Spacepower Theory and Organizational Structures

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Abstract

Spacepower theory is useful in describing, explaining, and predicting how individuals, groups, and states can best derive utility, balance investments, and reduce risks in their interactions with the cosmos. Spacepower theory should be more fully developed and become a source for critical insights as humanity wrestles with our most difficult and fundamental space challenges. This theory can help to guide us toward better ways to generate wealth in space, make tradeoffs between space investments and other important goals, reorder terrestrial security dynamics as space becomes increasingly militarized and potentially weaponized, and seize exploration and survival opportunities that only space can provide. This chapter reviews noteworthy efforts to develop spacepower theory and overviews recent changes in US organizational structures for spacepower. It then considers ways

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theory and structures could help to refine current US space policy and address some of the most significant challenges and issues surrounding space security, space commercialization, and environmental sustainability and survival.

Introduction

The goal of spacepower theory is to describe, explain, and predict how individuals, groups, and states can best derive utility, balance investments, and reduce risks in their interactions with the cosmos. These are long-term, broad, indeterminate, and ambitious goals – it is hardly surprising that more than 60 years into the space age humanity has yet to develop spacepower theory able to address these goals in comprehensive and accepted ways. Incomplete and immature theory inhibits our ability to identify, pursue, and sustain major space objectives. More mature spacepower theory would provide critical insights as humanity wrestles with our most difficult and fundamental space challenges and guide us toward better ways to generate wealth in space, make tradeoffs between space investments and other important goals, reorder terrestrial security dynamics as space becomes increasingly militarized and potentially weaponized, and seize exploration and survival opportunities that only space can provide. This chapter reviews noteworthy efforts to develop spacepower theory and overviews recent changes in US organizational structures for spacepower. It then considers ways theory and structure could help to refine current US space policy and address some of the most significant challenges and issues surrounding space security, space commercialization, and environmental sustainability and survival.

Current perceptions that more robust spacepower theory is needed are undoubtedly most acute in the United States, but they are also growing worldwide as space becomes an increasingly contested and important domain. For decades, space capabilities gave the United States important asymmetric advantages that provided foundational elements of America's strength in the information age. These advantages are now being undermined by many factors including the reemergence of great power competition, the rise of China as a near-peer competitor with significant space and counterspace capabilities, continuing growth in the numbers and capabilities of space actors, and US uncertainties and missteps in determining and implementing its best strategy for developing and employing space capabilities. The trajectory of spacepower development has reached an inflection point where business as usual will no longer improve or even maintain US advantages – a point where the United States must implement different approaches or face diminishing returns from its space investments and the loss of space leadership. Attempting to identify and act upon inflection points is associated with strategic thinking and concepts of operations for terrestrial military operations; these approaches now hold obvious appeal to Americans pondering their space future. More mature and robust spacepower theory could help provide a more broad and stable foundation for the United States to develop a more deliberate, comprehensive, long-term, and consistent space strategy that would draw on all instruments of power from all levels of government, foster unity of effort in national space activities, improve the viability of the US space industrial base, and, in particular, craft better ways to leverage state-of-the-world commercial and international space capabilities.

Despite its importance, movement toward developing better spacepower theory is likely to be slowed by discouraging attributes associated with spacepower that include lack of acceptance that such theory is needed, very large investments and long timelines, requirements for sustained popular and political support, and prospects for only potential or intangible benefits. These factors can erode acceptance of and support for improving spacepower theory at both the personal and political levels, but they also point to the need for an incremental approach and reinforce the long-term benefits of theory in providing guidance, stability, and predictability. Indeed, more robust spacepower theory could provide an essential foundation for improving the structure and predictability of humanity's interactions with the cosmos. Perhaps more than any other approach, the issues spacepower theory addresses, the precedents from which it is drawn, and the pathways ahead it helps to illuminate could help guide the future development of spacepower.

Noteworthy Efforts to Develop Spacepower Theory

Many studies touch on aspects of spacepower theory, but few focus solely on this topic, and fewer still address the topic comprehensively and have widespread acceptance. This section briefly considers some of the most noteworthy efforts as well as elements of major and enduring themes and analogies any robust spacepower theory would need to address. The first major, comprehensive, and focused effort to develop spacepower theory began in 1997 when the Commander of US Space Command, General Howell M. Estes III, commissioned Dr. Brian R. Sullivan to write a book on this topic. James Oberg then became the leader of the effort and he published *Space Power Theory* in 1999 (Oberg 1999). Oberg draws on his academic background in astrodynamics and computer science as well as more than 20 years' experience with the National Aeronautics and Space Administration (NASA) Space Shuttle program to present a cogent narrative about the importance of spacepower that is particularly strong on the technical underpinnings of spacepower and emphasizes the need for space control. The book provides a strong foundation for spacepower theory, details the range of elements that contribute to its development, reviews how major space-faring states developed and used spacepower, and discusses several significant technical and political impediments to its development. Unfortunately, the political dimension of Oberg's spacepower theory is less well developed, primarily because his analysis does not provide much focus on the ways the attributes of spacepower relate to strategy or the development and employment of power in other domains.

By contrast, Everett Dolman, a professor in the Schriever Scholars program and at the School of Advanced Air and Space Studies at Air University, provides a spacepower theory that is focused almost entirely on the political rather than technical aspects of spacepower. *Astropolitik: Classical Geopolitics in the Space*

Age (Dolman 2001) explains how the physical attributes of outer space and the characteristics of space systems shape the application of spacepower and then uses this *astropolitical* analysis to develop a compelling vision for the United States to reject the Outer Space Treaty (OST) regime, promote free-market capitalism in space, and use space to help provide global security as a public good. His book is intellectually grounded in the best traditions of geopolitics, has something genuinely new to say, makes vital contributions to the dialogue about the interrelationships between space and national security, and is easily the most important book on space and security since the publication of Walter A. McDougall's Pulitzer prize-winning *. . .the Heavens and the Earth: A Political History of the Space Age* in 1985. *Astropolitik* is a stunning intellectual achievement and the first book that can legitimately claim to present a comprehensive theory of spacepower. It challenges conventional thinking about the status quo for space and has generated a great deal of controversy and provoked many responses. To be sure, many of the major points Dolman asserts are open to debate, such as whether space will actually become a virtually limitless source of wealth, what technologies and strategies the United States might employ to assert dominance over low-Earth orbit (LEO), and how and why domestic and international political forces might come to align with his astropolitical prescriptions. But one mark of a great book is that it helps to define and structure subsequent debate; *Astropolitik* has clearly advanced the study of spacepower theory by providing the language and lines of argumentation for future discourse.

