proofs of concept, carried out by historically dominant and emerging space actors alike, have driven intelligence analysts, military officials, and politicians (on all sides) into a literal frenzy. Because the tyranny of distance associated with space does not allow counterparts to physically verify intent, intense speculation over the purpose of these actions carries on.

In the U.S., the Dual-Use Dilemma has had a significant and negative effect on the commercial sector. Because their organically manufactured launch vehicles meet ICBM criteria, American companies such as SpaceX, Blue Origin or Orbital ATK (just to name a few), with peaceful intentions aimed mostly at maximizing profit margins and facilitating space exploration, must follow strict guidelines that often discourage an international customer base. These International Trafficking in Arms Regulations (ITARs) are intended to prevent strategic adversaries from obtaining technology and/or intellectual property that could be used to threaten the national security of the U.S. While ITARs apply to the full spectrum of technological capabilities, they are particularly coercive on space technology.

**Figure 5.5. Space Shuttle Captures Orbital Object with Robotic Arm (NASA, 1990)**

**VI. <u>Orbital Debris</u>.** This chapter finalizes our pursuit of SRO 1 by providing fidelity to the orbital debris problem. Specifically, by defining orbital debris types and expanding upon the consequences of high-velocity collisions between debris and active space systems. Most importantly, we highlight the prominent role of CS weapons in contributing to environmental degradation by analyzing several case studies. Lastly, we expound on present-day debris measurement and management limitation and the concept of environmental capacity.

The lack of effective CS weapons regulation is nowhere more apparent than in orbital debris problem currently complicating all aspects of space operations. Continued access to the international space domain will require a conscious and coordinated international effort to slow debris generation and preserve this environment. In near-earth space, orbital debris is generally categorized as either man-made or naturally occurring. Each imposes hazards on spacecraft, that by their kinetic nature, can create additional debris.

**a. Debris Types.** Comets are believed to be the prevailing source of naturally occurring orbital debris affecting spacecraft in near-earth orbits. These frozen objects travel in highly elliptical orbits around our sun, emanating long debris trails as ambient temperatures increase near orbital perigee (Lanphear & Medina, 2009, Pg119). When these debris trails intersect with the earth's orbital path, they generate a phenomenon commonly referred to as meteor showers. The visual effects observable during a meteor shower are actually small meteoroids burning up in the upper layers of the earth's atmosphere. Naturally, these small meteoroids are traveling at extreme velocities and can cause significant damage when impacting with spacecraft (Moltz, 2019, Pg53). Space systems hosting components with large surface areas, such as solar panels and parabolic dish antennas, are particularly vulnerable to damage. Hypervelocity impacts of meteoroids (sometimes traveling in excess of 71km/sec) with spacecraft have also been known to cause plasma discharges that can severely damage electronic components (Lai, 2012, Pg188).

Generally speaking, man-made orbital debris (i.e. space debris or space junk) refers to any human-made object in orbit around the Earth that no longer serves a useful purpose (Liou, 2019, Pg2). This may imply defunct (i.e. non-operational but intact) spacecraft, mission related debris (e.g. explosive bolts, payload fairings, unburnt fuel particles, and even dropped tools and accidentally released items by astronauts), spent rocket bodies, and fragmentation debris. Considering orbital velocities in excess of 7km/sec in LEO, even miniscule objects can cause severe damage when impacting with operational spacecraft. Millimeter-size debris, possibly paint chips, have been known to cause visible damage to cockpit and copula windows on space shuttles and the ISS. As explained previously, the orbital altitude of debris dictates their lifetime. Items in low LEO orbits, most susceptible to the effects of atmospheric drag, eventually re-enter the earth's atmosphere. As orbital altitude increases and atmospheric drag decreases, the timeframe to re-entry grows. Debris in altitudes nearing GEO is essentially permanent.

Man-made orbital debris has been accumulating since the start of human space activity in the 1950s. Figure 6.1 is a product generated by the U.S. National Air and Space Administration's (NASA's) Orbital Debris Program Office (ODPO) that cumulatively depicts identified man-made orbital objects in LEO, by type. Immediately apparent is the alarming, and non-linear, growth of fragmentation debris, which does not seem to correlate with a steady and more predictable increase in other categories of orbital objects. This specific chart only includes objects with a diameter in excess of 10cm. The inclusion of millimeter-size fragmentation debris would skew the results even further, highlighting the impact of individual spacecraft anomalies.

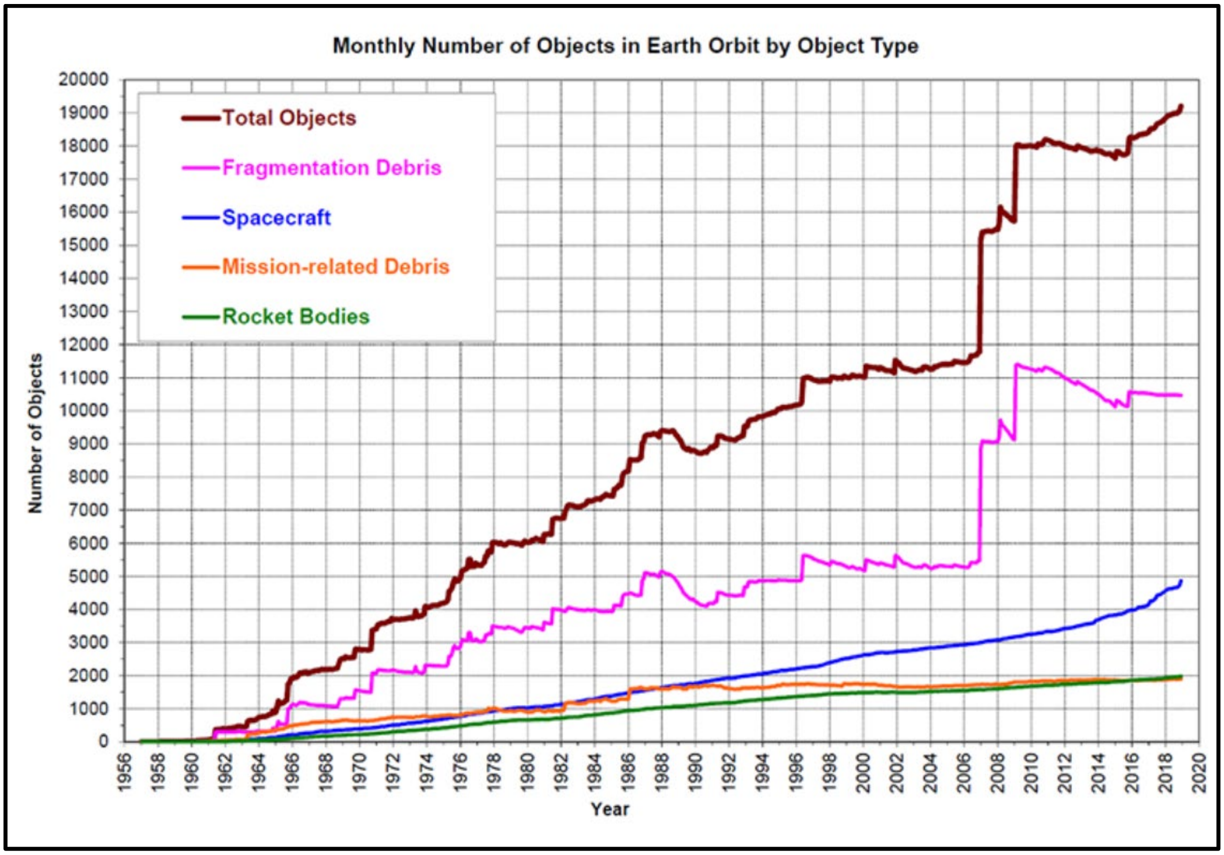


**Figure 6.1. Orbital Debris in LEO > 10 cm (NASA ODPO, 2019)**

**b. Effects on Space Systems.** Orbital debris can impose substantial kinetic impact hazards on spacecraft. Taking into account the fundamentals of physics, specifically the formula for kinetic energy (K.E. = 1/2m*v^2), the destructive potential of even small debris particles, traveling in excess of 7km/sec, becomes immediately apparent. As with most environmental risk management scenarios, risk is a function of probability and consequence.

Collision probability is a function of debris flux. I.e. the measure of particles that pass through a specific cross-sectional area over time (NRC, 2011, Pg27). The denser the concentration of particles at a specific orbital altitude, the higher the flux and correlated collision probability. According to NASA ODPO, flux associated with man-made and naturally occurring orbital debris ranging in size between 10 microns and 1mm is similar at LEO (NRC, 2011, Pg42). When addressing particles larger than 1mm in LEO, man-made objects far outweigh meteoroids (NRC, 2011, Pg42). Beyond LEO, man-made debris is much less common and meteoroids become the prominent impact hazard (NRC, 2011, Pg42). Nevertheless, meteoroid flux is not in any way related to human activity. Only man-made debris can be curtailed through the implementation of effective engineering principles and responsible policy measures. As such, reducing the collision probability between operational spacecraft and man-made orbital debris will serve as the primary objective for LOEs identified at the end of this thesis.

In the case of collisions between orbital debris and operational spacecraft, the type of damage (i.e. consequence) incurred depends on a wide variety of factors, including relative impact velocity (a function of the velocity vectors of both objects), impacting particle mass and density, and impact area specifics (Lai, 2012, Pg2). Kinetic hazards imposed by small debris fragments, ranging in size from 100 microns to 1mm, can be managed through ballistic shielding around critical systems in the spacecraft body, and redundant systems design (NRC, 2011, Pg87). However, protruding subsystems such as antennas and solar arrays, by nature of their composition and large surface area, remain vulnerable to penetrating damage. While not immediately destructive in nature, these types of impacts may gradually reduce solar panel efficiency and/or antenna gain over time. Naturally as the theoretical size of an impacting object increases, system resiliency provided by ballistic shielding and component redundancy becomes less effective. In most instances, the destructive and sometimes mission terminating effects of larger particles can only be circumvented through collision avoidance maneuvers.

Meteoroid impacts impose an additional, and somewhat unique, consequence. Traveling at a much faster rate than man-made debris (at times in excess of 71km.sec), hypervelocity impacts can cause spalling (i.e. secondary particle ejections on the backside of metallic surface or ballistic shielding) and charged plasma expansion (Lai, 2012). While spalling may further propagate kinetic damage throughout a spacecraft's interior compartments, hypervelocity impact induced plasma expansion has been proven to generate EM energy that can spread through and severely damage a spacecraft's electrical components, even when no physical damage has been incurred (Lee, et al., 2011, Pg1). This may result in temporary system and/or sensor failures. Severe plasma expansion events may destroy critical sub-systems entirely, leaving the satellite non-functional and (in the very worst case) uncontrollable.

As portrayed in the subsequent portions of this chapter, the most severe impact events result in the generation of additional debris. Depending on the circumstances of the event, thousands of additional objects can be created, some trackable and many more too small to trace. This debris can severely degrade an orbital regime and shorten the service life of neighboring spacecraft. In their 2010 paper, The Kessler Syndrome: Implications to Future Space Operations, Donald Kessler and his research partners classify collision consequence into three discrete categories:

> (1) Negligible Non-Catastrophic Collisions: A collision that produces only little subsequent debris and therefore has a negligible short and long-term impact on the space environment (Pg9).
>
> (2) Non-Catastrophic Collisions: A collision that produces subsequent debris roughly 100 times the mass of the impacting object. Subsequently produced debris adversely affects the short-time orbital environment (Pg9).
>
> (3) Catastrophic Collisions: A collision that produces significant subsequent debris of both all sizes. Subsequently produced debris adversely affects both the short and long-time orbital environment (Pg9).

Figure 6.2 was prepared by NASA ODPO to aid in visualizing orbital debris risk determinants. Inversely proportional trends pertaining to collision probability and consequence are displayed as a function of debris particle size in specific altitude ranges. These trends indicate the same flux vs. orbital altitude relationships described previously. That being, a decline in the comprehensive number of debris particles as altitude increases. When taking into account current measurement constraints, the figure also identifies a portion of residual (i.e. difficult to manage) risk associated with debris particles ranging in size from 1mm to 10 cm and 1cm to 1m in LEO and GEO respectively.

Episodic radar measurements, capable of detecting debris of this size, only allow statistical environmental modeling, and not real-time situational awareness, at these altitudes (NRC, 2011, Pg82). As such, informed avoidance maneuvers are not an option. Furthermore, the mass of these objects is enough to easily overcome most reasonable allocations of protective shielding on impact. This leaves a considerable amount of risk that can only be managed through passive controls attempting to stabilize, and ultimately reduce, the associated debris flux.

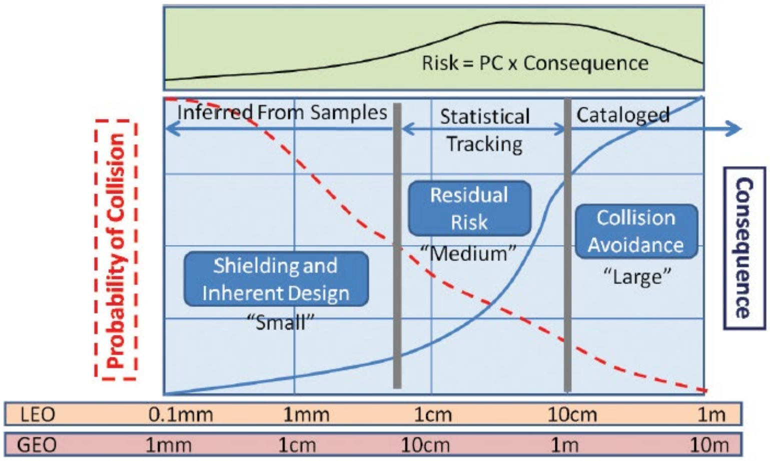


**Figure 6.2. Risk as Function of Probability and Consequence (NRC, 2011, Pg74)**

**c. The 2007 Chinese ASAT Test.** A significant portion of the man-made orbital debris, currently accounted for, can be contributed to two discrete events. Those being an ill planned and improperly executed attempt by the Peoples Republic of China (PRC) to test direct ascent ASAT technology in 2007, and an accidental collision between two communications satellites operating in LEO in 2009. The PRC ASAT test, in particular, had devastating effects on the near-earth space environment, creating orbital debris that will likely remain a hazard for hundreds of years.

On January 11, 2007, at 2228 Greenwich Mean Time (GMT), Peoples Liberation Army forces launched a two stage, solid fuel, ballistic missile from Xichang Space Center in Sichuan province (Kan, 2007, Pg1). The missile, a modified DongFeng-21 variant, was launched from a road-mobile transporter erector launcher (TEL) and carried a 600kg KKV (CSIS, 2020; Weeden

2010). Its target was the PRC weather satellite, Fenguyn-1C, orbiting in a sun-synchronous LEO orbit at an altitude of around 865km (Kelso, 2007; NRC, 2011). Ultimately, the KKV impacted with the satellite at a speed of over 9 km/sec (Weeden, 2010), creating thousands of pieces of orbital debris that, over time, propagated along the satellites orbital path in the general direction of the original velocity vector.

Initial observations from the U.S. SSN, then operated in large part by the U.S. Air Force and advertising the capability of identifying and tracking orbital debris as small as 10cm in diameter, reported a correlated addition of no less than 2,087 pieces of orbital debris immediately after the event (Kelso, 2007, Pg5). Furthermore, NASA ODPO estimates that the test created over 35,000 pieces of orbital debris larger than 1cm in diameter, but too small to track with traditional SSN sensors (Kelso, 2007, Pg5). To make matters worse, a comparison of orbital characteristics, conducted a little over six months following the event, suggested that nearly 1,900 other space systems routine pass through the debris field, to include the ISS (Kelso, 2007, Pg5). This imposes considerable increases in risk (and operating costs related to conjunction avoidance maneuvers), on respective system operators. Scientists contribute a 37% increase in the chance of future conjunctions to this event alone (Kelso, 2007, Pg6). Figure 6.3 depicts the steep increase in fragmentation debris, and total number of orbital objects, associated with the event.

Putting fundamental reasoning for the ASAT test aside, a complete lack of consideration for its environmental effects during the mission planning process, led to the selection of a target satellite with much too high of an operational altitude. Furthermore, the final angle of attack of the KKV was substantial enough to drive a significant portion of the debris, created on impact, to even higher altitudes. Figure 6.4 depicts the primary debris cluster near Fenguyn-1C's original operating altitude. However, the figure also shows how event related debris has been tracked at apogee altitudes nearing 3,800km.

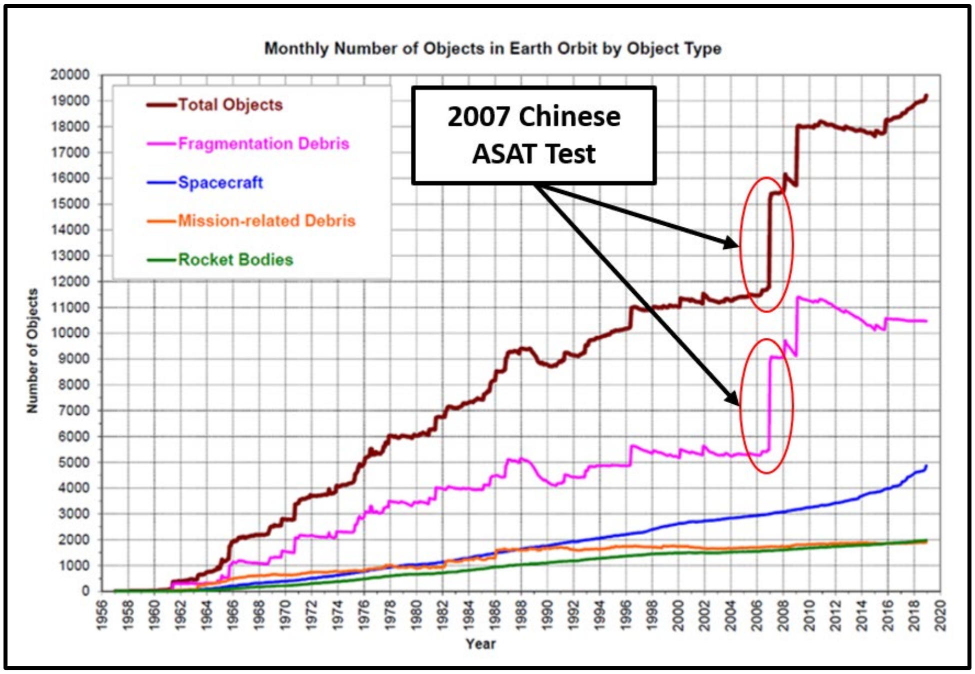
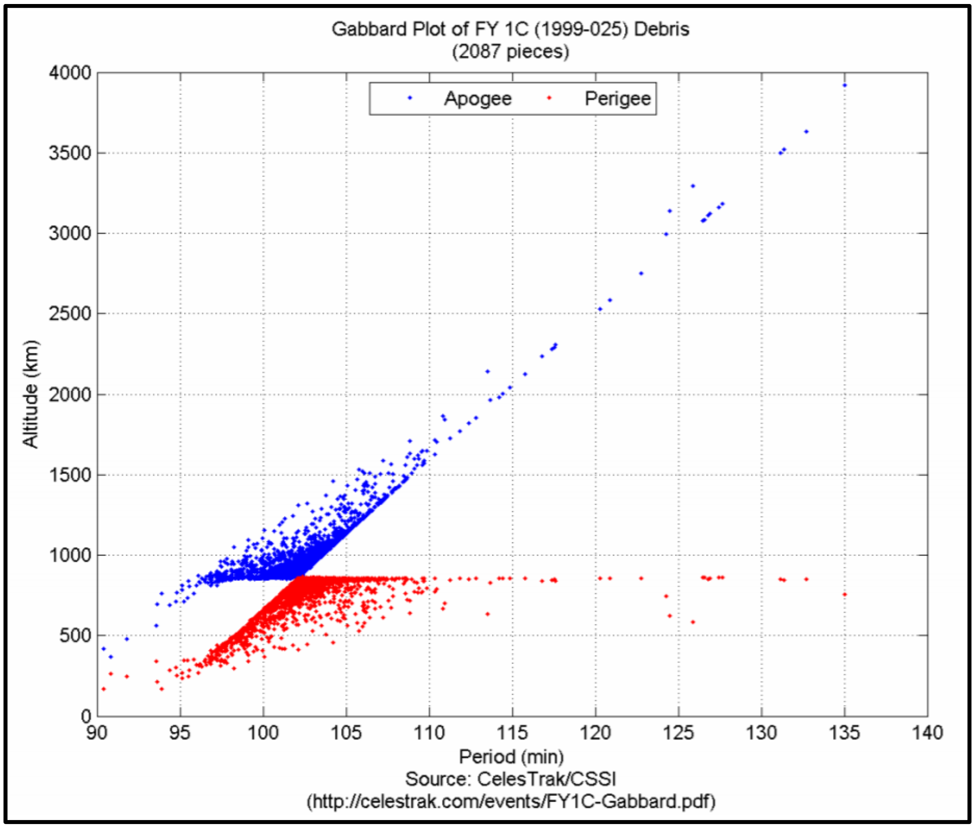


Figure 6.3. Orbital Debris Created by 2007 Chinese ASAT Test (NASA ODPO, 2019)



Source: CelesTrak/CSSI
(http://celestrak.com/events/FY1C-Gabbard.pdf)

Figure 6.4. Fengyun-1C Debris, 28/Aug/2007 (Kelso, 2007)

**d. 2009 Iridium 33 – Cosmos 2251 Collision.** February 10, 2009, marked the first time in history that two intact satellites collided in orbit (Kelso, 2009, Pg1). After the 2007 Chinese ASAT test, this collision became the second most debris producing event in history. Cosmos 2251 was a defunct Russian communications satellite that is thought to have ceased operations shortly after it was launched in 1993 (Kelso, 2009, Pg1). Iridium 33, on the other hand, was an active and fully operational component of the commercial, 66 satellite, Iridium constellation, facilitating global satellite phone services to a range of customers around the world.

