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38

The Theoretical Foundations of Spacepower:

From Economics to Asymmetric Warfare

Shawn W. Hackett

AIR UNIVERSITY

SCHOOL OF ADVANCED AIR AND SPACE STUDIES

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Director, Air University Press
Dr. Paul Hoffman

Project Editor
Donna Budjenska

Illustrator
Catherine Smith

Print Specialist
Cheryl Ferrell

Air University Press
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Please send inquiries or comments to

Commandant and Dean
School of Advanced Air and Space Studies
125 Chennault Circle
Maxwell AFB, AL 36112
Tel: (334) 953-3155
DSN: 493-3155
saass.admin@us.af.mil

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About the Author

Maj Shawn Hackett is an officer in the United States Air Force currently awaiting transfer into the United States Space Force. He is a 2008 graduate of the United States Air Force Academy with a master's degree in engineering physics from the Air Force Institute of Technology and a doctorate in optical science and engineering from the University of New Mexico. Major Hackett has served in numerous positions across the DOD with every service branch, including in satellite acquisitions units, in performing basic and applied research, and in a naval construction regiment in Helmand as well as a subject matter expert for the highest priority unit in US Army Special Operations Command and as the senior space intelligence officer on the Operation Resolute Support J2's staff.

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Abstract

The primary purpose of this study is to establish a foundation for a military theory of spacepower. This work proceeds to establish how the universal logical basis of military theory must be coupled with different assumptions for each separate domain of warfare to establish a unique theory of warfare in that domain. Military theory from one domain cannot be simply grafted into other domains. Naval and airpower theory are not also spacepower theory. I instead use past military theory as a starting place for examining what makes domains of warfare unique.

Initially, this study examines historical theories of warfare in the land, naval, and air domains to establish a series of four essential questions whose answers served as the catalyst for the creation of separate naval and air theories of warfare. These four questions revolve around four respective elements of either national or military power: concentration, lines of communications, attack and defense, and political objectives. The answer and examination of these four questions for the specific case of spacepower in detail form the bulk of this work.

To explain the idea of concentration of spacepower, I introduce the terms positive (beneficial) and negative (depriving) spacepower. I develop corresponding continuums of competition and conflict for positive and negative spacepower, respectively. With regard to lines of communications in space, I find that the vastness of space and reliance on photonic (light-based) communications and ground-based resupply impart a series of singular dynamics to the space domain. These dynamics—spectrum superiority, adaptive logistics, solar power—shape the conduct of space warfare in unexpected ways. To avoid unduly complicating space theory, I readapt Clausewitz's land-centric definitions of attack and defense to a nonterrestrial context. Employing these updated definitions, my examination then shows that depriving spacepower through asymmetric warfare is currently the most efficient strategy. I conversely show that gaining beneficial spacepower is typically most efficient via a symmetric approach in which most states build similar space assets. Lastly, I establish the importance of spacepower within a state's overall political and military strategy. I hold that space professionals must both recognize that space provides a critical linkage for warfare in other domains and that space warfare must be planned and conducted differently than conflicts in other domains.

Ultimately, this work concludes that spacepower is best sought by understanding both the deprivation and derivation of national power from space. In the near future, spacepower will become an increasingly critical component of economic and military discourse for both small and great states

alike. This work, therefore, seeks to regularize and apply rigor to the military theory of the space domain by discarding simplistic applications of military theory from other domains and instead examining space as a separate, unique warfighting domain.

1

Fundamentals

Introduction

One ubiquitous lesson learned during the last three decades of modern warfare is that states able to use spacepower in an uncontested manner gain a nearly immeasurable benefit in terms of targeting, tracking, integrating, and communicating. Many of the US's great power adversaries—such as China and Russia—and even allies have taken notice and followed suit by developing native-owned and -operated position, navigation, and timing (PNT) systems, reconnaissance satellites, and communications systems, spurning reliance on American systems.1 In reducing international dependence on US space systems, the risk to the US ability to operate freely in space increases. To put it briefly, "Space [has become] a war-fighting domain."2 Eventually, the benefits of gaining and depriving spacepower will become so great that even smaller states and actors will also desire all forms of space capabilities.