There are several other noteworthy additions to this field: M. V. Smith's *Ten Propositions Regarding Spacepower*, John J. Klein's *Space Warfare: Strategy, Principles and Policy*, the National Defense University's (NDU) edited volume *Toward a Theory of Spacepower: Selected Essays*, and Klein's *Understanding Space Strategy: The Art of War in Space* (Smith 2001; Klein 2006, 2019; Lutes et al. 2011; Klein 2019). *Ten Propositions Regarding Spacepower* is written from the perspective of an Air Force officer who spent several years integrating space-related capabilities into numerous exercises and real-world combat; the study seeks to answer the philosophical question "what is the nature of spacepower?" Smith describes the nature of spacepower by presenting ten propositions, supporting each with historical evidence: Space is a distinct operational medium; the essence of spacepower is global access and global presence; spacepower is composed of a state's total space activity; spacepower must be centrally controlled by a space professional; spacepower is a coercive force; commercial space assets make all actors space powers; spacepower assets form a national center of gravity; space control is not optional; space professionals require career-long specialization; and weaponizing space is inevitable. Smith's propositions build from and are consistent with main themes in Oberg's and Dolman's works, but they independently advance spacepower theory by providing a more comprehensive and thorough exposition of the attributes of spacepower and its employment.

John J. Klein is a naval aviator, his books build from Carl von Clausewitz and other classic military theorists. In particular, Klein modifies for space the classic maritime theory presented by Julian Corbett in *Some Principles of Maritime Strategy* and first published in 1911. Corbett's theory about maritime activity is among the best developed and comprehensive of all theories designed to explain military operations in terrestrial domains. Klein assesses airpower, seapower, and maritime strategies, finding that maritime strategy is most suitable for application to space; builds from Alfred Thayer Mahan's and Corbett's ideas about sea lines of communications to discuss the importance of celestial lines of communications; and asserts that there is an overemphasis on power and offensive space operations in current American spacepower thought. Klein's work advances spacepower theory by creating tight linkages with Corbett's well-developed maritime theory and providing a firm foundation for further refining spacepower theory.

The NDU spacepower theory study was commissioned by the Department of Defense (DoD) as the result of deliberations during preparation of the 2005 Quadrennial Defense Review. The study was a team effort to produce an edited volume and does not attempt to present a single point of view about spacepower theory. Instead, the study published 30 chapters written by national and international space experts and organized into six sections: introduction to spacepower theory; economics and commercial space perspectives; civil space perspectives; national security space perspectives; international perspectives; and evolving futures for spacepower. The strength of this approach is that it presents the most broad and wide-ranging perspectives ever assembled about spacepower theory, but weaknesses also stem from this approach, because there is no unified perspective or even many major common themes that emerge from the work. The overarching goal of the study was to foster dialogue and incubate further development of spacepower theory; it is hoped that the study's broad and wide-ranging perspectives will encourage advancement of spacepower theory along multiple paths.

Major and enduring themes and analogies any robust spacepower theory should address include perspectives on the growing use and importance of space, debates about the economic potential of space, debates over the need for and inevitability of space weaponization, perspectives of space as a frontier to be tamed, and perspectives that link space to humanity's purpose and destiny. Another set of factors shaping spacepower theory are the oft-invoked analogies between spacepower and seapower or airpower. Seminal theorists who developed important perspectives on sea and air operations include Mahan, Corbett, Giulio Douhet, William "Billy" Mitchell, and John Warden. (Several of these individuals were quite prolific; the following list represents their best known works: Mahan (1890), Corbett (1988), Douhet (1983), Mitchell (1988), and Warden (1988). On the importance of these works see Sumida (1997), Meilinger (1997), and Mets (1999).) Some of the key concepts that these theorists developed or applied to the air and sea mediums are command of the sea, command of the air, sea lines of communication, common routes, choke points, harbor access, concentration and dispersal, and parallel attack. Several of these concepts have been appropriated directly into various strands of embryonic space theory; others have been modified slightly and then applied. For example, Mahan's and Corbett's ideas about lines of communications, common routes, and choke points have been applied quite directly onto the space medium. Seapower and airpower concepts that have been modified to help provide starting points for thinking about spacepower include harbor access and access to space and command of the sea or air and space control. But, of course, to date, no holistic spacepower theory has yet emerged that is fully worthy of claiming a place alongside the seminal seapower and airpower theories listed above. There are also many fundamental questions concerning the basic attributes of the space medium and how appropriate it is to analogize directly from seapower or airpower theory when attempting to build spacepower theory. Few concepts from seapower theory translate directly into airpower theory, and it is not reasonable to expect either seapower or airpower theory to apply directly for the distinct space domain.

Organizational structures also play a critical role in shaping US spacepower. Creation of the US Space Force (USSF) in December 2019 marks a momentous change in the structure of the US military and a significant shift in American strategic thought about the military utility of space (National Defense Authorization Act 2019). While this development alone cannot resolve all spacepower theory and space strategy issues, it may end an era of more than 30 years when the US was not satisfied with how it organized its national security space activities and churned through several different structures. Yet, because organizational structure is only a second-order issue, deeper questions remain related to the lack of consensus and direction on US objectives and priorities for its spacepower theory. The United States has yet to focus enough or reach consensus even domestically, let alone internationally, on first-order issues such as the long-term viability of the Outer Space Treaty (OST) regime, space weaponization, options for exploiting space resources and creating wealth in and from space, or other overarching issues related to the objectives it seeks from space, why these are important, and what the best strategies are to pursue these objectives. Worse, far too much current attention has been diverted toward third-order issues such as in which congressional districts Space Force units should be located or even what the Space Force patch and uniforms should look like. These are all issues and decisions that deserve some level of attention and hold some importance, but, as it stands up its first new military branch in more than 70 years, it is critical for the United States to focus initially on the first-order issue of the spacepower theory that will prioritize what the Space Force should do. Focusing on the organizational structure of the Space Force and first-order priorities for space can help the United States ask the right questions and move toward doing the right things, at the right times, and for the right reasons.

For the past several years, the United States was not able to reach consensus on the need for a Space Force, Space Corps, or other potential major reorganizations. Between 2017 and 2019, the House of Representatives and Senate Armed Services Committees were unable to reach a compromise on the Space Force. Elevating the issue above these committees in the fall of 2019 during budget negotiations allowed broader compromises between the parental leave provisions some Democrats wanted and Space Force provisions the President and some Republicans wanted. Unfortunately, expansion of the scope for compromises on a new organization did not extend beyond considering only a very narrow slice of military structure options or even the name of the new organization – the President insisted it be called the Space Force. The new Space Force resulting from these uncertainties and compromises holds significant potential but faces continuing disagreements about its most important and appropriate near-term priorities and, as a military organization, is limited in its ability to effectively address the full range of first-order strategic space issues the United States currently faces. Another reflection of congressional concerns about the Space Force is the unprecedented level of oversight and reporting requirements Congress has levied on the new organization, including bi-monthly reporting on progress in establishing the Space Force.