A known debris hazard, Cosmos 2251 did not have ADAC capabilities and was actively tracked by various entities, to include the Center for Space Standards and Innovation (CSSI), which provides conjunction analysis and threat reporting to a number of stake holders. At the time of the collision, the possibility of a "close-approach" between the two space objects was specified by CSSI conjunction analysis models (Kelso, 2019, Pg13). However, the indications were not severe enough to call for collision avoidance maneuvers on the part of Iridium. The satellites collided at an altitude of 789km with nearly perpendicular velocity vectors, generating over 1,300 pieces of trackable orbital debris (Kelso, 2009, Pg2-3; NRC, 2011, Pg26). Figure 6.5 depicts the steep increase in fragmentation debris, and total number of orbital objects, associated with the event.

Figures 6.6 and 6.7 display cataloged orbital parameters associated with the Iridium 33 – Cosmos 2251 collision. Primary debris clusters are co-located at altitudes slightly below 800km. This orbital space is shared by over sixty other satellites in the Iridium constellation alone. However, the figures also make apparent that a substantial amount of debris was accelerated into higher, longer lasting, orbits. Apogee altitudes exceed 1,300km and 1,700km for debris associated with Iridium 33 and Cosmos 2251 respectively. Considering the associated perigee altitudes, over half of the debris associated with Iridium 33 is expected to remain an active hazard for more than a century (Kelso, 2009, Pg10).

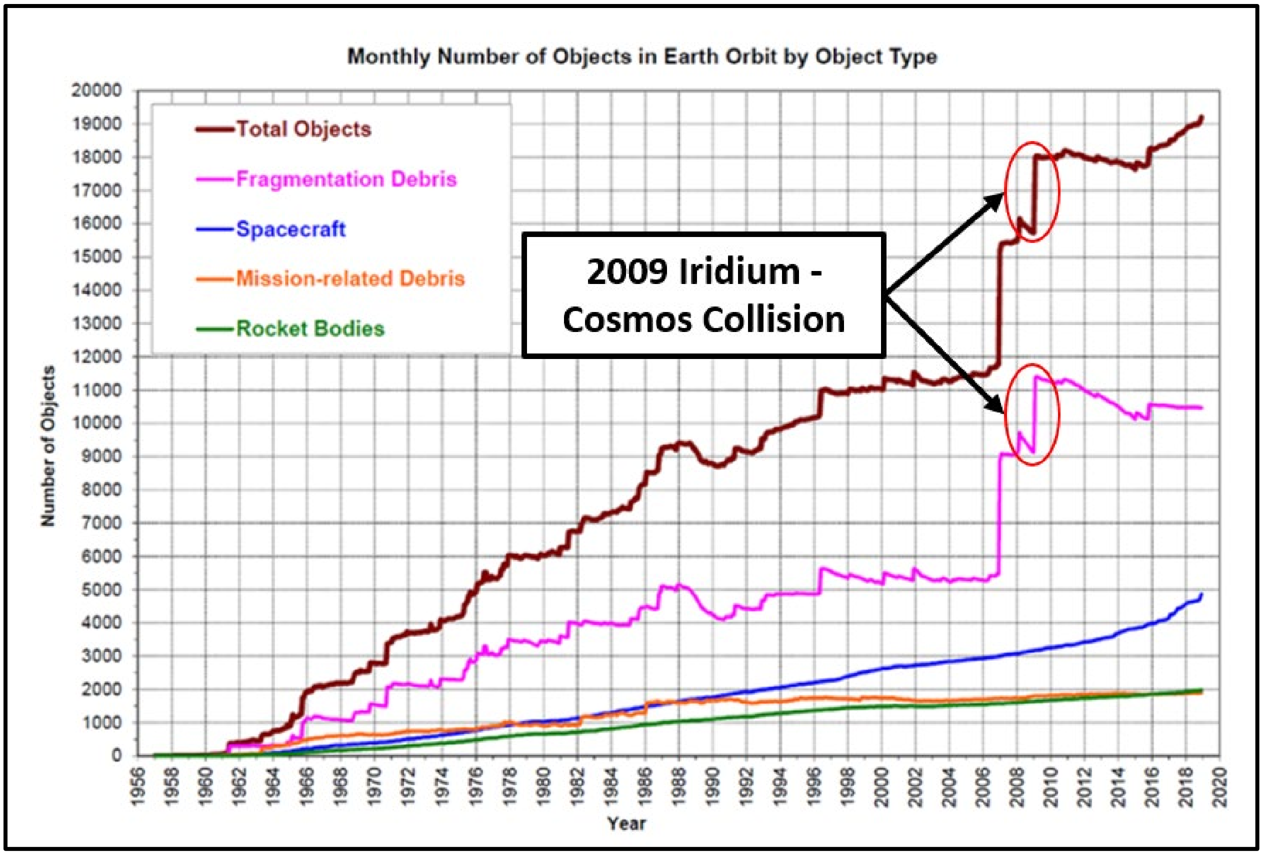
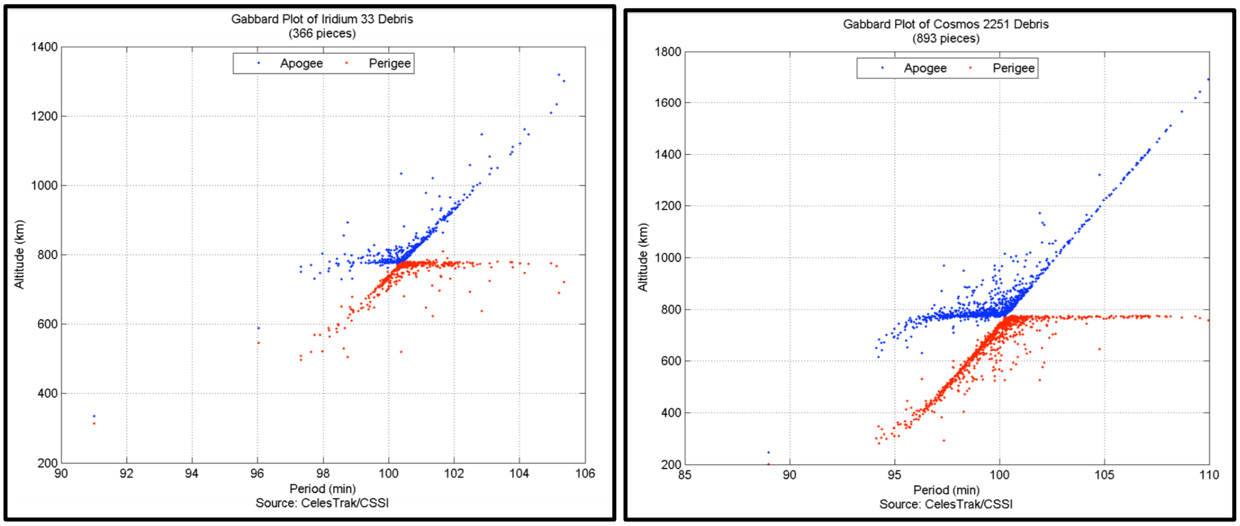


Figure 6.5. Orbital Debris Created by 2009 Iridium 33 – Cosmos 2251 Collision (NASA ODPO, 2019)



Figures 6.6&7. Iridium 33 / Cosmos 2251 Debris, 28/Apr/2010 (Kelso, 2009)

**e. Orbital Debris Management.** Because we do not yet possess the technology to actively remove space debris from orbit, current orbital debris management activities focus entirely on mitigation. I.e. until orbital debris remediation becomes technologically feasible, we must constrain the generation of new orbital debris to the maximum extent feasible. As with many other environmental risk management activities, this is best accomplished through the application of both active and passive controls.

Active controls include the identification and tracking of active spacecraft and orbital debris, the cataloging of pertinent orbital characteristics, and the conduct of conjunction analysis to avoid the possibility of collisions (and consequential generation of additional orbital debris). It takes a coordinated, interagency, effort and the application of substantial technological capabilities to develop an accurate and reliable catalog of orbital objects. By virtue of these factors, and the dual-use nature of many space situational awareness (SSA) sensors, only the most prominent space actors currently maintain capable SSNs. Within the U.S., this has traditionally been a role of the DoD. More specifically, the United States Space Force sponsored Combined Space Operations Center (CSOC), formerly known as the Joint Space Operations Center (JSPOC).

Passive controls, on the other hand, imply the use of environmental measurements, modeling, and statistics-based predictions to inform engineers and policymakers in the conduct of designing future spacecraft / mission-profiles and drafting pragmatic space policy. NASA ODPO is the principal sponsor of orbital debris research activities in the U.S. and therefore a key entity in facilitating the development of passive controls. As such, it has aligned its functional areas respectively (Liou, 2019). Because active controls associated with orbital debris management are rather intuitive (i.e. sense-track-coordinate-avoid), the subsequent section will place emphasis on providing context to the generation of passive controls. Individual policy measures informed by these methods are explored in later chapters.

**1. Orbital Debris Measurement.** Generally speaking, current sensor technology allows for the identification of orbital debris as small as 2mm in diameter, in LEO (NRC, 2011, Pg32). This is accomplished using a variety of ground-based optical telescopes and radars that, together, form a comprehensive SSA network. Subsequently, data and metadata collected by these sensors facilitate debris flux calculations as they pertain to certain orbital altitudes and inclinations. LEO debris flux for objects smaller than 1mm in diameter is determined by analyzing the surface of spacecraft that have returned to earth (NRC, 2011, Pg32). A number of purpose-built space-based sensors, often times serving as secondary payloads, have also been developed to sense the impact of micro debris during the conduct of an unassociated primary mission profile (Liou, 2019, Pg11).

Many of the same devices are used to conduct measurements in the GEO environment. Here, considering the significant increase in orbital altitude, optical telescope and radars are currently constrained to identifying debris with a diameter in excess of 1m (NRC, 2011, Pg30). Furthermore, because GEO spacecraft do no return to earth, the analysis of spacecraft surfaces is not possible. This imposes a significant amount of uncertainty in predicting micro-debris flux.

Naturally, individual sensors are constrained by virtue of their geographic position and capacity. As such, ODPO measurement activities do not imply the active tracking of every known piece of orbital debris at any given time. Much rather, a small section of the target environment is sampled to provide a basis for statistical environmental modeling. Figure 6.8 provides additional context pertaining to the capabilities of ODPO's most utilized measuring devices (Liou, 2019, Pg8). As can be seen, ODPO relies almost entirely on the DoD SSN to identify debris larger than 10cm in diameter. The SSN consists of optical and radar sensors strategically positioned throughout the world to maximize global coverage. Sensors data is analyzed and fed to the CSOC at Vandenberg Air Force Base, California, where it is shared with the appropriate entities.

The identification of smaller debris, ranging in size between 1mm and 10cm, is facilitated by a number of civilian (yet predominantly DoD funded) sensors. The Massachusetts based and Massachusetts Institute of Technology (MIT) Lincoln Labs operated Haystack and Haystack Auxiliary radars are capable of detecting debris as small as 2cm in diameter (MIT Lincoln Labs, 2020; NRC, 2011, Pg32). The Goldstone Radar, located near Barstow California, is part of the NASA Jet Propulsion Laboratory's (JPL's) Deep Space Communication Complex and can detect the presence of orbital debris in LEO with a diameter as small as 2mm (Liou, 2019, Pg8; NASA JPL, 2020). As mentioned previously, environmental flux calculations pertaining to micro-debris, requires the positioning of specialized on-orbit sensors and/or physical examination of impact damage on returned spacecraft surfaces.

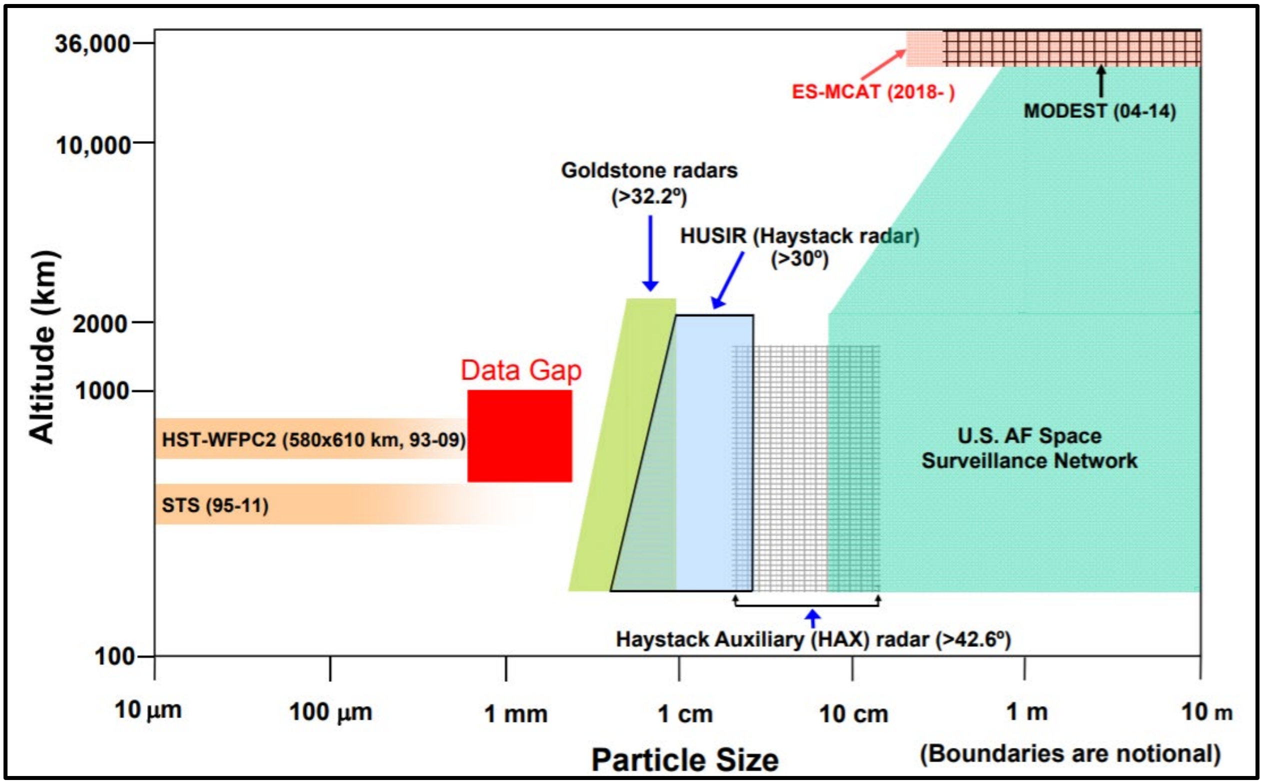


**Figure 6.8. Orbital Debris Measurement Methods (NASA ODPO, 2019)**

**2. Modeling and Simulation.** NASA ODPO uses a number of different modeling and simulation tools to facilitate work in its primary functional areas. Some are outside of the scope of this thesis. The statistical analysis tools most pertinent to informing orbital debris mitigation efforts are described below and include the NASA Orbital Debris Engineering Model (ORDEM) and the LEO-to-GEO Environmental Debris Model (LEGEND).

ORDEM compiles measurements from all previously described source sensors and inspections to calculate debris flux as a function of particle size and orbital characteristics (Liou, 2019, Pg17-19). Subsequently, this information can be used to estimate debris impact risks according to rate, size, impact velocity, and impact vector (Liou, 2019, Pg18). A quantifiable hazard analysis of this sort is extremely useful for engineers designing the physical characteristics and mission-profiles of future spacecraft. It may dictate the use of additional shielding or (depending on the individual scenario) call for an adjustment to orbital characteristics in order to reduce the possibility of debris induced anomalies. Ultimately, ORDEM aims to both reduce operational risk and facilitate continued access to near-earth orbital regimes by limiting the unnecessary generation of additional orbital debris.

LEGEND is NASA ODPO's primary model for the prediction of future orbital debris environments (NASA ODPO, 2019). Based on user defined scenarios (e.g. the application/non-application of passive and/or debris hazard controls) LEGEND is capable of estimating the long-term evolution of debris flux as a function of orbital altitude, latitude, and longitude (NRC, 2011, Pg38). This allows policy advisors to gauge the effectiveness of passive controls, both previously implemented and currently considered. Among other considerations, LEGEND forecasts have played a considerable role in shaping U.S. Government Orbital Debris Mitigation Standard Practices (ODMSPs).