The derivation of spacepower is well-documented by several authors. The process of deprivation of spacepower, however, has been somewhat ignored for myriad reasons ranging from security classification to disinterest. By reconceptualizing space warfare through a series of questions, this work aims to provide a holistic picture of space as a warfighting domain by including all possible actors within a fundamental exploration of the strategic calculus of space warfare. In examining new domains of warfare, some differences matter, and some do not. As with all previously identified warfighting domains, the best way to understand how to optimally conduct space warfare requires discovering the right questions first before characterizing what makes space warfare fundamentally different.

Space is nothing like Earth's physical environment; therefore, it follows that space as a warfighting domain is different than the terrestrial warfighting domains. Fundamentally the rules, intuition, and insights gained over millennia of warfighting on Earth do not apply in space as seamlessly as to other terrestrial domains. Rather, space warfighting professionals must think differently from their terrestrial counterparts. To win the wars of the future, space warfighters must envision how those wars in space will be fought. Envisioning that future starts with asking the right questions.

This work's primary purpose is to produce and answer four foundational questions that help reframe the debate surrounding spacepower's theoretical and actual employment. Ultimately, this work posits these four questions as starting places to think about space warfare. The main goal of asking these questions is not to graft theory onto space warfare by analogy but to discern what elements of previous theories of warfare changed as the venue or accessibility of the domain itself changed. Nonetheless, before examining spacepower, one must establish a definition for spacepower.

What Is Spacepower?

The father of American airpower, Brig Gen William Mitchell, said that airpower is "the ability to do something in the air."3 This definition is accurate but possibly unsatisfying. Doing something in a warfighting domain may or may not be strategically significant within the context of that domain. Adjusting Mitchell's powerful but laconic description, airpower could be doing *strategically beneficial* things in*, from*, *or through* the air. By extension, strategically beneficial actions in space are actions that employ space assets or develop space capabilities to fight wars more effectively in space and terrestrial domains. Thus, this work's definition of spacepower is: "the ability to derive benefit in, from, or through space capabilities and assets, while being able to deprive others of the same benefits."[4]

What Is Space Superiority?

The positive benefits of spacepower are awe-inspiring. Spacepower has the potential to transform the immemorial, heavy fog of war into a transitory light mist. States desiring the ability to gain the positive benefits of spacepower should seek to launch and build spacecraft, develop the required ground infrastructure for their use, and prepare for armed conflict in space. A state with space superiority has unrestricted physical and electromagnetic access to a given area of space, an orbital plane, or the space above important terrain. A military with complete space superiority can operate and communicate throughout space at will, irrespective of contested or enemy territory terrestrially. Thus, this work's definition of space superiority is *unrestricted physical and electromagnetic access to a given area of space or an orbital plane to operate and communicate at will.*

Inspiration for This Work

Most definitions of military power focus on the accrual of benefits rather than their denial. Nevertheless, the Prussian general Carl von Clausewitz repeatedly assured his reader that it is easier to gain a negative objective (e.g., defense of territory) than a positive one (e.g., acquisition of territory). He further adds that a war with only negative objectives is functionally unwinnable.[5] Clausewitz's characterization may be strictly true for warfare in general, but an actor could certainly only seek negative objectives in a particular domain to serve a greater multidomain strategy. For example, one state could deny an enemy's air force access to the air completely even without airpower assets. The denial of airpower is often decisive on land.

Many states cannot field a modern air force with precision-guided munitions, aerial refueling, and fifth-generation fighter aircraft. But an increasing number of states can field systems and capabilities that deny an enemy's use of airpower, including surface-to-air missiles, jamming, and other antiaccess area-denial (A2AD) capabilities. The rationale behind fielding airpower-denial capabilities is to prevent a state reliant on airpower from reaping its benefits. Antiaccess weapons often form the basis of a strategy that seeks to meet an overwhelming airpower with a denial of airspace.[6] Such an approach is fundamentally asymmetric because one actor seeks to deny the enemy its most vital airpower assets without building comparable airpower assets itself.