There are several important concepts that can help us examine the Space Force and determine where it fits in relation to previous models and structures. Aristotle originated the idea that "form follows function," a broad philosophical construct that includes deliberations on how organizational functions ought to determine organizational structure. This concept, along with Clausewitz's assessments about inflection and culminating points, may be helpful as we consider the development of spacepower and how organizational structures may need to evolve. Another consideration for framing discussions on the Space Force is the adage that "when all you have is a hammer, everything looks like a nail" and the potential consequences of the United States choosing this military organization model and discussing the need for space dominance. Unlike most other national security mission areas, during the past 30 years, the Pentagon was directed to or chose itself to make several significant changes in its national security space organizational structures including the Deputy Under Secretary of Defense for Space (1994–1997); National Security Space Architect (1998–2004); National Security Space Office (2004–2010); Department of Defense (DoD) Executive Agent for Space (2003–2015); and Principal DoD Space Advisor (2015–2018). In addition, Air Force Space Command was established in 1982 and redesignated as the Space Force under the 2019 Space Force Act; and US Space Command was established in 1985, merged underneath US Strategic Command in 2002, and reestablished as an independent geographic combatant command in 2019.

The Space Force Act gives DoD 18 months to establish the initial operational capability of the Space Force and implement several other key provisions. The Act established the Space Force, a distinct armed force within the Department of the Air Force under the Secretary of the Air Force, and created a new General Officer position, the Chief of Space Operations (CSO). On 14 January 2020, Vice President Mike Pence administered the oath of office to Air Force General John "Jay" Raymond, making Raymond the first CSO and first member of the Space Force. The CSO is already attending meetings of the Joint Chief of Staff (JCS) and under the Act becomes a member of the JCS on 20 December 2021. The Space Force must establish its headquarters along with determining its subordinate units and their basing locations. All Space Force units will initially come from the Air Force, but, over time, it is expected that some Army and Navy units, along with appropriate Guard and Reserve units, will also transfer to the Space Force. Likewise, officers and enlisted personnel, initially from the Air Force, can voluntarily transfer into the Space Force. It is expected that some officers and enlisted personnel from the other Services, along with new accessions to the military, will also volunteer for the Space Force. Other key provisions in the Space Force Act establish a new Assistant

Secretary of the Air Force for Space Acquisition and Integration (ASecAF SA&I) position and a new Space Force Acquisition Council (SFAC). The ASecAF SA&I is a Senate-confirmed position that serves as the senior architect for space systems and programs across the Department of the Air Force, chairs the SFAC, is to become the Air Force Service Acquisition Executive (SAE) for space systems and programs as of 1 October 2022, and provides fiscal and strategic guidance by overseeing and directing the Space Rapid Capabilities Office, the Space and Missile Systems Center, and the Space Development Agency. The SFAC is to meet monthly, and its membership includes the Under Secretary of the Air Force, the Assistant Secretary of Defense for Space Policy, the Director of the National Reconnaissance Office (NRO), the CSO, and the Commander of the US Space Command.

Spacepower Theory and Current US Space Policy

The United States has the most developed, open, and mature process for promulgating national space policy, and these space policies contain many elements that would be needed in robust and comprehensive spacepower theory. This is not to suggest that US space policy is the same as or can substitute for spacepower theory, but it does mean that attempts to develop spacepower theory need to be aware of and interact with these elements of US space policy. Widely accepted and comprehensive spacepower theory could help the United States refine its space policy, provide a stronger and more sustainable and consistent foundation for its implementation, and also improve its strategic-level management and organizational structures for implementing goals from the National Security Strategy, National Defense Strategy (NDS), and National Strategy for Space (NSfS).

The Trump Administration's National Security Strategy, released in December 2017, established America's vital national interest in space, reemphasized the importance of space for US security, and provided several overarching yet demanding objectives that will require focused attention and considerable effort to pursue:

> The United States must maintain our leadership and freedom of action in space. Communications and financial networks, military and intelligence systems, weather monitoring, navigation, and more have components in the space domain. As U.S. dependence on space has increased, other actors have gained access to space-based systems and information. Governments and private sector firms have the ability to launch satellites into space at increasingly lower costs. The fusion of data from imagery, communications, and geolocation services allows motivated actors to access previously unavailable information. This "democratization of space" has an impact on military operations and on America's ability to prevail in conflict.
>
> Many countries are purchasing satellites to support their own strategic military activities. Others believe that the ability to attack space assets offers an asymmetric advantage and as a result, are pursuing a range of anti-satellite (ASAT) weapons. 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.

> Priority Actions
> ADVANCE SPACE AS A PRIORITY DOMAIN: America's newly re-established National Space Council, chaired by the Vice President, will review America's long-range space goals and develop a strategy that integrates all space sectors to support innovation and American leadership in space.
> PROMOTE SPACE COMMERCE: The United States will simplify and update regulations for commercial space activity to strengthen competitiveness. As the U.S. Government partners with U.S. commercial space capabilities to improve the resiliency of our space architecture, we will also consider extending national security protections to our private sector partners as needed.
> MAINTAIN LEAD IN EXPLORATION: To enable human exploration across the solar system and to bring back to Earth new knowledge and opportunities, we will increase public-private partnerships and promote ventures beyond low Earth orbit with allies and friends. (National Security Strategy 2017)

Then Secretary of Defense James Mattis released an unclassified summary of the NDS in January 2018. The strategy sets three overarching objectives for DoD to address the reemergence of great power competition: rebuilding military readiness to develop a more lethal Joint Force, strengthening alliances and attracting new partners, and reforming DoD's business practices for greater performance and affordability. The NDS designates space as a "warfighting domain" and indicates DoD will "prioritize investments in resilience, reconstitution, and operations to assure our space capabilities" (National Defense Strategy 2018).

In March 2018, the White House released the National Strategy for Space. The strategy established four pillars for a unified approach:

- Transform to more resilient space architectures: We will accelerate the transformation of our space architecture to enhance resiliency, defenses, and our ability to reconstitute impaired capabilities.
- Strengthen deterrence and warfighting options: We will strengthen U.S. and allied options to deter potential adversaries from extending conflict into space and, if deterrence fails, to counter threats used by adversaries for hostile purposes.
- Improve foundational capabilities, structures, and processes: We will ensure effective space operations through improved situational awareness, intelligence, and acquisition processes.
- Foster conducive domestic and international environments: We will streamline regulatory frameworks, policies, and processes to better leverage and support U.S. commercial industry, and we will pursue bilateral and multilateral engagements to enable human exploration, promote burden sharing and marshal cooperative threat responses. (National Strategy for Space 2018, p. 2)

Cumulatively, these documents move the Trump Administration considerably beyond the space policy of the Obama Administration. They reflect the "America First" more unilateral tone of many Trump Administration policies and move away from the stress on cooperation and responsible behavior in space in the 2010 National Space Policy. More specifically, the Trump Administration rejected the Obama Administration's categorization of space stability and sustainability as vital national interests and returned to the previous approach that categorized just national security considerations as vital national interests in space as found in the 2006 and previous National Space Policies.