Figure 6.9 provides an example of the type of products LEGEND is capable of producing. Along with a historically cumulative number of orbital objects (greater than 10cm in diameter) in LEO, the chart provides two-century predictions for three user-defined scenarios. Calculations were based on the assumptions that no further, large, satellite constellations are deployed. The most extreme scenario takes into account the non-application of ODMSPs such as post-mission disposal (PMD) maneuvers to clear operational spaces and reduce the chance of collisions caused by defunct systems. It also takes into account the possibility of explosions / break-ups that are sometimes associated with severe system anomalies. The steep and cyclical increase of this model suggest a Kessler effect. I.e. in the theoretical absence of extensive debris mitigation measures, we have already reached a point of "no-return" at which orbital debris will self-multiply through regular collisions between orbiting objects.

The continued application of stringent mitigation measures yields only slightly more favorable results. Taking into consideration the assumption that 90% of all current and future LEO spacecraft conduct a PMD maneuver, and that no explosive spacecraft anomalies create additional large debris clouds, the number of orbital objects larger than 10cm is still predicted to increase by a factor of more than 60% over the next 200 years. Technically feasibility aside, these predictions drive some scientists to suggest that active debris remediation is truly the only manner of maintaining accessibility to the LEO environment (Liou & Johnson, 2006).

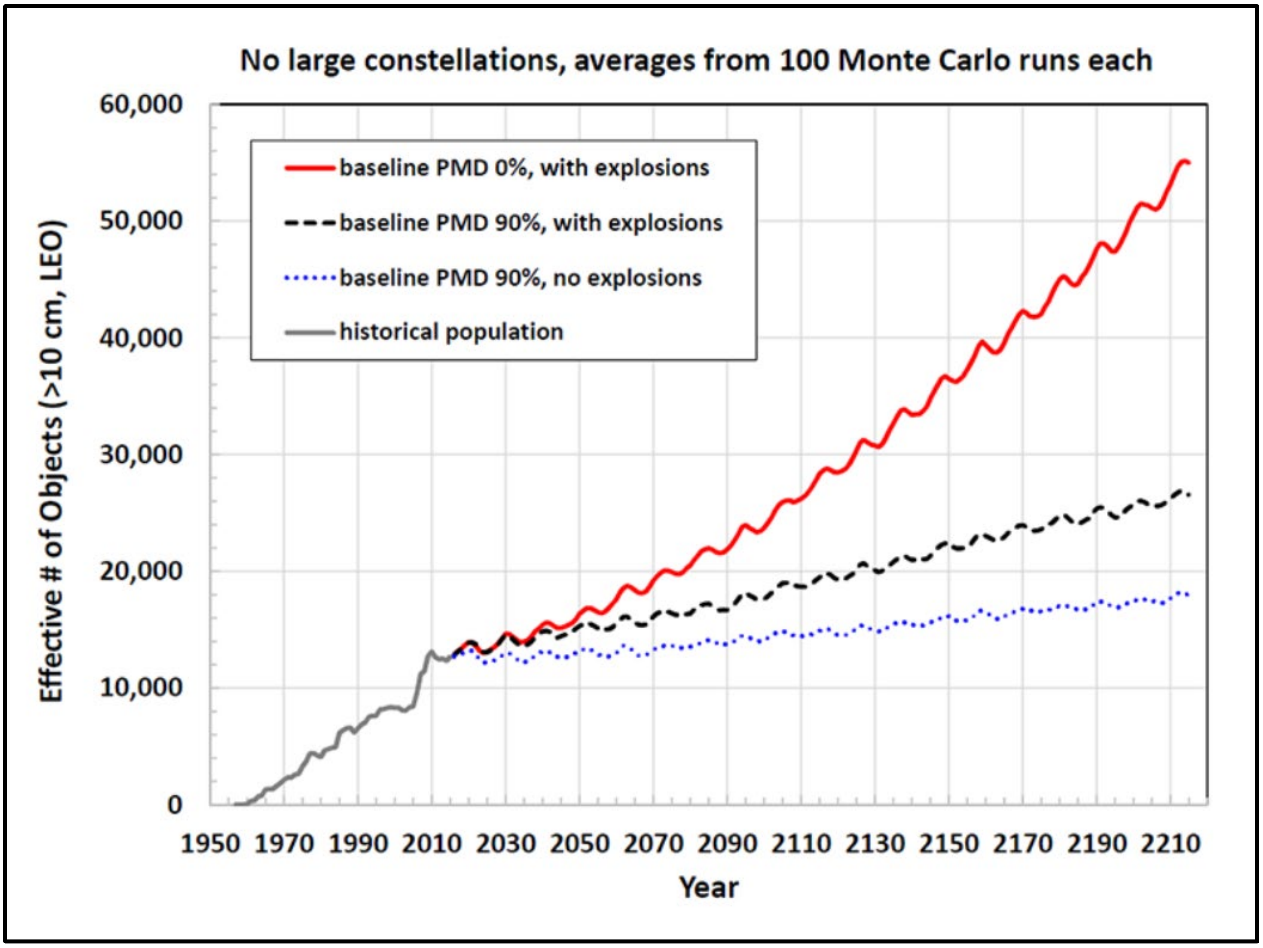


Figure 6.9. LEGEND Orbital Debris Predictions (NASA ODPO, 2019)

**f. Environmental Capacity and the Kessler Syndrome.** The vastness of space does not imply a boundless capacity for orbital debris. On the contrary, leading experts believe we may reach a point of saturation at which the magnitude of debris flux begins to induce random collisions between existing orbital objects in near-earth space, each producing subsequent debris particles (Kessler, et al., 2010). Ultimately this phenomenon could result in a cascading effect, a sort of runaway series of ever-more frequent collisions, that exponentially degrades the orbital environment until it is no longer able to be utilized safely (Kessler, et al., 2010, Pg1).

A number of recent studies suggest that in LEO specifically, atmospheric drag will not remove collision fragments at a rate faster than they can theoretically be generated by the existing population of space objects (Kessler, et al., 2010, Pg3-4), and that only selective retrieval (i.e. active hazard control currently unfeasible due to technological and economical constraints) of the most prominent debris hazards, in combination with an extremely stringent adherence to responsible standards of behavior, can reverse the trend of cascading debris growth (Kessler, et al., 2010, Pg15). The 2009 Iridium 33 – Cosmos 2251 collision may represent the commencement of this cascading chain reaction frequently referred to as the Kessler Syndrome.

One thing is certain, statistical analysis indicates that active debris removal will eventually be required. Until then, we are bound to the application of more feasible active controls, like maintaining coherent SSA and conducting timely collision avoidance maneuvers. Extensive and immediate room for growth, however, remains in the realm of passive controls. Increasing system and infrastructure resiliency through the application of evolving engineering principles will help to maintain adequate service life-spans in progressively contaminated orbital environments. Additionally, and most pertinent to the conduct of this thesis, pragmatic space policy measures can buy time. That is, to maintain manageable orbital debris growth rates until technological advancements facilitate supplementary courses of action.

Having addressed SRO 1 in its entirety, we should now possess an adequate understanding of the unique physical, environmental, and operational complexities of the international space domain. Furthermore, we hold the requisite knowledge of principles pertaining to CS weapons and orbital debris to facilitate an advance to the fulfillment of SRO 2. This will entail conducting a detailed analysis of pertinent IR forums, applicable international space legislation, and historical events to clearly define the status-quo as it pertains to CS weapons regulation. That is, to answer the questions: What international regulatory instruments exist? What types of CS weapons does it apply to? What do historical events tell us about compliance with this existing legal framework? And, how has the behavior of critical actors shaped the policy positions of counterparts?

**VII. <u>Relevant International Space Law - Existing Regulatory Institutions</u>.** In an effort to clearly define extent of existing CS weapons regulation and the associated foreign policy positions of individual actors within the international system (SRO 2), this chapter will examine international institutions with prominent roles in space governance. While UN forums have served as the principal setting for IR activities aimed at advancing this type space legislation, most technical considerations are rooted in contributions made by external agencies. The most pertinent of these will also be explored.

**a. Inter-Agency Space Debris Coordination Committee.** The Inter-Agency Space Debris Coordination Committee (IADC) is an international forum of space agencies collaborating for the purposes of orbital debris measurement, management, and modeling (IADC, 2019). Current members include the Italian Space Agency (ASI), the French National Center for Space Studies (CNES), the Chinese National Space Administration (CNSA), the Canadian Space Agency (CSA), the German Space Agency (DLR), the European Space Agency (ESA), the Indian Space Research Organization (ISRO), the Japanese Aerospace Exploration Agency (JAXA), the Korean Aerospace Research Institute (KARI), NASA, the Russian State Cooperation for Space Activities (ROSCOSMOS), the State Space Agency of the Ukraine (SSAU), and the United Kingdom Space Agency (UKSA) (IADC, 2019). Naturally, NASA representatives are informed by the previously described ODPO studies. IADC holds no legal authority and membership is completely voluntary. The organizations primary purpose is to facilitate information exchange, enable opportunities for cooperative research, and to identify effective orbital debris mitigation procedures (IADC, 2019).

**b. Conference on Disarmament.** The Conference on Disarmament (CD) has a well-established relationship with the UN, however, for the purpose of this thesis, it is listed as a separate entity. As it stands today, it is the successor to the Ten-Nation Committee on Disarmament, the subsequent Eighteen-Nation Committee on Disarmament, and ultimately the Conference of the Committee of Disarmament (UN, 2020). The CD budget is included in that of the UN and annual CD sessions are typically conducted on UN premises in Geneva, Switzerland (NTI, 2020). The Director-General of the UN Office at Geneva also serves as the Secretary-General of the CD (UN, 2020). That being said, the organization retains the liberty to adopt its own rules, procedures and agendas (UN, 2020). Naturally, considering the source of funding and principle leadership, agenda items are frequently aligned with topics of interest in the UN General Assembly. As the only existing international negotiating body for disarmament treaties, recent CD efforts have focused on a series of five cores issues. These include nuclear disarmament, fissile materials, negative security assurances, armament transparency, and the prevention of an arms-race in outer space (PAROS) (UN, 2020).

PAROS was first added as a CD agenda item in 1982 (Meyer, 2011, Pg2). Subsequently, an ad-hoc committee was established in 1985 to facilitate formal negotiations towards a legally binding instrument for CS weapons regulation (SWF, 2009, Pg2). Over the course of the next decade, little progress was made as the U.S. (along with several western allies) prevented any meaningful advances. Their arguments were based primarily on mistrust and a desire to maintain LOEs deemed pertinent to national security. Neoconservative legislators and lobbyists for a defense industry still actively pursuing national missile defense contracts likely had significant leverage in this matter (Johnson-Freese, 2017, Pg122). U.S. representatives downplayed the need for additional arms control in a post-Cold War environment. Others cited the dual-use dilemma as a complicating and preventative factor in establishing regulation that does not also unduly prohibit the conduct of civilian spaceflight activities. The ad-hoc PAROS committee met for the last time in 1994 (SWF, 2009, Pg2). Since then, stakeholders like Russia and China continue to press for legally binding CS weapons regulation and PAROS remains a topic of discussion during CD sessions. However, in the absence of U.S. policy changes, a treaty remains unlikely.

**c. The United Nations.** There is much debate amongst IR scholars about the concept of international governance, its theoretical utility, and formal representation. In the absence of any meaningful alternative, this thesis aligns itself with those hypothesizing that (despite its organizational faults) the UN most accurately embodies this role. In its forums, national representatives gather in an attempt to impose order on an otherwise anarchical international system. The six principle organs of the UN include the Security Council, the Economic and Social Council, the General Assembly, the International Court of Justice, the Secretariat, and the Trusteeship Council. Space is an important topic of discussion in several of these venues, particularly in the First and Fourth Committee of the General Assembly.

**1. Committee on the Peaceful Use of Outer Space.** The UN General Assembly established the Committee on the Peaceful Use of Outer Space (COPUOS) in 1959 to govern the exploration and use of outer space (UNOOSA, 2020c). Specifically, to maintain its peaceful utility in the midst of growing Cold War tensions between the U.S. and the USSR. COPUOS falls under the Fourth Committee of the UN General Assembly and has served as the principal entity in the establishment of existing international space law. At the time of this report, the committee has 95 member states and four observer organizations (UNOOSA, 2020c). COPUOS manages two principal subordinate bodies. They include the Scientific and Technical Subcommittee (STSC) and the Legal Subcommittee (LSC). A newly established working group titled Space 2030, that aims to facilitate peace and sustainable development through the application of space-based technologies, also reports to the committee. Figure 7.1. graphically portrays the COPUOS organizational hierarchy.

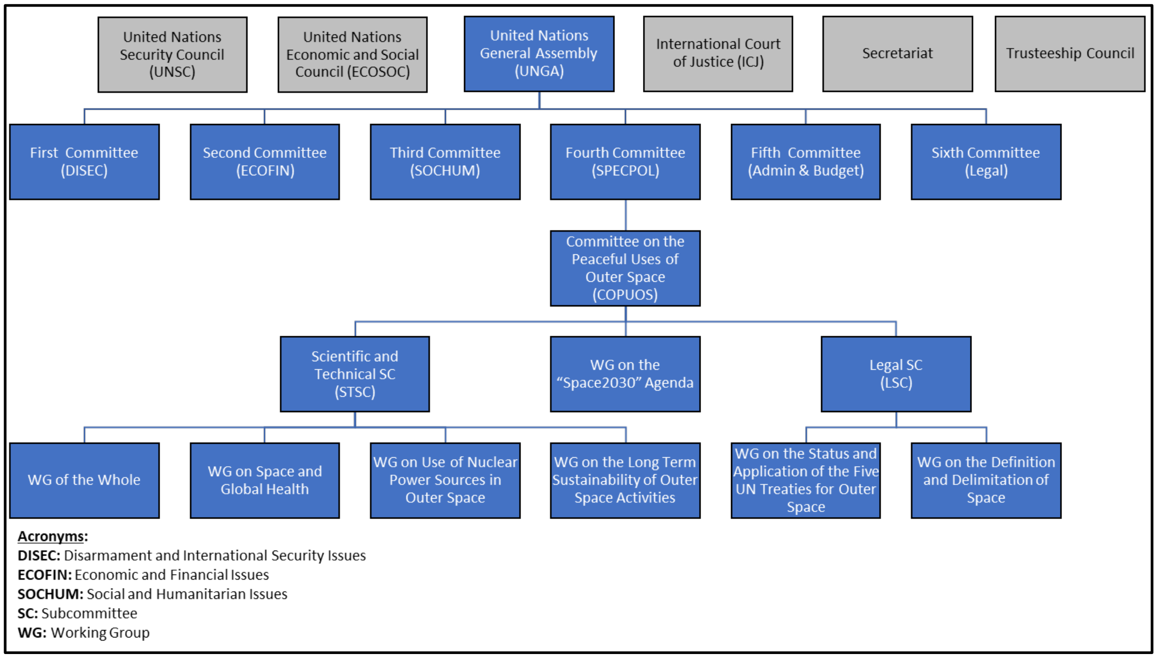


**Figure 7.1. COPUOS Organizational Structure (UNOOSA, 2020b)**

The STSC manages a series of working groups focusing on the scientific and technical aspects of space (UNOOSA, 2020c). Naturally, the themes of these working groups change over time. Currently, topics of interest include space and global health, the use of nuclear power sources, and the long-term sustainability of outer space activities (UNOOSA, 2020b). The orbital debris problem has been part of the STSC agenda since 1994 and is typically addressed within the Working Group on the Long-Term Sustainability of Outer Space Activities (UNOOSA, 2010). Significant progress has been made in this particular setting, including the drafting of a set of behavioral guidelines that were endorsed by the General Assembly in December of 2019.

The LSC manages working groups focusing on legal questions pertaining to the exploration and use of outer space (UNOOSA, 2020c). At the time of this report, topics of interest include the status and application of the five UN treaties for outer space, and the definition and delimitation of space (UNOOSA, 2020b).

**2. Office for Outer Space Affairs.** UNOOSA falls under the UN Secretariat, which carries out a majority of the organization's substantive and administrative tasks. Working in direct support of COPUOS, UNOOSA is one of 11 other secretariat offices that gather and prepare background information, carry out decisions made in UN leadership forums, organize international conferences, and prepare/translate/distribute documentation (UN, ND). The office is composed of a Committee, Policy and Legal Affairs Section (CPLA) and a Space Applications Section (SAS) (UNOOSA, 2019b). UNOOSA also maintains the UN Register for Objects Launched into Outer Space and manages the UN Platform of Space-based Information for Disaster Management and Emergency Response (UNOOSA, 2020d). Figure 7.2 graphically portrays the UNOOSA organizational hierarchy.

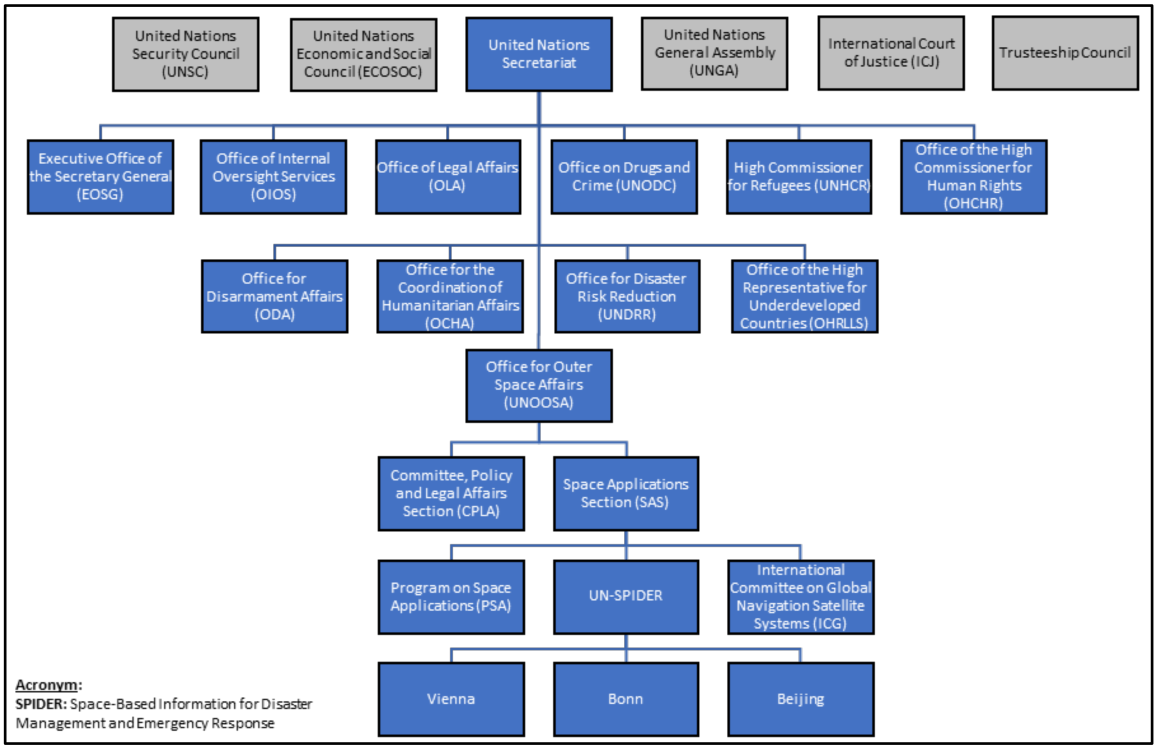


**Figure 7.2. UNOOSA Organizational Structure (UNOOSA 2, 2019)**

**3. United Nations Disarmament Commission.** Space is also pertinent to discussions within the First Committee of the UN General Assembly. As can be seen in Figure 7.3, the UN Disarmament Commission (UNDC) currently has two active working groups, the Nuclear Working Group (NWG) and Outer Space Working Group (OSWG) (UNODA, 2018). Because a number of attempts to codify binding CS weapons treaties have failed in recent years, UNDC efforts are now aimed at further implementing and measuring the effectiveness of Transparency and Confidence-Building Measures (TCBMs) for Outer Space Activities. UNDC TCBM deliberations are frequently informed by parallel CD discussions concerning PAROS.