Many states confronted by the supremacy of American airpower have embraced a negative airpower strategy to combat the US Air Force's seeming near-omnipotence. Initially, many states have been shocked and awed by the potency of American airpower. At some point, Germany, North Korea, Vietnam, Iraq, and Afghanistan all seemed to be on the edge of collapse due to US airpower's effectiveness. Still, after the shock wore off, most states adapted to American airpower superiority by adopting an asymmetric approach.

The US currently possesses a significant superiority in spacepower against its near-peer competitors, such as Russia and China. Nevertheless, as with airpower, states wanting to reduce American spacepower's potency can do so asymmetrically. Because the US military is so dependent on space capabilities, simply nullifying this advantage could hobble the American way of war.[7] Many theorists have, in fact, stated the US is as reliant on space as it is upon air.[8]

Theorists have hypothesized conflict between spacefaring nations, imagining armed satellites, weaponized debris, and conceptualizing space as an armed camp.[9] Space warfare theory to date has primarily focused on symmetrical spacepower, a competition of similar capabilities in a fight to attain dominance. This work does not seek to upend these arguments and largely agrees with those perspectives; however, they neglect the fact that, in the past, most states approached warfare through a series of rational cost-benefit choices. Still, this work uses the excellent theoretical arguments made by past space warfare theorists as a starting point for the conceptualization of space warfare.

As reaping benefits in space is costly, states will generally economize gaining power in space by developing the most cost-effective space system possible.[10] Diverse economic exploitation of space is currently limited to a dozen or so of the most wealthy and powerful states and a handful of nonstate actors, mostly large private companies. Nevertheless, all states should be prepared to compete in space or risk being overwhelmed by a future power with complete space superiority.[11] As with other domains, all nations, regardless of size or power, will seek to gain the ability to deprive an adversary of spacepower at the lowest possible cost. This rational, economic choice occurs mostly independent of a state's ability to use space for benefit, analogous to why states without organic air forces possess integrated air defenses (IAD).[12] In space, where the cost of denial-focused capabilities is meager compared to the cost of beneficial capabilities, the optimal strategy for many states is an investment in destructive or denial technologies to divert any military decision into another domain with lower entry costs (e.g., cyber or land).

The cost of reaping positive spacepower (i.e., benefits) is orders of magnitude greater than the cost of negative spacepower (i.e., denial of benefits). A satellite jammer costs a mere fraction of the cost of launching and operating even a small satellite. This peculiarity sets space intrinsically apart from other warfighting domains because the barriers to entry to gaining benefits are substantially greater than the costs of depriving those benefits.[13] As this work will illustrate, the physical and economic differences between the terrestrial and space domains affect how one crafts or applies past military theory. Clausewitzian and other conceptions of war may provide a logical foundation for space warfare, but those past military theories' precepts cannot be simply inserted into the space domain. Conceptualizing space as a warfighting domain does not require transferring doctrine, principles, or theories from other domains by analogy but rather requires reconceptualizing the domain as distinct on the basis of its inherent characteristics. Understanding space warfare requires asking the right questions.

Plan of the Work

Space is a unique domain of warfare, but the logic of its use, exploitation, or denial should not be unique. To attempt to codify the immutable logical foundation of space warfare within a space-centric context, this work develops four primary questions about space warfare derived from previous domain-focused theories of warfare. First, how do forces concentrate maximum effects for minimum losses in this domain? Second, how do forces communicate and reconstitute in this domain? Third, how does one attack and defend oneself from an attack in this domain? Finally, how can one translate the achievement of military objectives in this domain to the accomplishment of military or political objectives beyond this domain? Chapter 2 covers the derivation of these questions in detail. These questions reframe the discussion about space warfare into a discussion that flows from the intrinsic elements that make space warfare distinct while acknowledging elements unchanged from terrestrial warfare.