Additionally, the United States must continue to implement the many approaches and comprehensive actions detailed in the National Security Space Strategy (NSSS). The NSSS was signed by the Secretary of Defense and Director of National Intelligence and released in February 2011 (Secretary of Defense and Director of National Intelligence 2011). The NSSS publicly substantiated that space is growing increasingly congested, contested, and competitive: DoD is tracking over 22,000 man-made objects in space (including 1,100 active satellites), there are hundreds of thousands of additional debris pieces too small to track with current sensors but that could still damage satellites in orbit, and there is also increasing congestion in the radiofrequency spectrum due to satellite operations by more than 60 states and consortia and as many as 9,000 satellite communications transponders expected to be in orbit by 2012 (Secretary of Defense and Director of National Intelligence 2011, pp. 1–2).

Space is increasingly *contested* in all orbits. Today space systems and their supporting infrastructure face a range of man-made threats that may deny, degrade, deceive, disrupt, or destroy assets. Potential adversaries are seeking to exploit perceived space vulnerabilities. As more nations and non-state actors develop counterspace capabilities over the next decade, threats to US space systems and challenges to the stability and security of the space environment will increase. Irresponsible acts against space systems could have implications beyond the space domain, disrupting worldwide services upon which the civil and commercial sectors depend (Secretary of Defense and Director of National Intelligence 2011, p. 3).

And with respect to increasing competition, while the United States "maintains an overall edge in space capabilities," its "competitive advantage has decreased as market-entry barriers have lowered"; its "technological lead is eroding in several areas"; "US suppliers, especially those in the second and third tiers, are at risk due to inconsistent acquisition and production rates, long development cycles, consolidation of suppliers under first-tier prime contractors, and a more competitive foreign market"; and the US share of world satellite manufacturing revenue has dropped from an average of more than 60% during the 1990s to 40% or less during the 2000s (Secretary of Defense and Director of National Intelligence 2011).

To address these challenges, the NSSS seeks three strategic objectives: strengthening safety, stability, and security in space; maintaining and enhancing the strategic national security advantages afforded to the United States by space; and energizing the space industrial base that supports US national security (Secretary of Defense and Director of National Intelligence 2011, p. 4). The strategy advocates five strategic approaches to pursue these objectives: promoting responsible, peaceful, and safe use of space; providing improved US space capabilities; partnering with responsible nations, international organizations, and commercial firms; preventing and deterring aggression against space infrastructure that supports US National Security; and preparing to defeat attacks and to operate in a degraded environment (Secretary of Defense and Director of National Intelligence 2011, pp. 5–11). Pursuit and implementation of these strategic objectives has proven challenging, but the NSSS correctly assesses the most significant changes in the space strategic environment and presents a responsible way for the United States to address these changes that begins to approach the comprehensive advances needed for spacepower theory.

Spacepower Theory, Hard Power, and the Quest for Sustainable Security

There are several of hard power issue areas where spacepower theory might provide insights on space security including the OST regime and other transparency- and confidence-building measures (TCBMs), space situational awareness (SSA), space weaponization, and the rise of China as a major factor in space security. The OST regime is by far the most important and comprehensive mechanism in shaping space security. Although there is some substance to arguments that the OST only precludes those military activities that were of little interest to the superpowers and does not bring much clarity or direction to many of the most important potential space activities, the treaty nonetheless provides a solid and comprehensive starting point for spacepower theory and is an important foundation for thinking about additional theoretical structures needed to advance spacepower. Moreover, there is broad consensus on the merits and overall value of the OST regime; space-faring actors are much more interested in building upon this foundation than in developing new structures.

Spacepower theory should provide guidance on the most effective ways to confront the OST regime. Some theories would advocate abandoning this regime; most others would seek ways to improve and build upon the OST regime including working toward achieving more universal adherence by all space-faring actors to the regime's foundational norms and expanding the regime beyond just states to include all important space-faring actors. Beginning work to include major non-state space actors in the OST would be a significant step that would require substantial expansion of the regime and probably would need to be accomplished incrementally. The security dimensions of the regime have opened windows of opportunity, and important precedents have been set by expanding participation in the United Nations Committee on the Peaceful Uses of Outer Space (UN COPUOS) and the World Radio Conferences of the International Telecommunications Union (ITU) to include non-state actors as observers or associate members. Some form of two-tiered participation structure within the OST regime might be appropriate for a number of years, and it could prove impractical to include non-state actors in a formal treaty, but steps toward expanded participation should be carefully considered, both to capture the growing spacepower of non-state actors and to harness their energy in helping achieve more universal adherence to the regime. Perhaps most importantly, these initial steps would help promote a sense of stewardship for space among more actors and increase attention on those parties that fail to join or comply with these norms. Other particular areas within the OST regime that spacepower theory should address, perhaps through creation of a standing body with specific implementation responsibilities, include the Article VI obligations for signatories to authorize and exercise continuing supervision over space activities and the Article IX responsibilities for signatories to undertake or request appropriate international consultations before proceeding with any activity or experiment that would cause potentially harmful interference.

Another key area for security and spacepower theory for the United States and other leading space-faring actors that would help better define OST implementation obligations and demonstrate leadership in fostering cooperative spacepower would be improvements in how SSA data is developed and shared globally. Due to increasing use of space by more actors, the growing number of active satellites, and, especially, recent deliberate and accidental debris creating events caused by the Chinese ASAT test in January 2007, the February 2009 collision between Iridium and Cosmos satellites, and the Indian ASAT test in March 2019, there is now more worldwide interest in spaceflight safety and considerable motivation for improvements in developing and sharing SSA data with more users in more timely and consistent ways. As a result of the 11 January 2007 Chinese ASAT test, the US Space Surveillance Network has cataloged 2,378 pieces of debris with diameters greater than 5 cm, is tracking 400 additional debris objects that are not yet cataloged, and estimates the test created more than 150,000 pieces of debris larger than 1 cm^2. Unfortunately, less than 2% of this debris has reentered the atmosphere so far, and it is estimated that many pieces will remain in orbit for decades and some for more than a century (NASA Orbital Debris Proogram Office 2009).