The hope is that over time, TCBMs (while remaining non-binding) will facilitate mutual trust, paving the way for constructive dialogue and progress towards more compulsory international legislation (UN, 2013a, Pg21). Along with the recently adopted COPUOS Guidelines for the Long-Terms Sustainability of Outer Space Activities, TCBMs currently represent the most viable avenue for progress towards true stability in space. As we will see later, one such TCBM addresses the intentional break-up of orbital objects (e.g. kinetic physical ASAT employment) and calls for the prevention of long-lived space debris. In cases were debris is intentionally generated, it calls for the notification of potentially affected states (UN, 2013a, Pg17).

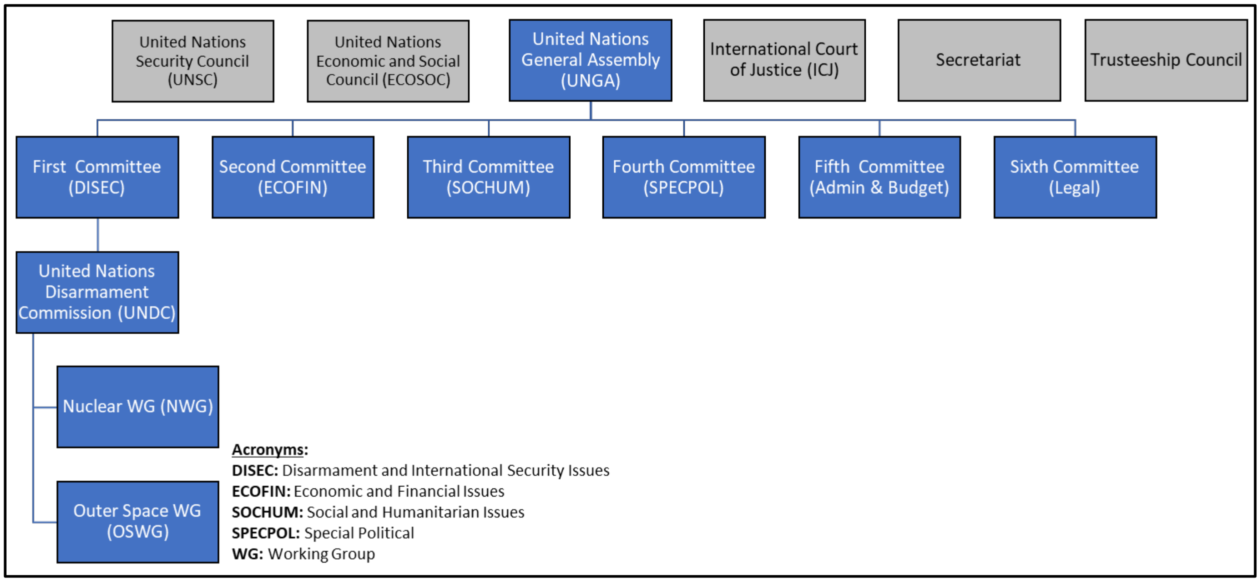


**Figure 7.3. UNDC Organizational Structure (UNODA, 2018)**

**4. Office for Disarmament Affairs.** The UN Office for Disarmament Affairs (UNODA) carries out direct support activities for the UNDC, just like UNOOSA does for COPUOS. To an extent it also supports the DC. The office was originally established as the Department for Disarmament Affairs in 1982 and, after several changes in title and organizational structure, rebranded as UNODA in 2007 (UNODA, 2020b). As indicated by Figure 7.4, UNOSA's subordinate entities are divided into four branches, each focusing on a discrete functional area. These functional areas include weapons of mass-destruction (WMDs), conventional weapons, information and outreach, and regional disarmament.

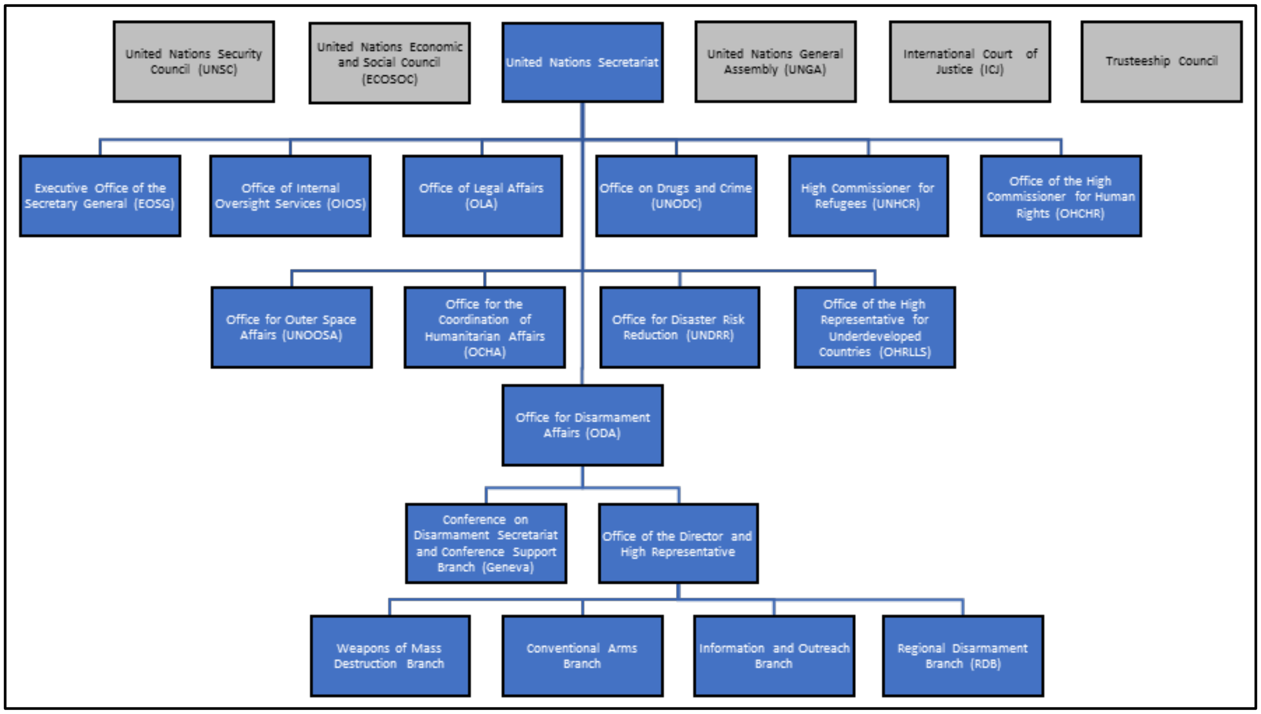


**Figure 7.4. UNODA Organizational Structure (UNODA, 2020a)**

**5. Economic and Social Council.** Although not directly tied to CS weapons regulation, the UN Economic and Social Council (ECOSOC) includes organizations very much pertinent to the conduct of international space governance. The International Telecommunications Union (ITU) serves as one of 14 specialized agencies, supporting the ECOSOC, that set global norms and standards (ECOSOC, 2020, Pg27). One of its primary responsibilities is to manage the operational EM spectrum and orbital assignment of satellites (ITU, 2020). Most prominently, the ITU receives requests for (via the appropriate national intermediaries) and subsequently assigns individual GEO slots. Because GEO real-estate is limited and assignments are conducted on a first-come first-serve basis, scrutiny of ITU policies is beginning to increase. Like the effective administration of orbital spaces, EM spectrum management is vital in maximizing the utility of the space domain. By preventing inadvertent signal jamming, ITU EM spectrum regulation helps to ensure both C2 and functional information flows freely between space and ground segments. Along with the International Standardization Organization (ISO), the ITU provided subject matter expertise that was key to the development of both UN TCBMs and Guidelines for the Long-Terms Sustainability of Outer Space Activities.

ECOSOC also includes a number of functional and regional commissions. The Commission on Science and Technology Development (CSTD) is one of eight functional commissions that facilitates the discussion of pertinent issues amongst representatives of national governments (UNCTD, 2020b). The most recent CSTD session, in June of 2020, included the use of space technologies to support UN Sustainable Development Goals as a primary topic (UNCTD, 2020a). Figure 7.5 displays ECOSOC's organizational hierarchy as it pertains to space.

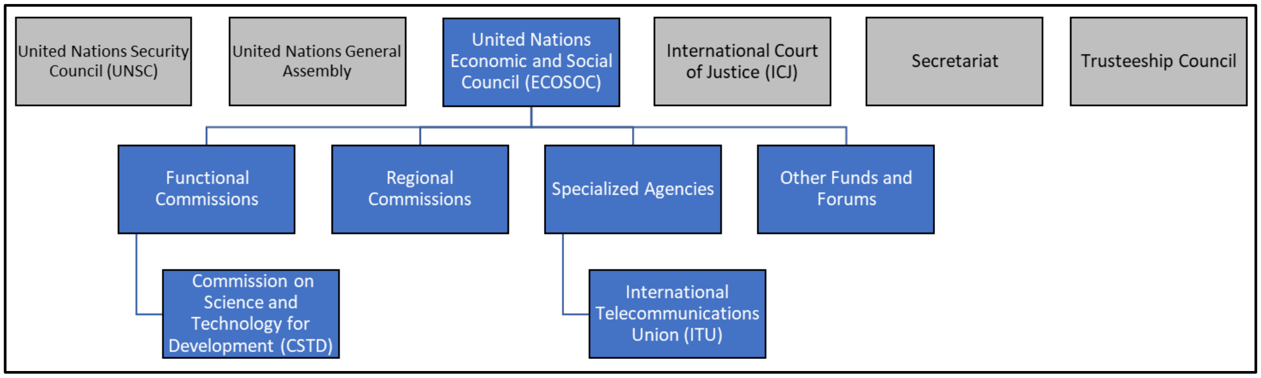


**Figure 7.5. Space in the UN ECOSOC (ECOSOC, 2020)**

**d. Private and Commercial Entities.** The concept of complex interdependence can be used to explain the growing influence of private and commercial entities in the conduct of space governance. Although not directly involved in legislative processes pertaining to treaties or codes of ethical conduct, a steadily increasing reliance on space-based services and support infrastructures allows transnational corporations such as Inmarsat (a well-known and widely utilized provider of wideband SATCOM services) to wield a substantial amount of soft power. SpaceX represents another such entity. Widely renowned for their recent advances in launch operations, this privately owned venture also aims to provide high-speed satellite internet services to most of the populated world via their growing STARLINK constellation.

As more and more national actors, including governmental and military agencies, utilize third-party service providers, the influence of these commercial entities grows. There will likely come a time when powerful businesses hold more political power in space than certain nation states. As troublesome as this trend may appear, it does create the potential for imposing additional stability. Because customers often-times share bandwidth or purchase transponder capabilities on the same spacecraft, compliance with responsible behavioral norms is simply in the best interest of all parties involved. In an increasingly interdependent space environment, the application of CS weapons against an enemy's commercially hosted military capability, would almost certainly impact a wide array of other customers. This, in turn, would draw wide-spread international outrage and condemnation. Interestingly enough, the interdependence concept may also provide opportunities for purposely advancing the resiliency of space system architectures.

**VIII. Relevant International Space Law - Existing Regulatory Instruments**. The previous chapter indicated a seemingly well-established system of international organizations engaged in the process of space governance. Next, in continued pursuit of SRO 2, we will examine the fruits of its labor. Specifically, through the examination of legal instruments in search for guidance (direct or implied) that inhibits the testing or operational employment of CS weapons. The circumstances surrounding the drafting and ratification of each legislative apparatus should also provide an insight into the historical foreign policy positions of primary stake holders. Only functioning regulatory instruments will be scrutinized. Treaties, resolutions, and bi-lateral agreements that have since expired / been superseded by other devices will not be addressed.

There are five international treaties that support the framework for international space law. These include the 1967 Outer Space Treaty, the 1968 Rescue Agreement, the 1972 Liability Convention, the 1976 Registration Convention, and the 1984 Moon Agreement. Only the Outer Space Treaty and Liability Convention can loosely be associated with the topic of CS weapons regulation. Because of the dual-use nature associated with many ICBM, ABM, and WMD technologies, a number of strategic arms treaties are also worth exploring. These include the 1963 Partial Nuclear Test Ban Treaty (PTBT), and the 2011 New Strategic Arms Reduction Treaty (New START).

**a. Partial Nuclear Test Ban Treaty.** This accord is also known as the Treaty Banning Nuclear Weapon Tests in the Atmosphere, in Outer Space, and Under Water. It serves as the first piece of international law applicable to the topic of CS weapons regulation and was signed by representatives of the U.S., Great Britain (GB), and the USSR on August 5th, 1963, following lengthy deliberations about compliance and verification procedures (DOS, NDa). After ratification by the U.S. Senate and President on September 24th and October 7th respectively, it entered into force on October 10th, 1963 (DOS, NDa). The treaty remains in effect to this day.

Efforts to severely curtail nuclear weapons testing followed a frenzy of activity between late 1961 and early 1963. A joint moratorium, agreed upon by the above parties in 1958, halted nuclear test activities for three years, until Moscow announced on August 30th, 1961, that it would resume atmospheric tests (Boyne, 2012). The following month, the soviets initiated a series of 59 nuclear tests that included the largest nuclear device ever detonated (Boyne, 2012), the 50 megaton Tsar Bomba deployed on October 30th, 1961, in the Mityushikha Bay Nuclear

Testing Range (AHF, 2014). President Kennedy (an arguably staunch opponent of provocative nuclear policies) was thus pressured into approving a U.S. response. He endorsed what would come to be known as Operation Dominick on March 2nd, 1962.

A Joint Task Force (JTF) titled JTF-8, under the command of Major General Alfred Starbird, was established to coordinate Operation Dominick (Boyne, 2012). Test events were to include underwater detonations (Operation Swordfish), submarine-launched ballistic missile tests with atmospheric air-burst detonations (Operation Frigate Bird), and exo-atmospheric detonations intended to study the viability of nuclear-tipped ABM interceptors (Operation Fishbowl) (DOE, 1998; Boyne, 2012). Among several operational test failures, Operation Fishbowl included five successful nuclear detonations in near-earth space, ranging in size from roughly 10 kilotons to over one megaton (Emanuelson, 2009). Tests were conducted using Thor, Nike-Hercules, and XM-33 Strypi missiles launched from Johnston Island in the Pacific Ocean, 900 miles southwest of Hawaii (DOE, 1998; Emanuelson, 2009).

The most prominent exo-atmospheric test event was dubbed Operation Starfish Prime. It took place on July 9th, 1962, when a 1.4 megaton warhead was deployed at an altitude of just over 400 km (Emanuelson, 2009). The blast illuminated the night sky for thousands of miles and was clearly visible from as far away as Fiji. The weapons immediate EMP effects were far stronger than expected and caused damage to electrical and communications infrastructure on the island of Oahu (Emanuelson, 2009). The subsequent effects of intense radiation remained persistent in LEO for months, ultimately rendering useless a multinational array of spacecraft.

Radiation linked to the Starfish Prime test event is believed to have been the primary cause in the failure of satellites Ariel (British ionospheric experimentation spacecraft), TRAAC (U.S. experimentation spacecraft), Transit 4B (U.S. navigation system spacecraft), Injun I (U.S. experimentation spacecraft), Telstar I (U.S. communications satellite), and Kosmos V (USSR research and technology demonstration spacecraft). It also damaged satellites Explorer 14 (U.S. radiation detection and magnetospheric mapping spacecraft), Explorer 15 (U.S. radiation detection and magnetospheric mapping spacecraft) and Relay 1 (U.S. communications satellite). Some of these, now defunct, satellites will remain in orbit for centuries. Operation Dominick concluded on December 31st, 1962, with a total of 36 conducted detonations (DTR, 2015, Pg1).

In addition to the physically destructive effects of exo-atmospheric nuclear detonations, a growing number of scientists and engineers were becoming concerned with the environmentally contaminating effects of nuclear fallout. Both U.S. and soviet stakeholders, pursuing parallel efforts to advance human space flight, warned that additional test events could eventually make LEO uninhabitable for crews of manned spacecraft. After John Glenn became the first American astronaut to orbit the earth on February 20th, 1962, NASA (operating under presidential directives to land a man on the moon before the end of the decade) had aspirations to continue sending American astronauts into space as part of the Mercury, Gemini, and Apollo programs (Moltz, 2019, Pg127). The soviets too, intended on continuing the space race. This gave both the Kennedy and Khrushchev administrations motive to enter pragmatic treaty negotiations.

Hardliners and neoconservative advisers on both sides urged strongly against a nuclear test ban treaty, citing both the necessity to continue evaluating technology and unacceptable circumstances pertaining to treaty verification. The soviets, especially, were unwilling to host international inspectors (Moltz, 2019, Pg128). Ultimately, it was the successful employment of the USSR's own photo reconnaissance satellite in April of 1962 that would provide enough common ground for the two super powers to willingly commit to a limited test ban treaty. The Zenit 2 system, developed in response to the American Corona fleet of photoreconnaissance satellites which had been operating since 1959, would give both entities the ability to monitor treaty compliance remotely via national technical means (NTM) (Moltz, 2019, Pg129).

The PTBT consists of five articles. These are summarized in Table 8.1. Article I strictly prohibits the testing of nuclear devices in all but underground environments. Even when conducted underground, signatories must guarantee that radioactive debris is prevented from propagating past territorial limits. Most pertinent to this thesis, the treaty prevents the testing of nuclear weapons in space. As made evident by the theoretical concepts described in previous chapters and the destructive effects of the Starfish Prime event, nuclear tipped ballistic missiles and ballistic missile interceptors can (under the premises of dual-use technology) also be considered ASAT weapons. The nuclear device is to be considered a proximity warhead capable of destroying target spacecraft via its explosive effects, EMP, or long-term radiation exposure. It can therefore be reasonably concluded that the 1963 PTBT also prohibits the testing of nuclear CS weapons. The treaty makes no mention of other CS weapons technologies.

| Article # | Synopsis |
|---|---|
| Article I | • Nuclear weapons testing shall not be conducted in the atmosphere, in outer space, or underwater (including territorial waters and high seas).<br>• Nuclear weapons testing shall not be conducted in any environment that would permit radioactive debris to be present outside of the territorial limits of the nation conducting the testing. |
| Article II | • Any signatory may propose treaty amendments.<br>• Treaty amendments must be approved by a majority vote. |
| Article III | • The treaty is open to all states for accession.<br>• The governments of the U.S., the USSR, and GB are designated as Depositary Governments. |
| Article IV | • The treaty duration is unlimited.<br>• Member states maintain the right to withdraw at any time; must provide notice no less than three months prior to withdrawal. |
| Article V | • Treaty documents maintain equal authenticity regardless of language.<br>• Document transmittal and storage instructions. |

**Table 8.1. Summary of the 1963 PTBT (UN, 1963b)**

**b. The Outer Space Treaty.** Also known as the Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies, the Outer Space Treaty embodies perhaps the single most widely recognized piece of space legislation to date and provides the framework for international space law. It was opened for signature on January 27th, and entered into force on October 10th, 1967 (DOS, NDb). Today, it has 89 signatories (states politically supportive but not legally bound to treaty obligations) and 110 parties (states that are legally bound to the provisions of the treaty) (UNODA, ND). The governments of the U.S., GB, and the USSR again served as depositories. The treaty remains in effect to this day.