The next four chapters focus on answering each of the questions presented in chapter 2. Chapter 3 addresses the concentration of spacepower assets in a vast domain populated by small, fast-moving objects. The central claim of chapter 3 is that, because of the inherently physical nature of the space domain, certain types of weaponry are preferential for specific missions and concentrations of power. Specifically, in space warfare, weapons based on light (lasers, high-power microwaves, and jammers) are typically more tactically versatile than weapons based on kinetic or physical action. This chapter also develops continuums of conflict and competition for spacepower related to the ideas of positive and negative spacepower.

Chapter 4 answers the question of how lines of communication and supply can form in space. Because most of the lines of communication in space are photonic and not strictly physical, this presents a challenge for theories of warfare that assume lines of communication are only physical things. Space warfare must reconceptualize communication lines as both a requirement for a spacecraft's use and as a critical vulnerability in any space system. Conversely, lines of supply or reconstitution in space are almost entirely physical and languid in their response time, again presenting another critical logistical vulnerability to space warfare, which one should address in the practical use of space warfare.

Chapter 5 examines the inherent asymmetric-symmetric nature of space warfare by investigating positive, beneficial, spacepower, and negative, designed to deny benefit, spacepower. As the barriers to entry of positive spacepower are so much higher than negative spacepower, the rules of the "game" of spacepower operate at two different levels from a game-theory perspective. The first game is associated with gaining positive spacepower. Scholars such as John Klein, Everett Dolman, and Brent Ziarnick have explored this first game.[14] The second game is that of negative spacepower and should have many more entrants than the positive spacepower game. The chapter then explains that this inherent dichotomy creates a situation where the strongest spacefaring states will want controls on the use of negative spacepower at odds with many smaller, more disadvantaged actors that will attempt to avoid any limitations or constraints on space warfare. In essence, the inherent, prohibitive expense of gaining spacepower compared to the cost of depriving it creates a landscape rife for smaller states and nonstate actors to exploit space warfare at low cost when faced with a superior space-reliant foe.

Next, chapter 6 discusses spacepower and space warfighting within the entire landscape of national power and warfighting across multiple domains. The primary intent is to articulate how actors should view the achievement of space warfighting objectives or the use of spacepower within a larger context of warfare and the use of national power. US Space Force (USSF) Doctrine denotes national spacepower as "the totality of a nation's ability to exploit the space domain in pursuit of prosperity and security."[15] As this quotation exemplifies, the overall goal of spacepower is not to gain spacepower for its own sake but rather to use spacepower to gain the advantages necessary to support a national grand strategy.

Finally, chapter 7 discusses the preceding chapters' broad implications and summarizes the core arguments of this work. Additionally, this chapter provides several suggestions for further study and for creating a rigorous theory of space warfare based upon the questions developed in this work.

2

A Theoretical Framework for Domain Warfare

Clausewitz famously said that "war is nothing but the continuation of *state politics* by other means."[16] This oft-quoted phrase is not necessarily prophetic, but it does impart the most crucial element of any employable theory of war.[17] Namely, a theory of war must show how achieving war goals—that is, the destruction of enemy equipment, the winning of battles, and the denial of enemy capabilities—translates to furthering political objectives. Many theorists have attempted to show generally how the achievement of objectives in war translates into political gain. Colin Gray deems Clausewitz the foremost among them.[18] The fundamental realignment that transformed Clausewitz's thinking was not simply realizing that war has a political dimension. Instead, Clausewitz reframed his thinking regarding warfare by answering the question, "why do we go to war?"[19] Clausewitz was not trying to reinvent warfare as a separate phenomenon from the rest of human life. He simply tried to ask and answer why wars occur. By asking why we go to war instead of trying to explain war by analogy or categorization, Clausewitz provided a foundational insight into war's nature. Thus, this work seeks to approach domain warfare in general and space warfare specifically using a method like that of Clausewitz. By developing the *right* questions to differentiate a domain in general, answering those questions should illuminate space warfare in specific.