Spacepower theory should provide guidance on the most effective approaches toward achieving these objectives. One approach would be continuation and improvements in US Government efforts to create a data center for sharing SSA data globally including ephemeris, propagation data, and pre-maneuver notifications for all active satellites. SSA issues are framed by specialized concepts and jargon. Conjunctions are close approaches, or potential collisions, between objects in orbit. Propagators are complex modeling tools used to predict the future location of orbital objects. Satellite operators currently use a number of different propagators and have different standards for evaluating and potentially maneuvering away from conjunctions. Maneuvering requires fuel and shortens the operational life of satellites. Orbital paths are described by a set of variables known as ephemeris data; two-line element sets (TLEs) are the most commonly used ephemeris data. Much of this data is contained in the form of a satellite catalog. The United States maintains a public catalog at space-track.org. Other entities maintain their own catalogs. Orbital paths constantly change, or are perturbed, by a number a factors including Earth's inconsistent gravity gradient, solar activity, and the gravitational pull of other orbital objects. Perturbations cause propagation of orbital paths to become increasingly inaccurate over time; beyond approximately four days into the future, predictions about the location of orbital objects can be significantly inaccurate (Weeden 2009; McGlade 2007). Under Space Policy Directive-3, the Trump Administration is working to improve space traffic management and is planning to move the center for sharing SSA data globally from DoD to the Department of Commerce. Another approach would be to transition and operate such a data center under international auspices and perhaps create an international space traffic management organization that would be somewhat analogous to the International Civil Aviation Organization (ICAO). A final approach would build from commercial efforts such as the Space Data Association and Commercial Space Operations Center to encourage the commercial sector, rather than governments, to play the leading role in providing SSA data globally. In each case, processes would need to be developed and refined for users to voluntarily contribute data to the center, perhaps through a Global

Positioning System (GPS) transponder on each satellite, and for spaceflight safety data to be constantly updated, freely available, and readily accessible so that it could be used by satellite operators to plan for and avoid conjunctions.

Spacepower theory should also address difficult legal, technical, and policy issues that inhibit progress on sharing SSA data that include bureaucratic inertia, liability, and proprietary concerns; nonuniform data formatting standards and incompatibility between propagators and other cataloging tools; and security concerns over exclusion of certain satellites from any public data. Some of these concerns could be addressed by working toward better cradle-to-grave tracking of all cataloged objects to help establish the launching state and liability; using opaque processes to exclude proprietary information from public databases to the maximum extent feasible; and indemnifying program operators, even if they provide faulty data that results in a collision, so long as they operate in good faith, exercise reasonable care, and follow established procedures.

Theories for operating in other domains and history suggest there are very important roles for militaries both in setting the stage for the emergence of international legal regimes and in enforcing the norms of those regimes once they emerge. Development of any TCBMs for space, such as rules of the road or codes of conduct, should draw closely from the development and operation of such measures in other domains such as sea or air. The international community should consider the most appropriate means of separating military activities from civil and commercial activities in the building of these measures, because advocating a single standard for how all space activities ought to be regulated or controlled is inappropriately ambitious and not likely to be helpful. DoD requires safe and responsible operations by warships and military aircraft, but they are not legally required to follow all the same rules as commercial traffic and sometimes operate within specially protected zones that separate them from other traffic. Moreover, operational security considerations dictate that these military forces often do not provide public information about their location and planned operations. More robust spacepower theory as well as full and open dialogue about these issues will help us develop space rules that draw from years of experience in operating in other domains and make the most sense for the unique operational characteristics of space.

Other concerns surround the implications of various organizational structures and rules of engagement for potential military operations in space. Spacepower theory should help us address key questions such as whether military space forces should operate under national or only international authority, who should decide when certain activities constitute a threat, and how such forces should be authorized to engage threats, especially if such engagements might create other threats or potentially cause harm to humans or space systems. Clearly, these and several other questions are very difficult to address and require careful international vetting well before the actual operation of such forces in space. In addition, we should consider the historic role of the Royal and US Navies in fighting piracy, promoting free trade, and enforcing global norms against slave trading, as well as the current international effort to combat piracy off the Horn of Africa. What would be analogous roles in space for the US military and other military forces today and in the future and how might the United States and others encourage like-minded actors to cooperate on such initiatives? Attempts to create legal regimes or enforcement norms that do not specifically include and build upon military capabilities are likely to be divorced from pragmatic realities and ultimately frustrating efforts (Joseph DeSutter 2006).

Robust and comprehensive spacepower theory should also address the viability and utility of various top-down and bottom-up approaches to TCBMs. The OST regime was developed through top-down methods, but since that success, many factors have made this approach increasingly difficult. The most serious of these problems include disagreements over the proper forum, scope, and object for negotiations; basic definitional issues about what is a space “weapon” and how they might be categorized as offensive or defensive and stabilizing or destabilizing; and daunting concerns about whether adequate verification mechanisms can be found for any comprehensive and formalized TCBMs that would likely prohibit certain space activities while seeking to encourage others. These problems relate to a number of very thorny, specific issues such as whether the negotiations should be primarily among only major space-faring actors or more multilateral, what satellites and other terrestrial systems should be covered, and whether the object should be control of space weapons or TCBMs for space; the types of TCBMs which might be most useful (e.g., rules of the road or keep out zones) and how these might be reconciled with the existing space law regime; and verification problems such as how to address the latent or residual ASAT capabilities possessed by many dual-use or military systems or how to deal with the significant military potential of even a small number of covert ASAT systems.

New space system technologies, continuing growth of the commercial space sector, and new verification technologies interact with these existing problems in complex ways. Some of the changes would seem to favor TCBMs, such as better radars and optical systems for improved SSA, attribution, and verification capabilities; technologies for better space system diagnostics; and the stabilizing potential of redundant and distributed space architectures that create many nodes by employing larger numbers of hosted payloads and less expensive satellites. Many other trends, however, would seem to make space arms control and regulation even more difficult. For example, very small satellites are becoming increasingly capable and might be used as virtually undetectable active ASATs or passive space mines; proliferation of space technology has radically increased the number of significant space actors to include a number of non-state actors that have developed or are developing sophisticated dual-use technologies such as autonomous rendezvous and docking capabilities; satellite communications technology can easily be used to jam rather than communicate; and growth in the commercial space sector raises issues such as how quasi-military systems could be protected or negated and the unclear security implications of global markets for dual-use space capabilities and products.

There is disagreement about the relative utility of top-down versus bottom-up approaches to developing space TCBMs and formal arms control, but, following creation of the OST regime, the United States and many other major space-faring actors have tended to favor bottom-up approaches, a point strongly emphasized by US Ambassador Donald Mahley in February 2008: “Since the 1970s, five consecutive U.S. administrations have concluded it is impossible to achieve an effectively verifiable and militarily meaningful space arms control agreement" (Ambassador Mahley 2008). Yet this assessment may be somewhat myopic since strategists need to consider not only the well-known difficulties with top-down approaches but also the potential opportunity costs of inaction and recognize when they may need to trade some loss of sovereignty and flexibility for stability and restraints on others. Because the United States has not tested a kinetic energy ASAT since September 1985 and has no program to develop a dedicated ASAT system, would it have been better to exchange the option to maintain this capability for pursuit of a global ban on testing kinetic energy ASATs, and would such a norm have produced a restraining effect on development and testing of the Chinese ASAT? This may have been a lost opportunity to pursue TCBMs but is a complex, multi-dimensional, and interdependent issue shaped by a variety of other factors such as inabilities to distinguish between ballistic missile defense and ASAT technologies, reluctance to limit technical options after the end of the Cold War, the emergence of new and less easily deterred threats, and the demise of the Anti-Ballistic Missile (ABM) Treaty.