Up until the signing of the PTBT, the USSR had directly linked negotiations pertaining to the weaponization of outer space to the topic of U.S. military capabilities stationed near its periphery, specifically the deployment of nuclear tipped Jupiter ballistic missile squadrons to Italy and Turkey (DOS, NDb). This caused stalemates in negotiation that would last until September 19th, 1963, when foreign minister Andrei Gromyko informed the UN General Assembly that the USSR was willing to consider an immediate agreement preventing the placement of nuclear weapons in outer space (DOS, NDb). With the consensus of U.S. Ambassador Adlai Stevenson, the General Assembly adopted the resolution titled Declaration of Legal Principles Governing the Activities of States in the Exploration and Use of Outer Space on

December 13th, 1963, during its 1,280th plenary meeting (UN, 1963a). This non-binding agreement would serve as the building block for what later became the Outer Space Treaty.

Beginning in 1966, with both U.S. and soviet efforts to send a man to the moon well underway, efforts to codify the contents of the 1963 UN resolution in an official treaty once again became a priority (Moltz, 2019, Pg149). Both sides were fearful of the possibility for territorial gains and/or strategic military advantages acquired by their counterpart, should they make it to the moon first. Negotiations were productive and brief. By the end of 1966, most substantive issues had been settled and, as mentioned previously, the treaty was opened for signature in January of 1967. The treaty is nearly identical to the 1963 resolution, the only difference being additional guidance pertaining to the conduct of military activities on celestial bodies (Moltz, 2019, Pg150).

| **Article #** | **Synopsis** |
|---|---|
| Article I | • Exploration of outer space (and celestial bodies) shall be carried out for the benefit of all states<br>• Outer space and celestial bodies free for exploration by all states, without discrimination. International cooperation is encouraged. |
| Article II | • No state may claim sovereignty of space or celestial bodies. |
| Article III | • States shall carry out space activities in accordance with international law (e.g. Charter of the UN) and in the interest of maintaining international peace and security. |
| Article IV | • States shall not place into orbit or station on celestial bodies any object containing nuclear weapons or other WMDs.<br>• States shall not construct military bases, conduct weapons testing, or carry out military maneuvers on the moon or other celestial bodies.<br>• The use of military personnel and/or equipment for peaceful exploratory purposes and scientific research is permitted. |
| Article V | • Astronauts shall be considered envoys of human kind. Signatories will render them all possible assistance in the event of an accident or distress.<br>• State parties shall immediately inform other treaty members of possible dangers to astronauts discovered in outer space or on celestial bodies. |
| Article VI | • States shall bear responsibility for national activities carried out in space (both by government agencies and non-governmental entities) |
| Article VII | • States that launch an object (or procure the launching of an object) into outer space are internationally liable for possible damages caused to other treaty signatories on the earth, in the air, or in outer space. |
| Article VIII | • States shall maintain jurisdiction and control over objects launched into outer space. |
| Article IX | • States shall be guided by the principles of cooperation and mutual assistance in the conduct of space activities. |

| | |
|---|---|
| | • States shall prevent the harmful contamination of space, celestial bodies and the earth environment as a result of space exploration activities.<br>• Space activities believed to impose potentially harmful interference call for international consultation before being carried out.<br>• States may request consultation if they believe the actions of another signatory are imposing potentially harmful interference. |
| Article X | • To promote international cooperation, states shall consider requests by other treaty signatories to observe the flight of space objects. |
| Article XI | • To promote international cooperation, states shall inform the UN Secretary General (to the greatest extent feasible and practical) the nature, conduct, location and result of space activities. |
| Article XII | • All stations, installations, equipment and space vehicles on the moon and other celestial bodies are open to visits by other treaty signatories. |
| Article XIII | • Treaty provisions apply space activities carried out by single state parties or via joint efforts between multiple signatories.<br>• Practical questions concerning space activities shall be resolved via the appropriate international organization or between treaty signatories. |
| Article XIV | • The treaty is open to all states for accession.<br>• The governments of the U.S., the USSR, and GB are designated as depositary governments. |
| Article XV | • Any signatory may propose treaty amendments.<br>• Treaty amendments must be approved by a majority vote. |
| Article XVI | • State signatories may withdraw from the treaty one year after ratification.<br>• Withdrawal will take effect one year after formal notification. |
| Article XVII | • Treaty documents maintain equal authenticity regardless of language.<br>• Document transmittal and storage instructions. |

**Table 8.2. Summary of 1967 Outer Space Treaty (UN, 1966)**

As indicated by Table 8.2, Articles III, IV, VI, VII, VIII, and IX are most applicable to debates pertaining to CS weapons regulation. While the 1967 Outer Space Treaty was a major step forward in international legislative affairs, tense relations between Cold War superpowers led to purposely vague treaty terminology. It was simply the only way to find the sufficient common ground. Loop-holes and liberal interpretation of treaty language are exploited to this day for "national security purposes." Article III, for example, indicates that states shall carry out space activities in accordance with international law and in the interest of maintaining international peace and security (UN, 1966). To a pragmatic and non-aligned party, this would seem to suggest that the development, testing and deployment of CS weapons is thereby proscribed. However, to U.S. policy makers convinced of their unalienable role and responsibility in maintaining global security and stability it may imply the exact opposite. It can be argued that under the auspices of hegemonic stability, Article III may actually support (at least the development and testing) CS weapons as a deterrent against potentially malicious actors. Article 51 of the UN Charter does, after all, guarantee the right to self-defense (Porras, 2018, Pg12).

Article IV prohibits the act of placing into orbit, for any purpose, any device carrying nuclear weapons or other WMDs. It is therefore reasonable to conclude that the treaty adequately regulates the employment of nuclear-tipped co-orbital ASAT weapons deployed with the intention to destroy a target spacecraft via a proximity detonation, through EMP effect, or radiation exposure. The article does not, however, make any mention of conventional weapons, physically destructive, temporarily degradative, or otherwise. This loophole has yet to be addressed and provides treaty signatories with the freedom to continue the development, testing, and potential employment of a wide range of CS weapons.

While not directly addressing weapons regulation, Articles VI, and VII relate to the potential aftermath of CS weapons testing and employment scenarios. Specifically, countries will bear full responsibility for activities carried out in space, regardless of whether conducted in an official governmental capacity or by non-governmental, commercial or private, entities under their jurisdiction (UN, 1966). The owning nation of a space object retains liability even when launched by a third party or contracted entity. As such, a nation state may be held financially liable for damages imposed on other international actors as a result of accidents, equipment failure, or malicious activity. The 1972 Convention on International Liability for Damage Caused by Space Objects would later elaborate on Article VI, providing additional guidance pertaining to factors of liability, compensation and the settlement of claims (UNOOSA, 2020a). Validity of the international claims process aside, Article VI should have been enough to dissuade events like the 2007 Chinese ASAT test, especially considering the ability of advanced SSNs to maintain debris source awareness. This suggests either a complete disregard for international law, or true ignorance on the part of engineers, scientists and mission planners.

Article IX prohibits the harmful contamination of the earth and space environments, as well as of celestial bodies like the moon (UN, 1966). While again subject to excessive interpretation, this can be assumed to include any form of orbital debris producing actions, such as the employment of kinetic physical and non-kinetic physical ASAT weapons. Because even electronic and cyberattack methods have the potential of leaving a satellite permanently disabled, it could be further contended that Article IX applies to the employment of all CS weapon. As history shows, however, this is clearly not how the language is being interpreted. A realistic counterargument may be that CS weapons are implements of national security, thereby not bound to regulation with verbiage providing guidance for the study and exploration of outer space. Lawyers and national security advisers in Washington DC, Moscow, and Beijing likely have countless other, extremely permissive, interpretations.

Article IX is, however, clear about the requirement for international consultation in cases where an activity or experiment (planned by official government agencies or commercial/private entities under respective national jurisdiction) is reasonably believed to impose potential harmful interference on other state parties in outer space or on celestial bodies. To date, especially when considering the employment of direct ascent ASAT technology, this has rarely been conducted. The PRC, in fact, gave no warning before their 2007 test and stayed silent for weeks as an enraged international community demanded answers for what is now considered the single-most significant debris producing event in the history of human space-flight. Shortly thereafter, the U.S. attempted to set a global example of acceptable behavior during the conduct of Operation Burnt Frost, holding international press briefings weeks ahead of the destruction of satellite USA 193 in February of 2008 (Weeden & Samson, 2019). Every attempt was made to ensure that both the necessity and efficacy of the operation were well advertised. International counterparts have not taken this standard of conduct to heart. Most recently, both India and Russia, each a signatory of the 1967 Outer Space Treaty, conducted direct ascent ASAT tests in March of 2019 and April of 2020 respectively. Neither party provided any form of official notification, or press release, prior to the conduct of these tests.

**c. New Strategic Arms Reduction Treaty.** After the U.S. withdrawal from the Anti-Ballistic Missile Treaty on 13 June, 2002 (ACA, 2017), and the Intermediate-Range Nuclear Forces Treaty on 2 August, 2019 (ACA, 2019), the New START Treaty remains the only active accord between the U.S. and the Russian Federation limiting the maintenance and deployment of nuclear weapons. After eight rounds of negotiations lasting from May to November of 2009, the treaty was signed by then Presidents Barrack Obama and Dmitry Medvedev, in Prague, on April 8th, 2010 (ACA, 2020). New Start entered into force on 5 February, 2011, replacing the 1991 Strategic Arms Reduction Treaty that had expired at the end of 2009 (ACA, 2020). The treaty remains in effect and will expire in 2021, with an option for a five-year extension.

The New START Treaty provides updated aggregate limits for deployed and non-deployed nuclear weapons and delivery vehicles (i.e. ICBM variants and strategic bombers) that became obligatory within seven years of the treaty going into effect (DOS, 2020). Treaty verbiage differentiates between deployed (operationally active either in the host nation or abroad) and non-deployed (operationally inactive; in long-term storage or maintenance overhaul cycles) systems and also provides guidance for how individuals weapons are to be counted. Lastly, in addition to ongoing monitoring of strategic forces conducted via NTM, the treaty provides for the conduct of 18 on-site inspection per year, allowing both U.S. and Russian officials to physically confirm treaty compliance (DOS, 2011; DOS, 2020).

New START limits the U.S. and Russia to no more than 1,550 deployed nuclear warheads, a combined 700 deployed missiles and bombers, and a combined deployed and non-deployed 800 missile tubes and bombers (ACA, 2020). Each side remains free to structure its nuclear forces as it wishes, as long as the numerical mandates imposed by the treaty are maintained (DOS, 2020). Keeping in mind the argument for dual-use technology, the treaty places no constraints on the testing, development or deployment of ABM technology or ballistic missiles with conventional warheads (DOS, 2020). As such, it cannot be reasonably concluded that New START places effective limitations on kinetic CS weapons. However, the fact that it calls for non-interference with NTM, to include space-based surveillance and intelligence collection assets, provides an interesting opportunity for lawfully discouraging CS attacks on certain spacecraft.

**d. Orbital Debris Mitigation Standard Practices and International Guidelines.** In 2001, the U.S. Government published ODMSPs to minimize the release of orbital debris generated over the course of normal spacecraft mission profiles and by accidental explosions, collisions, or failures to conduct PMD (USG, 2019, Pg1). Informed by DoD and NASA ODPO led consultancy efforts, ODMSP guidelines aim to convey a sense of ownership, at the national level, for the orbital debris problem (Liou, 2019, Pg32). Subsequent U.S. space policy documents, signed by then president George W. Bush in 2006 and 2010 respectively, dictated their implementation in the conduct of all U.S. government space activities (Liou, 2019, Pg32). 2001 ODMSPs have also been embedded in the regulations imposed by the U.S. Federal Communications Commission (FCC), U.S. Department of Transportation (DoT), U.S. Federal Aviation Administration (FAA), and U.S. Department of Commerce (DoC), making them applicable to all commercial and private space activities under U.S. jurisdiction (Liou, 2019, Pg32; Weeden, 2020).

ODMSPs were most recently updated in 2019, with the intention to further quantitatively define particle release and debris-producing anomaly probability limitations (USG, 2019, Pg1). Additionally, a number of standard practices were added to address emerging or rapidly evolving methods of space operations. These include the deployment of large constellations, small satellites, the conduct of rendezvous operations, active debris removal, and tethered maneuvers. A summary of the most current ODMSP objectives is provided in Table 8.3 below.

| # | **Objective** |
|---|---|
| OBJ 1 | Control of debris released during normal operations (Pg2). |
| OBJ 2 | Minimizing debris generated by accidental explosions (Pg3). |
| OBJ 3 | Selection of safe flight profile and operational configuration (Pg4). |
| OBJ 4 | PMD of spacecraft structures (Pg5). |
| OBJ 5 | Clarification and additional standard practices for certain operations (Pg7). |

**Table 8.3. Summary of 2019 ODMSP Objectives (USG, 2019)**

The 2001 ODMSPs played an integral role in developing similar products at the international level. A review of the IADC Space Debris Mitigation Guidelines, first released in 2002 and subsequently revised in 2007 and 2020, shows nearly identical verbiage. The 2020 revision even seems to have incorporated some of the new 2019 ODMSP updates pertaining to PMD considerations for large constellations. While individual governments are certainly capable of imposing these procedures on their subordinate space agencies and commercial entities as lawfully compulsory, IADC itself holds no legal authority. Realistically, membership is voluntary and implies nothing more than a moral obligation. As such, IADC can only encourage organizations to apply their recommendations. A summary of the measures recommended by the most recent IADC Space Debris Mitigation Guidelines is provided in Table 8.4 below.

| # | **Guideline** |
|---|---|
| GL 1 | Limit debris released during normal operations (Pg8). |
| GL 2 | Minimize the potential for on-orbit break-ups (Pg8). |
| GL 2.1 | Minimize the risk of post-mission break-ups due to stored energy (Pg8). |
| GL 2.2 | Minimize the potential for break-ups during operational phases (Pg8). |
| GL 2.3 | Avoid intentional destruction and other harmful activities (Pg9). |
| GL 3 | Conduct PMD (Pg9). |
| GL 3.1 | In GEO, PMD should place object above protected GEO region (Pg9). |
| GL 3.2 | In LEO, PMD should result in safe de-orbit or retrieval (Pg9). |

| | |
|---|---|
| GL 3.3 | PMD in other orbits should maximize lifetime reduction (Pg10). |
| GL 4 | Prevent on-orbit collisions (Pg10). |

**Table 8.4. Summary of 2020 IADC Space Debris Mitigation Guidelines (IADC, 2020)**

IADC Space Debris Mitigation Guidelines, in turn, directly informed the STSC of COPUOS in the process of generating the UN Space Debris Mitigation Guidelines. These were endorsed by the General Assembly via resolution 62/217 on 22 December, 2007, and like the IADC guidelines, rely on voluntary adherence by member states (UN, 2010, Pg6). Similar directions were also captured in documentation published by the ISO in 2010. A summary of the UN guidelines is provided in Table 8.5 below.

| # | Guideline |
|---|---|
| GL 1 | Limit debris released during normal operations (Pg8). |
| GL 2 | Minimize the potential for break-ups during operational phases (Pg8). |
| GL 3 | Limit the probability of accidental collision in orbit (Pg9). |
| GL 4 | Avoid intentional destruction and other harmful activities (Pg9). |
| GL 5 | Minimize potential for post-mission break-ups resulting from stored energy (Pg9). |
| GL 6 | Limit the long-term presence of spacecraft and launch vehicle orbital stages in the LEO region after the end of their mission (Pg9). |
| GL 7 | Limit the long-term interference of spacecraft and launch vehicle orbital stages within the GEO region after the end of their mission (Pg10). |

**Table 8.5. Summary of 2007 UN Space Debris Mitigation Guidelines (UN, 2010)**

Both IADC Guideline 2.3 and UN Guideline 4 talk to the creation of orbital debris as a result of the intentional destruction of space objects. While not directly specified, this logically includes the testing and operational employment of ASAT weapons. However, because neither document is legally binding, signatories are free to continue developing CS capabilities at will. Interestingly enough, every nation state known to have carried out kinetic physical ASAT weapons testing to date, is also an IADC and COPUOS member. This leads us to the conclusion that, while most space faring nations are well aware of acceptable conduct in space, they decide to ignore these shared standards of behavior to demonstrate power or make political statements.

**e. Transparency and Confidence Building Measures.** In accordance with UN General Assembly Resolution 65/68, a Group of Governmental Experts (GGE) on TCBMs in Outer Space Activities was formed in 2011 (Johnson, 2014). Considering a lack of progress pertaining to PAROS discussions in the CD and UN First Committee forums, the establishment of voluntary TCBMs was seen as a sensible method for continuing the pursuit of space stability measures. The GGE examined the complete spectrum of international space law, the (then draft) Guidelines for the Long-Term Sustainability of Outer Space Activities, and conducted significant consultation with COPUOS and the CD to develop practical, clearly defined, and verifiable approaches (Johnson, 2014). Ultimately a final GGE report was endorsed by the UN General Assembly on December 5th, 2013, during its 60th plenary meeting (UN, 2013b). As with the previously recognized debris mitigation guidelines, UN Resolution 68/50 calls on states to maximize the voluntarily implementation of TCBMs via the appropriate national mechanisms (UN, 2013b).

The 2013 report defines TCBMs in Outer Space Activities as "means by which governments can share information with the aim of creating mutual understanding and trust, reducing misperceptions and miscalculations, and thereby helping both to prevent military confrontation and to foster regional and global stability" (UN, 2013c, Pg12). The implementation of individual TCBMs is meant to vary and may range from unilateral adherence to regional or multilateral agreements (UN, 2013c, Pg14). Naturally, adoption within multilateral frameworks is most likely to encourage wider acceptance within the international community (UN, 2013c, Pg12). Table 8.6 summarizes what are essentially 27 discrete TCBMs below.

| **TCBM #** | **Synopsis** |
|---|---|
| **Category** | **Enhancing the Transparency of Outer Space Activities** |
| 1 (para 37) | • States should publish national space policies and strategies.<br>• States should publish information pertaining to major research and space application programs supporting both civil and military initiatives. |
| 2 (para 38) | • States should report military space expenditures. |
| 3 (para 39) | • States should exchange information on the basic orbital parameters of outer space objects under their jurisdiction.<br>o Exchange of orbital elements and conjunction warnings.<br>o Timely submission of data to UN Registry for Outer Space Objects.<br>o Public access to national registries of space objects. |
| 4 (para 40) | • States should promulgate knowledge of potential natural space hazards. |
| 5 (para 41) | • States should provide notification of pending space-vehicle launches. |
| 6 (para 42) | • States should inform potentially affected parties when space-vehicle maneuvers impose risk on their spacecraft. |
| 7 (para 43) | • States should inform potentially affected parties of high-risk entry events with the potential of causing damage or radioactive contamination. |
| 8 (para 44) | • States should inform potentially affected parties of spacecraft emergencies which may lead to high-risk re-entry or collisions. |

| | |
|---|---|
| 9 (para 45) | • States should avoid the intentional destruction of spacecraft or other activities with the potential of generating lasting orbital debris.<br>• When intentional break-ups are required, states should inform potentially affected parties and conform with UN Space Debris Mitigation Guidelines. |
| 10 (para 46) | • States should consider familiarization visits of pertinent space facilities. |
| 11 (para 47) | • States should consider expert visits of pertinent space facilities. |
| 12 (para 48) | • States should consider demonstrations of rocket and space technologies. |
| **Category** | **International Cooperation (for Development)** |
| 13 (para 49) | • States should conduct international cooperation in the peaceful use of outer space. States should also consider cooperation on scientific and technical matters with non-spacefaring nations to facilitate confidence building. |
| 14 (para 53) | • States should consider the Outer Space Treaty as a basis for advancing international cooperation in outer space activities. |
| 15 (para 54) | • States should also take into account the Declaration on International Cooperation in the Exploration and Use of Outer Space for the Benefit and in the Interest of All States, Taking into Particular Account the Needs of Developing Countries when advancing international cooperation. |
| 16 (para 55) | • Capacity building programs should focus on theory, research, applications, field exercises and pilot projects in order to advance social and economic development in target states. |
| 17 (para 56) | • States should consider adoption of an open satellite data-collection and dissemination policy for sustainable economic and social development.<br>• States should consider establishing programs for developing countries that allow for the receipt and interpretation of relevant satellite data. |
| **Category** | **Consultative Mechanisms** |
| 18 (para 57) | • States should participate in timely and routine consultations through diplomatic exchanges and other government-to-government mechanisms. |
| 19 (para 58) | • States should consider use of existing consultative mechanisms. |
| **Category** | **Outreach** |
| 20 (para 60) | • States should implement political and diplomatic outreach measures relating to the conduct of outer space activities. |
| 21 (para 61) | • States should inform the UN, the public and the international community of the character, location, and results of outer space activities. |
| 22 (para 62) | • States should encourage internal stakeholders (e.g. academia or NGOs) to raise public awareness of space policies and activities. |
| **Category** | **Coordination** |
| 23 (para 63) | • States should coordinate space policies and programs to enhance the safety and predictability of outer space activities. |
| 24 (para 64) | • States should participate in coordination with multilateral organizations engaged in developing the TCBMs in Outer Space Activities. |
| 25 (para 65) | • States, international organizations and private actors conducting space activities should establish focal points for coordination. |
| 26 (para 66) | • UNOOSA and UNODA should coordinate on the topic of TCBMs.<br>• UN should consider an interagency mechanism for TCBM implementation. |

| | |
|---|---|
| 27 (para 67) | - States should maximize participation in UN space forums. |

**Table 8.6. Synopsis of TCBMs in Outer Space Activities (UN, 2013c)**

The TCBM identified in paragraph number 45 is directly associated to the topic of CS weapons. It echoes Guideline 4 of the 2007 UN Space Debris Mitigation Guidelines in calling for the avoidance of intentionally destructive behavior in space. Theoretically, inclusive compliance would prevent the unsafe testing of direct ascent ASAT systems in manners similar to that of the 2007 event carried out by the PRC. Low-altitude tests, with little risk for generating long-lived debris, would still be allowed as long as the necessary pre-cautions can be advertised to the international community. As mentioned previously, the destruction of USA 193 (Operation Burnt Frost) likely provides the most pertinent historical example of satisfactory compliance with such standards of behavior. The TCBM does not address the application of CS effects where debris generation could be considered accidental.

**f. Guidelines for the Long-Term Sustainability of Outer Space Activities.** Under the premise that space activities are vital to reaching UN Sustainable Development Goals, the STSC (specifically, the Working Group on the Long-Term Sustainability of Outer Space Activities) has developed a series of voluntary guidelines for enhancing the safety of space operations and ensuring continued access to near-earth orbital regimes (UN, 2019a, Pg56). The Guidelines for the Long-Terms Sustainability of Outer Space Activities were adopted by COPUOS on June 21st, 2019, during its 62nd session (UN, 2019a, Pg28). They were subsequently endorsed by the General Assembly's Fourth Committee on November 1st, 2019, and forwarded to the General Assembly as part of the Draft Resolution for International Cooperation in the Peaceful Uses of Outer Space (UN, 2019b, Pg2). Finally, on December 13th, 2019, the UN General Assembly formally adopted the guidelines under Resolution 74/82 without a vote (UN, 2019c, Pg3).

The broad scope of these guidelines addresses nearly every aspect of space operations and makes them relevant to both governmental, civil and commercial applications. Ultimately, they represent the culmination of nearly a decade of collaboration between subject matter experts and the representatives of over 90 nations (UNOOSA, 2019a). While their effectiveness is yet to be measured, for many space professionals, they represent a meaningful advance in the right direction. Because the purpose of the guidelines is to inform national legal instruments, future COPUOS efforts will include determining the scope of guideline implementation by member states (UN, 2019a, Pg59). Table 8.7 provides a summary of the guidelines. Those most applicable to the theme of CS weapons regulation will be examined in further detail.

| # | Guideline |
|---|---|
| **A** | **Policy and Regulatory Framework for Space Activities** |
| GL A.1 | Adopt, revise and amend, as necessary, national regulatory frameworks for outer space activities. |
| GL A.2 | Consider a number of elements when developing, revising or amending, as necessary, national regulatory frameworks for outer space activities. |
| GL A.3 | Supervise national space activities. |
| GL A.4 | Ensure the equitable, rational and efficient use of the radio frequency spectrum and the various orbital regions used by satellites. |
| GL A.5 | Enhance the practice of registering space objects. |
| **B** | **Safety of Space Operations** |
| GL B.1 | Provide updated contact information and share information on space objects and orbital events. |
| GL B.2 | Improve accuracy of orbital data on space objects and enhance the practice and utility of sharing orbital information on space objects. |
| GL B.3 | Promote the collection, sharing and dissemination of space debris monitoring information. |
| GL B.4 | Perform conjunction assessment during all orbital phases of controlled flight. |
| GL B.5 | Develop practical approaches for pre-launch conjunction assessment. |
| GL B.6 | Share operational space weather data and forecasts. |
| GL B.7 | Develop space weather models and tools and collect established practices on the mitigation of space weather effects. |
| GL B.8 | Design and operation of space objects regardless of their physical and operational characteristics. |
| GL B.9 | Take measures to address risks associated with the uncontrolled re-entry of space objects. |
| GL B.10 | Observe measures of precaution when using sources of laser beams passing through outer space. |
| **C** | **International Cooperation, Capacity-Building and Awareness** |
| GL C.1 | Promote and facilitate international cooperation in support of the long-term sustainability of outer space activities. |
| GL C.2 | Share experience related to the long-term sustainability of outer space activities and develop new procedures, as appropriate, for information exchange. |
| GL C.3 | Promote and support capacity-building. |
| GL C.4 | Raise awareness of space activities. |
| **D** | **Scientific and Technical Research and Development** |
| GL D.1 | Promote and support research into and the development of ways to support sustainable exploration and use of outer space. |
| GL D.2 | Investigate and consider new measures to manage the space debris population in the long term. |

**Table 8.7. COPUOS Guidelines for Long-Term Sustainability of Outer Space Activities (UN, 2019a, Pg60-75)**

Although the individual guidelines are quite loosely worded, a number suggest behavioral standards pertaining to the use CS weapons.  Guideline A.1 suggests adopting national regulatory frameworks that take into consideration generally accepted international norms, standards and practices for the safe conduct of outer space activities.  This directly infers such items as the 2007 UN Space Debris Mitigation Guidelines which call for avoidance of the intentional destruction of spacecraft, and other environmentally harmful activities (UN, 2019a, Pg60).  Guideline A.2 addresses the 2007 UN Space Debris Mitigation Guidelines directly, calling for their implementation through the applicable national mechanisms to the maximum extent practicable (UN, 2019a, Pg60).  It also urges the enactment of regulations that serve to minimize human impact on the space environment.

Guideline A.3 echoes Article VI of the 1967 Outer Space Treaty by affirming that states bear international responsibility for national activities in outer space, to include civil and commercial entities under their jurisdiction (UN, 2019a, Pg61).  Pragmatically, this includes accountability for debris producing events or the application of CS effects that lead to the permanent damage of another actor's spacecraft.  Guideline A.4 urges states and other institutions to ensure their space activities do not result in harmful interference on the reception or transmission of radio signals related to space activities being conducted by other actors (UN, 2019a, Pg63).  It is only reasonable to assume that this includes the employment of electronic CS weapons.

Guideline B.1 calls for states to effectively coordinate, and share information about, situations which have the potential of adversely impacting the safety of space operations (UN, 2019a, Pg65).  This echoes Article IX of the Outer Space Treaty in suggesting that international consultation is to be conducted in situations thought to impose harmful interference.  This clearly infers that the testing of kinetic ASAT technology should be communicated to the international community, providing other stake-holders (specifically those with more advanced capabilities and expertise) an opportunity to collaborate for the purpose of minimizing environmental impacts.  Subsequent guidelines C.1-3 promote such helpful collaboration and capacity building.

Guideline B.10 calls for states to observe measures of precaution when employing laser beams passing through space (UN, 2019a, Pg72).  This primarily intends to prevent the disruption or destruction of space objects that are accidentally illuminated by beams of directed energy.

However, the guideline also logically prohibits the purposeful dazzling of electrooptical imaging sensors aboard space-based intelligence collection platforms, a non-kinetic physical CS tactic that is thought to be frequently employed by prominent threat actors.

Guideline D.1 reiterates the importance of implementing safety measures to protect the earth and space environment, specifically harmful contamination (e.g. orbital debris). Items such as the UN Space Debris Mitigation Guidelines are again alluded to (UN, 2019a, Pg75). The guideline also mentions developing new mitigation measures as appropriate. Technically, this could imply the continued pursuit of legally binding instruments, including those aimed at CS weapons regulation. This language continues into Guideline D.2 which calls on stakeholders to further pursue effective methods for managing space debris (UN, 2019a, Pg75).

It should now be apparent that existing international space law displays obvious shortfalls in its ability legally curtail, via binding and enforceable means, the testing and employment of CS weapons. However, this paper argues that non-binding instruments have clearly and explicitly defined acceptable standards of behavior. That is, there should be absolutely no confusion amongst international actors (to include Russia and China) about the ethicality of testing and/or employing CS weapons. As alluded to previously in our description of Social Norms Theory, non-compliance with these standards of behavior would serve to indicate a misalignment of national priorities and possibly malicious intent. The next chapter will conduct a review of recent events to see if these standards of behavior have, in fact, been complied with.

**IX. The Shaping of Modern U.S. Space Policy.** Through our initial pursuit of SRO 1, we have defined the space environment (in all of its physical and operational aspects), CS weapons and their employment considerations, and the nature of the orbital debris problem. This has led us to determine that CS weapons have significantly contributed to environmental degradation. We can now reasonably acknowledge that a failure to curtail their use will likely result in the permanent degradation of a shared domain with profound international utility.

Furthermore, in our effort to address SRO 2, we have analyzed existing space law (both regulatory institutions and instruments) concerned with CS weapons regulation and environmental sustainability. IADC and UN COPUOS membership profiles indicate that the worlds spacefaring nations acknowledge the orbital debris problem and its potential to limit the utility of near-earth orbital regimes. We also know that recent advances in the UN have led to the long-awaited promulgation of TCBMs in Outer Space Activities and behavioral standards for space operations in the Guidelines for the Long-Term Sustainability of Outer Space Activities. One would think, therefore, that the necessary framework enhancing stability in the space domain is in place. The persistence of CS activities, however, indicates that this is not the case.

In order to achieve full compliance with SRO 2, this chapter will review a number of recent events pertaining to the employment of CS weapons. We will then look at how these actions have shaped the most current U.S. space policy. There must, after all, be a reason for why the U.S. is such a strong opponent of additional space legislation. What should become immediately apparent is the hypocritical behavior displayed by strategic competitors to the U.S. While advocating for legally binding CS weapons regulation in UN and CD forums, Russia and China are concurrently developing comprehensive ASAT capability portfolios. The testing of these capabilities continues to this day, often times with tremendously provocative timing. The conveyance of behavioral norms has had no impact on this behavior. In fact, some of the most pretentious capability demonstrations have come after their passing. U.S. officials, therefore, have no confidence that international counterparts would adhere to another treaty. As we will see, this has resulted in an extremely aggressive foreign policy aimed at maintaining space dominance through deterrence.

**a. Recent Events - Russia.** On April 15th, 2020, Russia conducted a test of its PL-19 Nudol direct ascent interceptor from the Plesetsk Cosmodrome in northern Russia (Wall, 2020).

Luckily, the weapon did not make contact with a physical target and therefore did no create orbital debris. The event marked the tenth test of the Nudol system which, according to experts, is only several years away from reaching maturity (Wall, 2020). While being constructed under the premises of an ABM role, once deemed operationally capable, Nudol will also provide Russia with an assured method of applying kinetic-physical CS effects in LEO (Wall, 2020).

The PL-19 is a TEL launched weapons system, facilitating mobility, concealment and survivability. A previous test event took place on November 15th, 2019 (Shaikh, 2020), only two weeks after the Guidelines for the Long-Terms Sustainability of Outer Space Activities were endorsed by the UN's 4th committee. Unsubstantiated reporting also alludes to a test on June 30th, 2019, just over a week after the Guidelines for the Long-Terms Sustainability of Outer Space Activities were approved in COPUOS (RSNF, 2019). It is hard to believe that the timing of these test events is coincidental.

**Figure 9.1. Russian PL-19 Nudol Direct Ascent Interceptor on TEL (Varghese, 2020)**

On July 15th, 2020, Russia is believed to have conducted a test of a space-based ASAT weapons (USSPACECOM, 2020). According to U.S. defense officials, the event took place in GEO and consisted of the controlled ejection of an orbital object from the Russian satellite Cosmos 2543 (USSPACECOM, 2020). Russia describes the released orbital objects as a "space apparatus inspector." However, according to U.S. Chief of Space Operations, General John Raymond, there is reason to believe the object was actually a co-orbital ASAT, potentially capable of destroying or target spacecraft or disrupting its mission profile (Trevithick, 2020). A similar such event sparked concern in August of 2018, when only days after the plan to establish the U.S. Space Force was made public, a mysterious Russian spacecraft began to display what is described as abnormal and potentially threatening behavior (Wall, 2018).

The nature of Cosmos 2543 was already concerning to many space professionals. A Russian launch in November of 2019 placed into orbit Cosmos 2542. One month after orbital insertion, Cosmos 2542 deployed Cosmos 2543 from inside of it (Trevithick, 2020). Subsequently, in February of 2020, the two spacecraft were identified shadowing a U.S. satellite (Pickrell, 2020). Depending on the asset followed and the nature of activities conducted, Cosmos 2542 and 2543 may very well have breached New START regulations pertaining to non-interference with NTM. U.S. Space Command indicates that similar activity was carried out in 2017 when Russian satellite Cosmos 2519 is believed to have released two other orbital objects, now identified as Cosmos 2521 and Cosmos 2523 respectively (Trevithick, 2020; USSPACECOM, 2020).

Other than a Notice to Airmen (an administrative safety measure used to clear airspace over missile ranges), none of the above-mentioned test events were previously advertised to any member of the international community. Furthermore, like the most recent Nudol trials, the July 15th event in GEO (the most sensitive region of near-earth orbital space) comes after the endorsement of both TCBMs in Outer Space Activities and the Guidelines for the Long-Terms Sustainability of Outer Space Activities by the UN General Assembly. It is clear that the Russian Federation has no intentions of conceding from its intense power competition. It should therefore be of no surprise that U.S. representatives consider the arms control regulations it is so adamantly advocating for, in forums like the CD and UNDC, as woefully disingenuous.

Russia considers electronic warfare (EW) a critical part of establishing battlefield superiority. As such, they have developed a wide array of capabilities capable of disrupting GPS, SATCOM and radar signals (DIA, 2019, Pg28). EW was utilized in the annexation of Crimea with overwhelming effectiveness. According to U.S. officials, the quality and sophistication of EW effects applied in the Ukraine exceeds anything the U.S. is currently capable of (Gould, 2015). Advanced multipurpose EW systems like the Krasukha-4, displayed in Figure 9.2, have also been employed with great success in Syria. Here localized GPS jamming has significantly hindered the utility of small unmanned aerial vehicles (Varfolomeeva, 2018). The system is also said to be capable of jamming radar imaging satellites in LEO (Army Recognition, 2019).

**Figure 9.2. Russian Krasukha-4 Multi-Role EW System (Army Recognition, 2019)**

**b. Recent Events - China.** As indicated by the famed 2007 PLA ASAT test, China possesses the capability to destroy objects in LEO with direct ascent interceptors. In a 2014 report published by the Secure World Foundation, technical advisor and space professional Brian Weeden indicates that technology demonstrations carried out in 2013 also suggest an ability to target space objects in MEO and GEO (Pg7). A 2019 report released by the U.S. Defense

Intelligence Agency (DIA) confirms Weeden's hypothesis, stating that China launched an object into space in 2013 that reached a ballistic apex above 30,000 km (DIA, 2019, Pg21).

Most recently, China has been advancing its testing of the DN-3 missile. Like the Russian Nudol system, the DN-3 is being developed under the auspices of an ABM role. However, the dual-use concept implies it may also be used to target satellites in LEO. On February 5th, 2018, PLA successfully conducted an exo-atmospheric intercept of a DF-21 ICBM using the DN-3 (Panda, 2018). The test did not create lasting orbital debris but its timing appears enormously provocative, taking place only weeks after unclassified summaries of the U.S. NDS and NSS were published on January 19th, 2018, and December 18th, 2017, respectively (Panda, 2018).

**Figure 9.3. Chinese DF-21 Intermediate Range Ballistic Missile (Andrew, 2010)**

China has been experimenting in the conduct of remote proximity operations (RPO) since 2008. As more recently demonstrated by the Russian Cosmos 2521 and 2523, this implies purposely maneuvering a spacecraft to within close vicinity of another object in order to employ a primary mission payload. Theoretically, this could include the servicing and/or repair of aging satellites or the conduct of active debris removal. However, the dual-use concept also dictates that this capability may be used for nefarious purposes, such as covertly collecting signals intelligence or physically damaging satellite subsystems with projectiles or robotic arms. As such, without direct insight into a program's principal objectives, it is nearly impossible to tell whether RPO capabilities are intended to advance environmental sustainability co-orbital ASAT weapons.