To circumvent significant challenges with top-down approaches, there have been several attempts to make progress through primarily incremental, pragmatic, technical, and bottom-up steps. Examples of this approach include the December 2007 adoption by the United Nations General Assembly of the Inter-Agency Debris Coordination Committee (IADC) voluntary guidelines for mitigating space debris, work initiated by the European Union toward an International Code of Conduct for outer space activities, the Long-Term Sustainability of Space Activities effort at UN COPUOS, and the United Nations Group of Governmental Experts on TCBMs (Council of the European Union 2008; United Nations General Assembly Resolution 62/217 2008).

Moreover, the Chinese, in particular, apparently disagree with pursuing only bottom-up approaches and, in ways that seem both shrewd and hypocritical, are currently developing significant counterspace capabilities while simultaneously advancing various top-down proposals in support of prevention of an arms race in outer space (PAROS) initiatives and moving ahead with the joint Chinese-Russian draft treaty on Prevention of Placement of Weapons in Outer Space (PPWT) introduced at the Conference on Disarmament in 2008 and updated in 2014. Thus far, the Chinese have seemed quite disinterested in pursuing space TCBMs; they are moving further and faster than any previous spacefaring actor and in 2013 tested a dedicated high-altitude ASAT system able to hold geostationary satellites at risk, a capability never pursued by the superpowers at the height of the Cold War. With respect to the PPWT in particular, while it goes to considerable lengths in attempting to define space, space objects, weapons in space, placement in space, and the use or threat of force, there are still very considerable definitional issues with respect to how specific capabilities would be addressed. An even more significant problem relates to all the terrestrial capabilities that could eliminate, damage, or disrupt normal functioning of objects in outer space such as the Chinese direct ascent ASAT. One must question the utility of a proposed agreement that does not address the significant security implications of current space system support of network-enabled terrestrial warfare, does not deal with dual-use space capabilities, seems to be focused on a class of weapons that does not exist or at least is not deployed in space, is silent about all the terrestrial capabilities that are able to produce weapons effects in space, and would not even ban development and testing of space weapons, only their use (Reaching Critical Will, "Preventing the Placement of Weapons in Outer Space: A Backgrounder on the draft treaty by Russia and China"). Given these glaring weaknesses in the PPWT, it seems plausible that it is designed as much to continue political pressure on the United States and derail US missile defense efforts as it is to promote sustainable space security.

Since Sino-American relations in general and space relations in particular are likely to play a dominant role in shaping spacepower theory and the quest for sustainable security during this century, proposed Sino-American cooperative space ventures or TCBMs are worthy of special consideration. For example, the United States could make more specific and public invitations for the Chinese to become involved with the International Space Station program and join other major cooperative international space efforts. The United States and China could also work toward developing non-offensive defenses of the type advocated by Philip Baines (2003). Kevin Pollpeter explains how China and the United States could cooperate in promoting the safety of human spaceflight and "coordinate space science missions to derive scientific benefits and to share costs. Coordinating space science missions with separately developed, but complementary space assets, removes the chance of sensitive technology transfer and allows the two countries to combine their resources to achieve the same effects as jointly developed missions" (Pollpeter 2008). Michael Pillsbury outlined six other areas where US experts could profitably exchange views with Chinese specialists in a dialogue about space weapons issues: "reducing Chinese misperceptions of U.S. Space Policy, increasing Chinese transparency on space weapons, probing Chinese interest in verifiable agreements, multilateral versus bilateral approaches, economic consequences of use of space weapons, and reconsideration of U.S. high-tech exports to China" (Pillsbury 2007). Finally, Bruce MacDonald's report on *China, Space Weapons, and U.S. Security* for the Council on Foreign Relations offers several noteworthy additional specific recommendations for both the United States and China. For the United States, MacDonald recommends: assessing the impact of different US and Chinese offensive space postures and policies through intensified analysis and "crisis games," in addition to wargames; evaluating the desirability of a "no first use" pledge for offensive counterspace weapons that have irreversible effects; pursuing selected offensive capabilities meeting important criteria – including effectiveness, reversible effects, and survivability – in a deterrence context to be able to negate adversary space capabilities on a temporary and reversible basis, refraining from further direct ascent ASAT tests and demonstrations as long as China does, unless there is a substantial risk to human health and safety from uncontrolled space object reentry; and entering negotiations on a kinetic energy ASAT testing ban. MacDonald's recommendations for China include providing more transparency into its military space programs; refraining from further direct ascent ASAT tests as long as the United States does;

establishing a senior national security coordinating body, equivalent to a Chinese National Security Council; strengthening its leadership's foreign policy understanding by increasing the international affairs training of senior officer candidates and establishing an international security affairs office within the People's Liberation Army; providing a clear and credible policy and doctrinal context for its 2007 ASAT test and counterspace programs more generally and addressing foreign concerns over China's ASAT test; and offering to engage in dialogue with the United States on mutual space concerns and become actively involved in discussions on establishing international space codes of conduct and confidence-building measures (MacDonald 2008).

Spacepower Theory, Harvesting Energy, and Creating Wealth in and from Space

Moving from hard to soft power considerations, spacepower theory can help to guide spacefaring actors in a number of important areas including further developing and refining the OST regime, adapting the most useful parts of analogous regimes such as the Law of the Sea and Seabed Authority mechanisms, and rejecting standards that stifle innovation, inadequately address threats to humanity's survival, or do not provide opportunities for rewards commensurate with risks undertaken. Revising and further developing the OST regime could be a key first step toward seeking better ways to harvest energy and create wealth in and from space. Expanding participation in the OST as discussed above might also be helpful, but other steps such as reducing liability concerns and improving legal incentives for harvesting energy and generating wealth are likely to be even more effective in pursuit of further commercial development of space. Of course, as with security, more comprehensive and robust spacepower theory would be helpful in considering a range of objectives and values that are in tension and require considerable effort to change or keep properly balanced. The OST has been extremely successful thus far with respect to its primary objective of precluding replication of the colonial exploitation that plagued much of Earth's history. The international community should now consider whether the dangers posed by potential cosmic land grabs continue to warrant OST restrictions that stifle development of spacepower, and, if these values are found to have become imbalanced, how these restrictions might best be changed. Space-faring actors should use an expansive approach to consider how perceived OST restrictions and the commercial space sector have evolved and might be further advanced in a variety of ways including reinterpreting the OST regime itself, becoming more intentional about developing spacepower, creating space-based solar power capabilities, and improving export controls.