In July of 2013, China launched satellites Chuangxin-3, Shiyan-7, and Shijian-15 into LEO (Military News, 2013). Upon reaching orbit, the three spacecraft began conducting RPO maneuvers. One of the three is believed to possess a mechanical arm that was later used to grapple and seize its partner spacecraft (Harrison Et al., 2020, Pg17; Military News, 2013). Another such multi-ship experimentation mission was launched in 2016. Among the four satellites deployed into LEO were Aolong-1 and Tianyuan-1 (Harrison Et al., 2020, Pg17). Aolong-1 also possessed a robotic arm and has been described by Chinese officials as having been purposely designed to facilitate active debris removal (Spaceflight101, 2016). Its design, supposedly, allows it to grab onto prominent debris objects and assist in accelerated de-orbiting. Although few details have been made public, Tianyuan-1 is said to have successfully refueled another satellite in orbit (Fingas, 2016). If true, this would represent mastery of an extremely complex series of maneuvers. Like the demonstration of direct ascent capabilities, the previous events have caused significant concern amongst U.S. defense officials, especially after a 2019 article, in the South China Morning Post, revealed Chinese scientists actively confirming the use of such technology to develop weapons systems (Chen, 2019).

China also has a history employing non-kinetic CS effects. In September of 2006, U.S. officials confirmed that they had reason to believe U.S. government spacecraft were actively being targeted with ground-based laser devices positioned in Chinese territory (Kessler, 2011). Although no permanent physical damage was said to have been incurred, the events certainly raised eyebrows amongst leading U.S. space professionals and members of the House Armed Services Committee. White not breaking the provisions of the Outer Space Treaty, the events were certainly provocative in nature and well outside of the bounds of responsible behavior.

A 2009 report by Yousaf Butt, a consultant to the Federation of American Scientists, titled Effects of Chinese Laser Ranging on Imaging Satellites, indicates that these laser illumination events were likely intended to determine the exact orbital elements of the spacecraft using a technique called Satellite Laser Ranging (SLR) (Pg1). Detailed knowledge of orbital regimes, in turn, would allow PRC entities to schedule nefarious activity or hide critical assets while within the FoV of intelligence collection assets. He goes on to explain that while unlikely, SLR does impose the risk of permanently damaging sensitive spacecraft components (Pg8-12). Specifically, the light sensitive elements that compose electrooptical imaging sensors (Pg8). Naturally, China has continued its development of directed energy capabilities. DIA reporting indicates that the PLA will likely field high-power lasers, capable of structurally damaging spacecraft in the mid-to-late 2020s (DIA, 2019, Pg20).

**c. Recent Events - India.** After a failed attempt several weeks earlier, India became the fourth nation to successfully demonstrate direct-ascent ASAT capabilities on March 27th, 2019 (GoI MoEA, 2019; Weeden & Samson, 2019). The test event, titled Mission Shakti, was sponsored by the Indian Defense Research and Development Office (DRDO) and utilized a modified PDV Mk-II ABM interceptor to destroy an Indian earth-observation satellite in LEO (Wright, 2020). The PDV MK-II's KKV impacted Microsat-R at an altitude of 274 kilometers, creating hundreds of pieces of orbital debris large enough to be identified and tracked by the U.S. DoD's SSA network (Clark, 2019). The number of fragments less than 10cm in diameter is likely to be in the thousands. The generated debris is particularly concerning to NASA officials as some pieces were propelled to orbital altitudes above that of the ISS (Foust, 2019). This dictates that as the debris' altitude gradually decays, ISS crew members are placed at risk.

The Indian Ministry of Foreign Affairs published a webpage to address frequently asked questions after the conclusion of the test event. Here, official statements indicate an awareness for the utility and fragility of the space environment and a desire to facilitate PAROS. Observance of both the 1967 Outer Space Treaty and the IADC Space Debris Mitigation Guidelines is specified, as well as the implementation of several TCBMs (GoI MoEA, 2019). This would imply awareness, amongst Indian officials, of the responsibility to coordinate such an activity with (at least select) members of the international community. However, testimony by the Deputy Commander of the U.S. Space Command in front of the U.S. Senate Armed Services Committee suggests that, while aware of a pending test event, the DoD did not receive any form of formal notification (Erwin, 2019). It seems that, like Russian and China, India has chosen to ignore responsible standards of behavior and exploit loopholes in international space law to make a political statement. Considering intense regional competition with China, the act was likely carried out under the pre-text of addressing a perceived power imbalance.

**Figure 9.4. Indian PDV Mk-II ASAT Missile (Wright, 2020)**

As inflammatory as India's recent ASAT test may seem, the nation holds a completely different relationship with the U.S. than Russia or China. India is not seen as a strategic competitor. On the contrary, the potential of a strengthened strategic alliance between the U.S. and India represents a tremendous opportunity for refuting China's growing influence. Fostering this relationship has been a principal objective for the Trump administration, leading to numerous defense deals and the conduct of the first-ever joint military exercise between the two nations (Economic Times, 2020; Montague, 2020). Under the auspices of constructivist theory (specifically, Alexander Wendt's example described in Chapter II), their ability to impose CS effects is therefore not seen as a direct threat to U.S. national security or continued dominance in space. As we will see in the following section, this position is very much apparent in U.S. foreign policy and the resulting strategy documents.

**d. Resulting U.S. Policy Positions.** The capabilities of strategic competitors may be growing, but the U.S. (at least for the time being) retains undeniable dominance in the international space domain. As such, its foreign policy sets the tone for all other to follow and proposed international legislation is destined for failure without its support. Generally speaking, U.S. policy positions are set by the Executive Branch. Funding is then provisioned by the legislative Branch, allowing executive entities like the U.S. Department of State (DoS) and/or DoD to apply said policy in the conduct of IR.

Space policy is no different. Presidential administrations develop foreign policy positions through input from subject matter experts, political advisors, and intelligence agencies. Naturally, national security remains the single most dominant policy objective. This is especially apparent in times of mounting strategic competition. Policy positions are then captured in national strategy documents, which (along with informal guidance) inform the Executive Branch's various subordinate entities in the conduct of their duties. Subordinate departments, in turn, usually publish their own strategies for meeting their commander's intent. Figure 9.5 provides a hierarchy of U.S. strategy documents most pertinent to the discussion at hand. Each will be analyzed in detail below.

**Figure 9.5. Hierarchy of Pertinent U.S. Strategy Documents**

**1. National Security Strategy.** The National Security Strategy (NSS) describes the president's national security goals, and corresponding strategies for achievement, to the U.S. Congress (Haley, 2013). It also serves as a medium to telegraph foreign policy positions to the international community, to include potential adversaries. Annual submission is dictated under public law. Specifically, Section 108 of the 1947 Goldwater Nichols National Security Act (Haley, 2013). That being said, annual (let alone timely) submission is uncommon. The NSS is prepared by the National Security Council and informs a variety of subordinate strategy documents in both classified and unclassified forms. Naturally, only the unclassified version is available to the public. The most recent NSS was released by the Trump Administration in 2017.

The 2017 NSS is based on four pillars. Protecting the American people, the homeland, and the American way of life (Pillar 1), promoting American prosperity (Pillar 2), the preservation of peace through strength (Pillar 3), and the advancement of American influence (Pillars 4) (POTUS, 2017, Pg4). Power competition, as defined by multiple realist IR theories, remains the fundamental challenge to U.S. global leadership. As such, the NSS identifies three discrete sets of challengers to U.S. national security interests. These are the revisionist states of Russia and China, the rogue states of Iran and North Korea, and transnational threat organizations (POTUS, 2017, Pg35). As made clear through a review of current events and taking into consideration the concept of dual-use technology, all of these actors possess CS capabilities. The continued and provocative advancement of these competencies, along with advertised intentions of employment, leaves the U.S. with no other choice than to consider space a war fighting domain.

Pillar 3 identifies both the space and cyberspace domains as principal areas of competition in which the U.S. must strive to maintain its global leadership role. ASAT technology, being developed and tested by threat actors to provide a perceived asymmetric advantage, is specifically addressed (POTUS, 2017, Pg41). Recognizing a tremendous and growing reliance on space-based capabilities the 2017 NSS makes the following statement.

> The United States considers unfettered access to and freedom to operate in space to be a vital interest. Any harmful interference with or an attack upon critical components of our space architecture that directly affects this vital U.S. interest will be met with a deliberate response at a time, place, manner, and domain of our choosing (Pg41).

This statement is intended to serve as a clearly defined and unmistakable deterrent to any actor considering the employment of CS weapons against the U.S. or its allies. It also implies that any form of legally binding treaty, preventing the U.S. from developing, testing and employing CS weapons technology as an option for responding in like manner to an attack on its spacecraft, is fundamentally implausible. Especially, since the threat actors in question have a history of non-compliance with international law and published standards of behavior.

However, the NSS also makes clear that the U.S. remains prepared for meaningful cooperation with counterparts across areas of mutual interest (Pg35). This suggests that further advancing non-binding concepts remains a viable option for fostering the preservation of the international space domain. Behavior indicating the contrary is easily explained. The U.S. has clearly articulated its recognition and compliance with TCBMs pertaining to PAROS (CD, 2016). A similar response has not been received from the international community. This, combined with escalating frustrations at Russia and China's aggressive behavior, likely explains recent U.S. votes against TCBM resolutions in the UN's First Committee.

**2. National Strategy for Space.** Building upon guidance provided in the 2017 NSS, the Trump administration approved a National Strategy for Space (NSfS) in March of 2018. This document is designed, in part, to replace the National Space Policy issued in 2010 under the Obama administration (Smith, 2018). In addition to promoting national security, the NSfS intends to facilitate the continued growth and potential of the U.S. civil and commercial space sectors. To date, the NSfS is not available for public release. However, an unclassified summary of its contents can be found on the official White House website.

Like every Trump policy, the NSfS takes on an "America First" theme. The concept of peace-through-strength is reiterated as a fundamental principle with verbiage very similar to that of the NSS. It is the first national space strategy document that openly recognizes space as a warfighting domain, placing strong emphasis on a desire for stability but making clear that hostile actions will not be tolerated. Like the NSS, it is also centered around four pillars. Those being a transformation to more resilient space architectures (Pilar 1), the strengthening of deterrence and warfighting options (Pilar 2), the improvement of foundational capabilities, structures and processes (Pilar 3), and the fostering of conducive domestic and international environments (Pilar 4) (The White House, 2018).

Pilar 3 alludes to the strengthening of U.S. and allied deterrence options. It also indicates the ability and willingness to counter hostile actions (The White House, 2018). Naturally, the exact nature of such a response would depend on a number of factors, to include the specific threat actor, the type of CS weapon employed, the exact system or architecture targeted, and the current political environment. It is only reasonable to conclude, however, that theoretical counterattack options would include a strike on analogous adversarial system, using a similar method of attack. This leaves ASAT weapons on the table for both deterrence and response. Any form of legally binding agreement that limits their development, testing, and employment will not be viewed favorably. That being said, the NSfS does call for strengthening the safety, stability and sustainability of space activities (The White House, 2018). This could very well include supporting the advance of non-binding concepts previously discussed.

**3. National Defense Strategy.** The National Defense Strategy (NDS) describes the DoDs intentions for implementing the president's NSS. Like the NSS, its submission is mandated by public law. Specifically, Section 941 of the 2017 National Defense Authorization Act and the 1947 Goldwater Nichols National Security Act (OSD, ND). The document is prepared by the Office of the Secretary of Defense for promulgation every four years. The Secretary of Defense holds final approval authority. While the comprehensive document is classified, unclassified summaries are available to the general public. The most recent NDS was released by, then Secretary of Defense James Mattis in 2018. It echoes the NSS by identifying China and Russia as strategic competitors. Along with the rogue states of Iran and North Korea, and transnational terrorist groups, they embody the principal threats to U.S. national security.

Both space and cyberspace are mentioned throughout the document. Like in the NSS and NSfS, space is recognized as a contested warfighting domain where emerging threats and threat actors (to both commercial and military applications) attempt to exploit and ever-growing reliance on space-enabled services and digital capabilities (DoD, 2018, Pg5). The theme of peace-through-strength remains a primary concept as the 2018 NDS makes the following statement.

> As we expand the competitive space, we continue to offer competitors and adversaries an outstretched hand, open to opportunities for cooperation but from a position of strength and based on our national interests. Should cooperation fail, we will be ready to defend the American people, our values, and interests. The willingness of rivals to abandon aggression will depend on their perception of U.S. strength and the vitality of our alliances and partnerships (Pg7).

To facilitate this position, the DoD plans to modernize a series of critical capabilities. These include nuclear forces, C2 and ISR, missile defense, joint lethality in contested environments, freedom of maneuver and resilience, autonomous systems, agile logistics, and (most pertinent to this thesis) space and cyberspace warfighting competencies (DoD, 2018, Pg8-9). Within the space domain, investments aim to bolster resilience, reconstitution and operational capabilities (DoD, 2018, Pg8).

A purely academic analysis of these statements suggests a number of potentialities. Investments in resilience and reconstitution intend to harden existing space system architectures against potential attacks. Resilient systems and architectures aim to retain acceptable operational capacity in degraded environments. Resiliency is a broad term that may infer anything from informed avoidance maneuvers to structural hardening. Reconstitution, on the other hand, is typically associated with the ability to rapidly replace a destroyed or operationally degraded space system. Most importantly, investments in operational capabilities specifically aimed at "building a more lethal force" may theoretically imply the advance of U.S. CS initiatives to address recent progress made by Russia and China. Regardless of its exact contents, the available summary of the 2018 NDS clearly indicates that any form of legally binding agreement preventing the U.S. from developing, testing, and employing whatever technologies it deems necessary to maintain space dominance will not be considered. TCBMS and international behavioral norms remain the most viable option for curtailing irresponsible, and potentially environmentally degradative, actions.

**4. Defense Space Strategy.** The Defense Space Strategy (DSS) replaces the National Security Space Strategy issued by then Secretary of Defense Robert Gates and Director of National Intelligence James Clapper. Its contents, rooted in the 2018 NSfS and NDS, provide guidance to the DoD for achieving desired conditions in space over the next 10 years (DoD, 2020, Pg7). While the comprehensive document is classified, unclassified summaries are available to the general public. It is the first of its kind in addressing not only established DoD components, but also the newly formed U.S. Space Force and U.S. Space Combatant Command. Space is identified as a distinct warfighting domain in the second sentence of its executive summary (DoD, 2020, Pg7). Russia and China are once again acknowledged as immediate strategic threats. Iran and North Kora are described as emerging threats (DoD, 2020, Pg9).

The 2020 DSS identifies three principal defense objectives. These include the maintenance of space superiority (Objective 1), the continued provision of space support to national, joint and combined operations (Objective 2), and the long terms sustainability of outer space activities (Objective 3) (DoD, 2020, Pg8). Interestingly enough, Objective 3 specifically addresses the DoD's role in maintaining the recently passed Guidelines for the Long-Term Sustainability of Outer Space Activities. Ultimately, the DoD intends to meet these objectives via four LOEs. These include building a comprehensive military advantage in space (LOE 1), integrating military space power into national, joint and combined operations (LOE 2), shaping the strategic environment (LOE 3), and cooperating with allies, partners, industry and other governmental agencies (LOE 4) (DoD, 2020, Pg12).

LOEs 1 and 3 are of particular interest in the CS weapons discussion. Each provides a series of more refined objectives. While naturally vague in specificity, LOE 1 talks to further developing the U.S. Space Force in the context of both doctrine and warfighting capacity, developing and fielding capabilities to counter hostile use of space, and improving C2 to enable a military advantage in the space domain (DoD, 2020, Pg13). It is once again only reasonable to conclude that "capabilities for countering the hostile use of space" directly refer to the ability to also impose CS effects on a perceived threat actor, should the situation be deemed critical enough to warrant such an action. This negates the viability of legally binding regulations. LOE 3, however, directly identifies the promotion of behavioral standards as a principal objective.

**e. Affirmation of Research Hypothesis.** We can now see how the recent behavior of U.S. strategic competitors has facilitated the social construction (through the democratic election of leaders with distinct political dispositions) of aggressive and neoconservative foreign policy positions that, on the surface, appear contradictory to advancing international space governance. This thesis argues that such voting patterns are apparent in the content of modern U.S. space policy and strategy documents, each accounting for the continued (and very much provocative) testing and employment of CS capabilities by competing actors, despite the promulgation of clear behavioral guidelines. The constructivist viewpoint is further reinforced by the fact that similar activity, conducted by potential strategic allies, is not seen as a threat.

It must be stated, however, that the initial research hypothesis failed to accurately account for the gravity of Power Transition Theory as a primary motive in the impasse on CS weapons regulation. Specifically, in explaining the generation of increasingly persistent external impulses on U.S. foreign policy. These, in turn, have helped shape the political disposition of the elected leaders alluded to above. Power Transition Theory should, therefore, be held in the same esteem as any constructivist principle when explaining the current state of affairs. Figure 9.6 attempts to visually depict these findings. It should also be noted that the physical and operational principles of the international space domain dictate, to some extent, the consideration of interdependence.

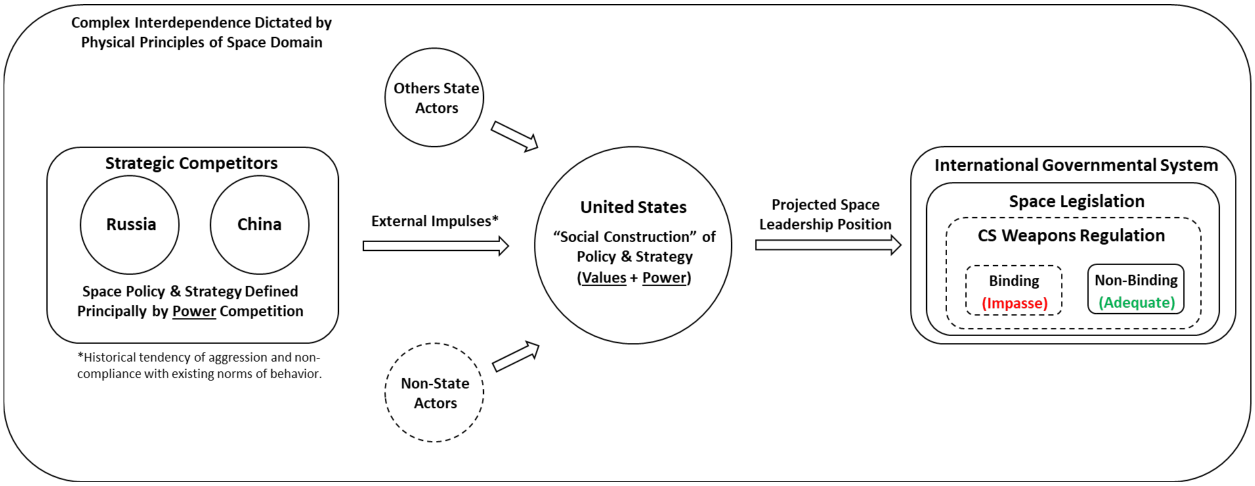


**Figure 9.6. A Visual Depiction of Theory Based Motives**

The subsequent positions serve to finalize our pursuit of SRO 2. After the end of the Cold War, the U.S. enjoyed undisputed superiority in space. While the global political environment may have been more conducive to revised space legislation at that time, the hegemonic stability enjoyed by the U.S. simply did not warrant its pursuit. In the absence of any real CS threat, existing legal instruments were deemed sufficient. Furthermore, lobbyists representing a defense industrial base with devout intentions to continue pursuing aspects of the Strategic Defense Initiative, like space based Brilliant Pebble ABM interceptors and other national missile defense technologies, maintained consistent pressure on elected officials to refrain from legally binding commitments that could inhibit potential contracts.

Following the attacks of September 11th, 2001, U.S. foreign policy became hyper-focused on the maintenance of national security. The subsequent Global War on Terror also provided the nation's strategic competitors with an opportunity to make tremendous advancements. While the U.S. was actively engaged in two simultaneous conflicts, their technical superiority and global leadership capacity in space began to atrophy. Russia and China, in turn, made notable investments to advance their space capabilities across the complete spectrum of functional areas, to include CS. Aside from having to account for additional debris in the aftermath of direct ascent ASAT testing, U.S. and allied spacecraft have since routinely been subject to provocative non-kinetic CS effects that include laser illumination, jamming, and cyber-attacks.

As mentioned at the beginning of this paper, kinetic ASAT technology has not been used as part of an offensive attack on another country's space assets. However, its ill-planned testing has significantly contributed to the orbital debris problem. Competitive status aside, this has degraded the U.S. perception of China, especially, as a responsible and trustworthy space actor. Orbital debris has since become a topic of intense discussion. Experts have indicated that a point-of-no-return may have already been reached. Pointing to active debris removal as an absolute necessity for maintaining the viability of near-earth orbital regimes.

Notwithstanding, and in a near text-book demonstration of Power Transition Theory, Russia and China continue to confrontationally advance CS capabilities. Furthermore, as U.S. technological reliance and vulnerabilities in space become more apparent, threat actors like Iran and North Korea also seek to acquire ASAT weapons. In response, U.S. national strategies have become increasingly antagonistic, emphasizing the maintenance of peace through strength and willingness to respond with overwhelming force, should such an action be justified.

Along with TCBMs, the recently endorsed Guidelines for the Long-Term Sustainability of Outer Space Activities should have provided a sensible turning-point for IR in space. The U.S. has, routinely voiced its support for such normative values and openly demonstrated compliance with the associated behavioral guidance in international forums. Instead of receiving a reciprocal response, inflammatory activity continues, with Russia testing its NUDOL interceptor only weeks after these guidelines were endorsed by COPUOS and the UN 4th Committee, respectively. Most recently, the testing of what is believed to be a co-orbital ASAT in GEO proves that Russia has no intentions of complying with behavioral standards, even while it is simultaneously advocating for legally binding arms control measures in the CD and UNDC.

Over the last decade, this trend of behavior (along with Russia's incursion into sovereign Crimean territory, its direct support of Bashar al-Assad's murderous Syrian regime and China's increasingly bellicose conduct in the South China Sea) has shaped the mindset of U.S. voters. The Trump administration NDSS and NSfS, in turn, attempt to confront strategic threat actors head-on with aggressive, neo-conservative, space policy based on maintaining peace through strength, the recognition of space as a warfighting domain, and intense opposition to any legally binding instrument deemed contradictory to national security. To an extent, this attitude is completely logical. However, this paper also argues that room for progress remains. Accordingly, and in support of SRO 3, the subsequent chapter will propose a number of LOEs thought to be capable of realistically curtailing the employment of CS weapons.

**XI. Recommendations.** In compliance with SRO 3, this chapter will take into consideration our previous findings to proposes three LOEs for IR activities aimed at maintaining the viability of near-earth orbital regimes. Specifically, by formulating realistic proposals for advancing the conduct of responsible behavior in space and curtailing the testing or employment of CS weapons. These proposals should not be considered representative of any official policy position. Instead, they are merely intended to serve as a starting point for subsequent research activities and stimulating debate amongst members of the IR and space policy community.

At this time, accounting for the established nature of the CD and UN, it is believed that adding or altering international regulatory institutions would only impose unnecessary complexity on the problem at hand. Associated infrastructure development, staffing, and budgeting requirements are best avoided by utilizing the already available IR forums. Consequently, the following LOEs are entirely procedural in nature. While maintaining its hegemonic leadership position and considering its extensive strategic and cultural reliance on space-based technological enablers, the U.S. should consider actively sponsoring these initiatives in a synchronized fashion.

| LOE # | Description |
|---|---|
| IR LOE 1 | The evaluation of promulgated TCBMs in Outer Space Activities and Guidelines for Long-Term Sustainability of Outer Space Activities. Specifically, the extent of implementation by individual states and their impact on debris flux. |
| IR LOE 2 | The pursuit of five-year New START extension that incorporates China. |
| IE LOE 3 | A fair and well-defined multilateral treaty prohibiting the testing and employment of purposely designed CS weapons. |

**Table 10.1. Proposed IR LOEs for Advancing Responsible Behavior in Space**

While the proposed IR LOEs attempt to improve the future international framework for responsible behavior in space, individual states retain a moral obligation to adopt existing regulations and guidelines. Vigorous technological development, aimed specifically at facilitating environmental conservation, should also be considered. Therefore, this paper also proposes a number of LOEs for individual spacefaring nations to pursue.

| LOE # | Description |
|---|---|
| LOE 1 | Stringent adherence to existing debris mitigation guidelines (e.g. ODMSPs, IADC Space Debris Mitigation Guidelines, UN Space Debris Mitigation Guidelines). |
| LOE 2 | Adherence to TCBMs and comprehensive implementation of Guidelines for Long-Term Sustainability of Outer Space Activities using the appropriate national mechanism. Provision of feedback to COPUOS. |

| | |
|---|---|
| LOE 3 | Aggressive advance of SSA, information sharing, and active debris removal capabilities. |

**Table 10.2. Proposed Individual LOEs for Advancing Responsible Behavior in Space**

Additionally, stakeholders should consider continuing to develop architectural resiliency through entanglement. The space domain, by its very nature, imposes a sense of complex interdependence on its participants. Growing this interdependence with operational concepts such as shared-use or the leasing of commercial services may levy additional barriers on malicious actors looking to impose CS effects.

**a. International Relations Line of Effort #1.** Following the UN General Assembly endorsement of both TCBMs in Outer Space Activities and the Guidelines for Long-Term Sustainability of Outer Space Activities, targeted COPUOS working groups should now focus on registering their scope of implementation by individual member states. Specifically, the adaptation of such principles into national regulatory framework via organizations equivalent to the U.S. FCC, DoT, FAA, and DoC. Assuming the willful participation of critical stakeholders, this data may then be compared to forthcoming orbital debris studies conducted by such entities as NASA ODPO or IADC to generate a feedback loop for adjusting the guidelines and their implementation methods appropriately. Ultimately, this process will allow an informed system of international governance to determine the effectiveness of non-binding behavioral standards. Should orbital debris management be adequately facilitated by TCBMs and COPUOS guidelines, continued advocacy is warranted. If not, a legally binding treaty may be a more viable option.

**b. International Relations Line of Effort #2.** As mentioned in Chapter 8, New START includes an NTM non-interference clause. The treaty therefore legally prohibits its signatories from applying CS effects on space-based intelligence collection platforms participating in treaty verification activities. Exercising the embedded option for a five-year extension, therefore, has the potential of imposing a temporary sense of stability in the international space domain, at least until other LOEs can advance more permanent and comprehensive solutions. The inclusion of China as a legally bound treaty member would further add to New START's utility in space. The Trump administration remains highly supportive of Chinese membership. Recent statements by Chinese officials, however, indicate an unwillingness to commit (Reuters, 2020).

**c. International Relations Line of Effort #3.** While unlikely in the short term, should a legally binding, multilateral, treaty become desirable at some point, the Draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects may provide a practical starting point for negotiations. This section attempts to identify some of the documents most imperative modification requirements. Emphasis is placed on properly defining critical terms and addressing the full spectrum of CS effects. Naturally, room for improvement and subject matter expertise will remain.

The draft treaty, co-authored by Russia and China, was first introduced to the CD in 2008 (NTI, 2020). Because of its shortfalls, it was quickly dismissed by the U.S. as a disingenuous attempt to establish a strategic military advantage (NTI, 2020). An updated draft was presented to the CD in 2014. The U.S. maintained its unaccommodating position, citing (amongst a number of other factors) a lack of consideration for ground-based CS weapons such as direct-ascent ASAT and directed energy systems. Table 10.3 provides a synopsis of the 2014 draft treaty's contents.

| Article # | Synopsis |
|---|---|
| Article I | • Outer Space Object defined as "any device placed in outer space and designed for operating therein."<br>• Weapon in Outer Space defined as "any outer space object, or its component, produced or converted to eliminate, damage or disrupt normal functioning of objects in outer space, on the Earth's surface or in the air, as well as to eliminate population, components of biosphere important to human existence, or to inflict damage to them by using any principles of physics."<br>• Placement in outer space defined as "orbiting the Earth at least once, or following a section of such an orbit before leaving this orbit, or being placed in any location in outer space or on any celestial bodies other than the Earth."<br>• Use of force defined as "any intended action to inflict damage to outer space object under the jurisdiction and/or control of other States."<br>• Threat of force defined as "clearly expressed intention, in written, oral or any other form, to inflict damage to outer space object under the jurisdiction and/or control of other States." |
| Article II | • Parties shall not place weapons in outer space.<br>• Parties shall not threaten or use force against outer space objects belonging to other states.<br>• Parties shall not engage in outer space activity inconsistent with treaty subject matter.<br>• Parties shall not assist or incite activity inconsistent with treaty subject matter. |

| | |
|---|---|
| Article III | • Treaty in no way prevents use of space for peaceful purposes, in accordance with UN charter and 1967 Outer Space Treaty. |
| Article IV | • States retain the right to exercise individual / collective self-defense. |
| Article V | • Recognition of treaty compliance and verification obligations.<br>• Voluntary implementation of TCBMs. |
| Article VI | • Directions for the establishment of an executive organization for treaty implementation. |
| Article VII | • Directions for addressing concerns and possible treaty violations. |
| Article VIII | • Treaty obligations may also apply to international intergovernmental organizations. |
| Article IX | • The treaty is open to all states for accession.<br>• Signatory states will ratify according to internal procedures.<br>• Secretary General of the UN designated as treaty depositor. |
| Article X | • Treaty to enter into force upon ratification by 20 states (to include all permanent members of the UN Security Council).<br>• For later signatories, treaty will go into effect on date of submission of instrument of ratification.<br>• Treaty party notification requirements for UN Secretary General. |
| Article XI | • Any signatory may propose treaty amendments.<br>• Treaty amendments must be approved by a majority vote. |
| Article XII | • The treaty duration is unlimited.<br>• Member states maintain the right to withdraw at any time; must provide notice no less than six months prior to withdrawal. |
| Article XIII | • Treaty documents maintain equal authenticity regardless of language.<br>• Document transmittal and storage instructions. |

**Table 10.3. Draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects (Matignon, 2019)**

Article I clearly requires some modification. The method of defining an outer space object, as any device placed in outer space and designed for operating therein, appears reasonable. No immediate change is required. The description of the use/threat of force only requires minor modification. Verbiage used to define a weapon in outer space, however, is woefully inadequate. As it stands, the definition does not address direct ascent ASAT weapons or the application of CS effects using EW, directed energy, or cyber manipulation. As we now know, these methods also have the potential of creating long lasting orbital debris and should be considered for implementation in any effective treaty enforcing CS arms control. Should the Draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the Threat or Use of Force Against Outer Space Objects continue to be pursued in CD and UN forums, this research project proposes the following changes to Article I.

Redefine the Use of Force as *"Any intended action to inflict damage to, or disrupt, an outer space object under the jurisdiction or control of another party. This does not apply to actions carried out in accordance with Article 51 of the UN Charter."* This verbiage is believed to address both the imposition of permanent damage and the temporary disruption of space systems caused by the application of hostile CS effects. Although Article IV makes specific mention of the continued right to exercise self-defense, redefining the use of force in this fashion clarifies that individual stake-holders retain the ability to apply kinetic-physical CS effects on hostile spacecraft in extreme contingency scenarios.

Redefine the Threat of Force as *"Any clearly expressed intention, in written, oral or any other form, to inflict damage to, or disrupt, an outer space object under the jurisdiction or control of another party. This does not apply to expressed intentions to exercise Article 51 of the UN Charter."* This verbiage is believed to address both the imposition of permanent damage and the temporary disruption of space systems caused by the application of hostile CS effects. Redefining the threat of force in this fashion allows individual stake-holders to retain the ability to leverage published space policy documents as deterrents. Specifically, documents such as the most recent U.S. NSS, NSfS, NDS, or DSS, that aggressively voice intentions for exercising self-defense and enforcing responsible behavior in the international space domain, cannot be considered actionable threats of force (within the UN system of treaty enforcement) by strategic competitors or threat actors.

Redefine a Weapon in Outer Space as *"Any purposely produced or converted device, to include its components, emissions, and/or signals, that is placed into outer space with the intention of damaging, destroying, or disrupting another outer space object and/or object within the earth's atmosphere."* This verbiage is believed to adequately address both the full spectrum of acknowledged and theoretical co-orbital ASAT capabilities and the potentiality of space-based weaponry with the ability to engage targets on. Because the 1967 Outer Space Treaty already addresses WMD, specific mention of nuclear devices or other WMD technology is not required. Emphasis is placed on operational purpose and intent. This should prevent undue impact on the development and use of technologies meant for the peaceful exploration of outer space.

Add detailed guidance to address ongoing capability development, and technology demonstrations, being conducted by U.S. strategic competitors. Define a Direct Ascent CS

Weapon as *"Any purposely produced or converted device, to include its components, emissions, and/or signals, that is launched from within the earth's atmosphere (but not placed into orbit), with the intention of damaging, destroying, or disrupting the normal functioning of another outer space object."* This verbiage is believed to adequately address the full spectrum of acknowledged and theoretical direct ascent ASAT capabilities. Its implementation in a legally binding instrument would address the most prominent shortfall of the 1967 Outer Space Treaty by preventing both the testing and operational employment of weapons that, historically, have the highest propensity for creating long-lasting orbital debris. Again, to minimize the imposition of unintended restrictions imposed by the dual-use concept, specific emphasis is placed on the objects operational purpose and intent. That is, devices not specifically designed for the application of CS effects should not be considered ASAT weapons.

Consider adding detailed verbiage to address terrestrial non-kinetic physical, electronic and cyber capabilities with CS effects. Define a Terrestrial EW, Directed Energy or Cyber CS Weapon as *"Any purposely produced emission or signal, originating from within the earth's atmosphere, that is directed at an outer space object with the intention of damaging, destroying, or disrupting its normal functioning."* If applied, this verbiage is believed to adequately address the full spectrum of acknowledged and theoretical EW, directed energy, and cyber capabilities that are routinely employed to impose CS effects. In conjunction with the previous recommendations and an effective method of ensuring treaty compliance, this clause could tentatively limited malicious activity to the non-intrusive collection of signals intelligence.

Significant criticism has been aimed at the draft treaties lack of consideration for effective verification procedures. The changes proposed by this research project don't necessarily prohibit the development of CS technologies. As indicated by previously examined policy positions and national strategy documents, this would prove fatal to any realistic attempt aimed at advancing a legally binding arms control instrument. Instead only the physical testing and employment of such technologies is prohibited. Because CS weapons are not being quantitatively regulated, physical compliance verification (e.g. on-site inspections or engineering reviews) would serve primarily to prevent the abuse of dual-use technology. Realistically, all other verification can be conducted via NTM. New START may provide preliminary corroboration methodologies. Should the Draft Treaty on the Prevention of the Placement of Weapons in Outer Space, the

Threat or Use of Force Against Outer Space Objects continue to be pursued in CD and UN forums, this research project proposes the following changes to Article V.

Provide for the conduct of treaty compliance via NTM and limited on-site inspections. *"In order to prevent the misapplication of dual-use technology being placed into outer space for the purpose of peaceful space exploration, this treaty provides for the conduct of 6 on-site inspections per year. Additionally, signatories agree to a policy of non-interference with NTM being employed to facilitate the verification of treaty compliance.* Naturally, this Article is likely to spark intense debate amongst stakeholders. The exact nature and number of on-site inspections is surely best determined by governmental representatives. Perhaps the correct answer even has inspection requirements varying according to the nature of the stakeholder. Treaty signatories with little to no space faring capability, for example, would likely not require much attention. This thesis does, however, view the facilitation of mandated treaty compliance procedures as an absolute necessity. Especially amongst actors with developed CS capability portfolios. Although the newly defined Articles I and II would address interference with space-based NTM, adding specificity to Article V addresses potential terrestrial NTMs.

**d. National Line of Effort #1.** Stringent adherence to existing debris mitigation guidelines (e.g. ODMSPs, IADC Space Debris Mitigation Guidelines, UN Space Debris Mitigation Guidelines) should, at this point, be standard practice for space fairing nations. Their implementation by the appropriate national regulatory institutions should take into account recent updates providing quantifiable limits for debris-generating events and new methods of space operations. Critical stakeholders should continue to advocate for more stringent timelines pertaining to PMD maneuvers in IADC and COPUOS forums, especially as the normalized deployment of large constellations (e.g. SpaceX STARLINK or O3B) begins to intensify the orbital debris problem.

**e. National Line of Effort #2.** As mentioned in IR LOE #1, the implementation of TCBMs in Outer Space Activities and the Guidelines for Long-Term Sustainability of Outer Space Activities, via applicable national regulatory frameworks, should be viewed as a moral responsibility for space fairing nations. The scope and method of such enactment is to be shared with the international community in COPUOS forums to determine if the voluntary guidelines are meeting their intent. The willful participation of critical stakeholders in this process will influence individual foreign policy positions and may facilitate progress on other IR fronts.

**f. National Line of Effort #3.** In addition to the passive risk management controls associated with IR LOEs #1-3 and National LOEs #1-2, this thesis proposes a number of active measures. National LOE #3 entails the aggressive advance of SSA competencies in order to address the orbital debris measurement capability gaps identified in Chapter 6. Specifically, the assured ability to identify sub-meter diameter debris in GEO and millimeter-diameter debris in LEO. This may entail both the improvement of existing sensor technologies or the implementation of new measurement techniques. Modeling and simulation capabilities exceeding those provided by ORDEM and LEGEND may then serve to more accurately define the space environment, allowing engineers and policy makers to take the appropriate actions. Improving SSA capabilities will not just benefit traditional stakeholders. As the space domain diversifies, more international actors have reason to establish SSA capacity and participate in information exchange. This in turn, may inform more effective collision avoidance maneuvers.

Chapter 6 also alluded to the space domain's limited environmental capacity for orbital debris. As indicated by Kessler, et al., cascading debris-growth may already be well underway. The selective retrieval of prominent debris hazards may therefore be obligatory for maintaining the viability of the most sensitive near-earth orbital regimes. We know the technology necessary to carry out these types of operations, within reasonable fiscal constraints, currently does not exist. Its pursuit, however, should be considered a top-priority. Considering the dual-use dilemma, the advance of such capabilities will surely spark intense opposition. A focus on establishing a commercialized debris removal industry may therefore help to ease tensions, as state actors are less likely to consider the abilities of a foreign business venture as elements of national power.

By adequately defining a number of methods for advancing the status-quo, we have achieved full compliance with SRO 3, bringing us to the end of this research activity. The proposals listed above will likely be picked apart experts in both the IR and space policy fields with significantly more experience in their respective fields. Hopefully so! Constructive criticism is, after all, an absolutely requirement in the composition of effective solutions. While we wait to see what the next decades bring, one this is for certain: **Space is the future and its preservation should be paramount**.

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