While the OST has thus far been unambiguous and successful in foreclosing sovereignty claims and the ills of colonization, it has been less clear and effective with respect to pragmatic property rights and commercialization issues. Part of the problem in this regard stems from the fact that OST is not linked to robust and mature spacepower theory; the regime is also embedded within a broader body of international law and that regime is evolving, sometimes in unclear ways and under different interpretations. Elements within the regime are of unclear and unequal weight: the Moon Agreement with its Common Heritage of Mankind (CHM) approach to communal property rights and equally shared rewards has some effect but more limited standing as customary international law due to its lack of signatories, especially among major spacefaring states; moreover, it falls well short of the OST, a treaty that has been signed by 109 states and in force for over 50 years. Most fundamentally, however, the lack of clarity within space law about property rights and commercial interests is the result of the regime still being underdeveloped and immature. There is also a “Catch-22” factor at work since actors are discouraged from undertaking the test cases needed to develop and mature the regime because of the immaturity of the regime and their unwillingness to be guinea pigs in whatever legal processes would be used to resolve property rights and reward structures. The most effective way to move past this significant hurdle would be to create clear mechanisms for establishing property rights and processes by which all actors, especially commercial actors, can receive rewards commensurate with the risks they undertake. In addition, consideration should be given to reevaluating liability standards by assessing factors, including how much of a disincentive toward appropriate risk taking they may create and whether use of graduated or reduced liability standards might be more suitable in advancing positive incentives for more commercial space activity. Although Art. VII of the OST discusses liability, that article was further implemented in the Convention on International Liability for Damage Caused by Space Objects, commonly referred to as the Liability Convention. Under the Liability Convention, Article II, a launching state is absolutely liable to pay compensation for damage caused by its space object on the surface of the Earth or to aircraft in flight. However, under Articles III and IV, in the event of damage being caused elsewhere than on the surface of the Earth by a space object, the launching state is liable only if the damage is due to its fault or the fault of persons for whom it is responsible (i.e., commercial companies), under a negligence standard. The challenge is how best to evolve the existing space law regime with its two-tiered liability system based on either absolute liability or fault/negligence, depending upon the location of the incident, into a structure that might provide more incentives for commercial development of space (Convention on International Liability for Damage Caused by Space Objects (resolution 2777 (XXVI) annex)). In the Commercial Space Launch Act of 2015 and subsequent legislation, the US Congress indicated that US citizens “engaged in commercial recovery of an asteroid resource or a space resource under this chapter shall be entitled to any asteroid resource or space resource obtained, including to possess, own, transport, use, and sell the asteroid resource or space resource obtained in accordance with applicable law, including the international obligations of the United States.” Other states including Luxembourg and the United Arab Emirates have enacted similar legislation, but in all cases the details of how these domestic laws will be implemented and remain compliant with state obligations under the OST remain to be seen. Finally, any comprehensive reevaluation of space property rights and liability concerns should also consider how these factors are addressed in analogous regimes such as the

Seabed Authority in the Law of the Sea Treaty. Unfortunately, however, several of the analogous regimes like the Law of the Sea are largely premised on CHM approaches and may be somewhat better developed than the OST but are also currently underdeveloped and immature with respect to actual commercial operations, limiting the utility of attempting to draw from these precedents.

Provisions of the OST regime are probably the most important factors in shaping commercial space activity, but they are clearly not the only noteworthy legal and policy factors at work influencing developments within this sector. Commercial space activity was not that significant during the Cold War, but that has changed radically. In the 1960s, the United States was first to begin developing space services such as communications, remote sensing, and launch capabilities but did so within the government sector. This approach began to change in the 1980s, first with the November 1984 Presidential Determination to allow some commercial communication services to compete with Intelsat, and continued with subsequent policies designed to foster development of a commercial space sector. By the late 1990s, commercial space activity worldwide was outpacing government activity, and although government space investments remain very important, they are likely to become increasingly overshadowed by commercial activity. Other clear commercial and economic distinctions with the Cold War era have even more significant implications for the future of spacepower: the Soviet Union was only a military superpower, whereas China is a major US trading partner and an economic superpower that recently passed Germany and Japan to become the world's second largest economy and, if current growth projections hold, is on a path to become larger than the US economy by 2030. Because of its economic muscle, China can afford to devote commensurately more resources to its military, including a wide range of increasingly capable space and counterspace capabilities.

The United States and other major spacefaring actors lack, but undoubtedly need, much more open and comprehensive visions for how to develop spacepower theory and advance spacepower. This study is one attempt to foster more dialogue about space security, but the process should continue, become more formalized, and be supported by enduring organizational structures that include the most important stakeholders in the future of spacepower. Spacepower theory should be a foundational part of creating and implementing spacepower and guide approaches "focused on opening space as a medium for the full spectrum of human activity and commercial enterprise, and those actions which government can take to promote and enable it, through surveys, infrastructure development, pre-competitive technology, and encouraging incentive structures (prizes, anchor-customer contracts, and property/exclusivity rights), regulatory regimes (port authorities, spacecraft licensing, public-private partnerships) and supporting services (open interface standards, RDT&E [research, development, test, and evaluation] facilities, rescue, etc.)" (Garretson 2009). In addition, consideration should be given to using other innovative mechanisms and nontraditional routes to space development, including a much wider range of federal government organizations and the growing number of state spaceport authorities and other organizations developing needed infrastructure. Finally, the United States should make comprehensive and careful exploration of the potential of space-based solar power its leading pathfinder in creating a vision for developing spacepower. Working toward harvesting this unlimited power source in economically viable ways will require development of appropriate supporting structures, particularly with respect to incentives, indemnification, and potential public-private partnerships.

Better spacepower theory should also provide guidance on better ways to implement global licensing and export controls for space technology. It is understandable that many states view space technology as a key strategic resource and are very concerned about developing, protecting, and preventing the proliferation of this technology, but the international community, and the United States in particular, needs to find better legal mechanisms to balance and advance objectives in this area. Many current problems with US export controls began after Hughes and Loral worked with insurance companies to analyze Chinese launch failures in January 1995 and February 1996. A congressional review completed in 1998 (Cox Report) determined these analyses violated the International Traffic in Arms Regulations (ITAR) by communicating technical information to the Chinese. The 1999 National Defense Authorization Act transferred export controls for all satellites and related items from the Commerce Department to the Munitions List administered by the State Department. The January 1995 failure was a Long March 2E rocket carrying Hughes-built Apstar 2 spacecraft, and the February 1996 failure was a Long March 3B rocket carrying Space Systems/Loral-built Intelsat 708 spacecraft. Representative Christopher Cox (R-California) led a 6-month-long House Select Committee investigation that produced the "U.S. National Security and Military/Commercial Concerns with the People's Republic of China" Report released on 25 May 1999. In January of 2002, Loral agreed to pay the US government $20 million to settle the charges of the illegal technology transfer, and in March of 2003, Boeing agreed to pay $32 million for the role of Hughes (which Boeing acquired in 2000). Requirements for transferring controls back to State were in Sections 1513 and 1516 of the Fiscal Year 1999 National Defense Authorization Act. Related items were defined as "satellite fuel, ground support equipment, test equipment, payload adapter or interface hardware, replacement parts, and non-embedded solid propellant orbit transfer engines." The stringent Munitions List controls contributed to a severe downturn in US satellite exports. To avoid these restrictions, foreign satellite manufacturers, beginning in 2002 with Alcatel Space (now Thales) and followed by European Aeronautic Defense and Space Company (EADS), Surrey Satellite Company, and others, replaced all US-built components on their satellites to make them "ITAR-free" (de Selding 2005; Barrie and Taverna 2006).

Following the recommendations for rebalancing overall US export control priorities in the congressionally mandated National Academies of Science (NAS) study (National Research Council 2009), the Center for Strategic and International Studies (CSIS) study on the space industrial base (Briefing of the working group on the health of the U.S. space industrial base and the impact of export controls 2008), and the congressionally mandated section 1248 report completed by the Departments of State and Defense that assessed risks associated with removing satellites and related components from the US Munitions List, both the Obama Administration and Congress moved to reform US export controls in significant ways. The administration's proposal was advanced in August 2009 and called for "four singles": a single export control licensing agency for both dual-use and munitions exports, a unified control list, a single enforcement coordination agency, and a single integrated information technology (IT) system supporting the export control process. Following the significant space export control reforms enacted in 2014, the Trump Administration is looking toward additional export control reforms as well as streamlining efforts for other regulatory and licensing procedures under Space Policy Directive-2. These changes will help the United States avoid two major problems with an overly restrictive export control regime: First, an overly broad approach that tries to protect too many things dilutes resources and actually results in less protection for "crown jewels" than does a focused approach; and second, a more open approach is more likely to foster innovation, spur development of sectors of comparative advantage, and improve efficiency and overall economic growth.

Spacepower Theory, Environmental Sustainability, and Survival

The area where insights from spacepower theory undoubtedly could help provide the most significant contributions would be in improving environmental sustainability and humanity's odds for survival. More mature and robust spacepower theory is needed, because advancements in these areas face many daunting challenges, including a high "giggle factor," very long timelines that can be beyond our political and personal awareness, and potential returns that are uncertain and intangible. While difficult, work in these areas is absolutely critical, since it may hold the key to humanity's very survival, and it must be pursued with all the resources, consistency, and seriousness it deserves. The quest to improve the ways spacepower theory can support environmental and survival objectives should focus in three areas: space debris, environmental monitoring, and planetary defense.

Human space activity produces many orbital objects; when these objects no longer serve a useful function, they are classified as space debris. Over time, human activity has generated an increasing amount of debris from a variety of causes; the number of cataloged debris objects has gone from about 8,000 to over 22,000 over the past 20 years. The most serious cause of debris is deliberate hypervelocity impacts between large objects at high orbital altitudes such as the Chinese direct ascent kinetic energy ASAT weapon test of January 2007. If current trends continue, there is growing risk that space, and LEO in particular, will become increasingly unusable. Fortunately, there is also growing awareness and earnestness across the international community in addressing this threat. Overall goals for spacefaring actors with respect to space debris include minimizing its creation while mitigating and remediating its effects – spacepower theory can play an important role in raising awareness and providing guidance in all these areas. Key approaches to minimizing creation of debris and mitigating against its effects are commercial best practices and evolving regimes such as the IADC voluntary guidelines. Space-faring actors need to consider mechanisms to transition these voluntary guidelines into more binding standards and ways to impose specific costs such as sanctions or fines on actors that deliberately or negligently create long-lived debris. Fines could be applied toward efforts to further develop and educate spacefaring actors about the debris mitigation regime as well as to create, implement, and improve remediation techniques. An additional potential source of funding for mitigation and remediation would be establishing auctions for the radiofrequency spectrum controlled by the ITU that would be analogous to the spectrum auctions conducted at the national level by organizations like the Federal Communications Commission. Finally, it must be emphasized that techniques for remediating debris using lasers or other methods are likely to have significant potential as ASAT weapons, and very careful consideration should be given to how and by whom such systems are operated.

Space provides a unique location to monitor and potentially remediate Earth's climate. It is the only location from which simultaneous in situ observations of Earth's climate activity can be conducted and such observations are essential to develop a long-term understanding of potential changes in our biosphere. Because so much is riding on our understanding of the global climate and our potential responses to perceived changes, spacepower theory could play a particularly important role in helping us apply apolitical standards in getting the science right and controlling for known space effects such as solar cycles when making these observations and building climate models. If alarming models about global warming are correct and the global community must implement active measures to remediate these effects, space also provides a unique location to operate remediation options such as orbital solar shades, and space-based solar power has the potential to replace the use of some fossil fuels on Earth.

It is also imperative that the United States and all spacefaring actors use insights from spacepower theory and other sources to be more proactive, think more creatively, and transcend traditional approaches toward emerging threats to our survival. Spacepower theory can help to illuminate paths toward and develop incentives to create a better future. Space, perhaps more than any other medium, is inherently linked to humanity's future and very survival. We need to link these ideas together and better articulate ways spacepower can light a path toward genuinely cooperative approaches for protecting the Earth and space environments from cataclysmic events such as large objects that may collide with Earth or gamma ray bursts that have the potential to extinguish all life on Earth if we are unlucky enough to be in their path. Better knowledge about known threats such as near-Earth objects (NEOs) is being developed, but more urgency is required. The predicted near approach of the asteroid Apophis on 13 April 2029 ought to serve as a critical real-world test for our ability to be proactive in developing effective precision tracking and NEO mitigation capabilities. In the near term, it is most important for national and international organizations to be specifically charged with developing better understanding of NEO threats and developing avoidance techniques that can be effectively applied against likely impacts. Ultimately, however, as any robust and comprehensive spacepower theory would tell us, we cannot know of or effectively plan for all potential threats but should pursue multidimensional approaches to develop capabilities to improve our odds for survival and one day perhaps become a multi-planetary species.

Conclusions

This chapter reviewed noteworthy efforts to develop spacepower theory, considered ways it could help to refine current US space policy, and used it to address some of humanity's most significant space challenges including space security, space commercialization, and environmental sustainability and survival. Spacepower theory can describe, explain, and predict how individuals, groups, and states can best derive utility, balance investments, and reduce risks in their interactions with the cosmos; it should be more fully developed and become a source for critical insights. It could help to guide us toward better ways to generate wealth in space, make tradeoffs between space investments and other important goals, reorder terrestrial security dynamics as space becomes increasingly militarized and potentially weaponized, and seize exploration and survival opportunities that only space can provide.

There will be inevitable missteps, setbacks, and unintended consequences, but the inexorable laws of physics and of human interaction indicate that we will create the best opportunities for success in advancing spacepower by beginning long-term, patient work now rather than a crash program later. Spacepower theory should provide an essential foundation for this progress.

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