From General Theories of War to the Specific

General theories of warfare provide a broad context for warfare as a phenomenon, much like a general study of human anatomy provides a broad understanding of organs and bodily systems' functions. A study of domain warfare theories, by extension, functions much like a study of comparative anatomy for the medical student. By studying the different elements that previous theorists proposed regulated warfare in previous domains, this work develops a series of questions and answers to assist in clarifying the governing attributes of a new domain of warfare. The land domain is the oldest, most common, and most prototypical form of warfare.[20] Therefore, many of the theories, such as Clausewitz's, are essentially foundational anatomies for land warfare. The differences between land warfare and other domains become apparent by examining the corollaries, or adjustments, other theorists have made in applying older theories to the air and sea.[21]

To condense centuries of military theory into a few words, this work holds that in all domains, the main differences between domains relate to how military forces concentrate, communicate, reconstitute, attack, and defend—employment of forces as a whole—to achieve political objectives. In essence, one could distill the main differences between domains into a series of questions to identify the core elements that make a domain a unique realm of warfare. To this end, Alfred Thayer Mahan and Julian Corbett's works serve as a basis for an examination of the sea domain and the development of questions relating to concentration, communication, and reconstitution. Similarly, Giulio Douhet and Mark Clodfelter's works provide a lens to examine the air domain and develop questions relating to attack, defense, and the achievement of political objectives. In sum, the four questions established in this section provide a synthetic framework for illuminating the space domain warfare theories presented in chapters 3 through 6.

Question 1: Concentration of Military Power

Alfred Thayer Mahan was the first theorist to develop a truly distinct naval warfare theory separate from land warfare.[22] Mahan's *The Influence of Sea Power Upon History 1660–1783* showed that proper development and employment of sea power made states wealthy and powerful throughout history.[23] Mahan, a captain in the US Navy, wanted to illustrate that the US needed a powerful navy nurtured by thoughtful, long-term investments if it wanted to be a world power.[24] In arguing that naval power *is* national power, Mahan provided a window into a more general idea that a lack of power in any one domain can allow another actor to exploit that domain to its own advantage.[25] However, Mahan's fundamental philosophical idea that is important for this work is not that states *should* mass their combat power on a single point but rather *how states* can translate the accumulation of forces into a judicious use of force. Mahan primarily thought that naval power should be concentrated to deliver maximum chance of victory with minimum risk of losses of friendly forces.[26] Mahan's ideas on concentration hint at a more quintessential truth about victory in warfare: simply massing one's combat power to gain victory without regard for further strategic decisions is usually a questionable doctrine. Yet, in all domains, understanding how combat power is focused and used judiciously to gain military objectives is an essential element of understanding how to fight in that domain. Concentrating combat power to enable control over a domain either locally or globally is unique to a domain because each domain is physically different. Ships, soldiers, airplanes, and spacecraft cannot follow the same process for concentrating their combat power for maximum effect. Thus, the concentration of combat power is a fundamental element of what makes a domain distinct. Hence, the principal question this works derives from Mahan's insight is: "How should forces concentrate maximum effects with minimum losses in this domain?"

Question 2: Lines of Communication

Among all the seamen who could develop a theory of sea warfare, Julian Corbett was an unlikely candidate. A British barrister by profession who never served in the Royal Navy, Corbett provided a Clausewitzian counterpoint to Mahan's naval theory.[27] Corbett held that Mahan's theory of concentrating combat power for a decisive engagement was not the sole function of naval forces and that concentration of forces against the lines of communication or supply of a fleet was often more decisive than a major battle. Mahan showed *how* effective the concentration of forces could be; Corbett revealed *why* the concentration of forces was so challenging in practice. The interplay between Corbett's and Mahan's theories is incredibly profound for space warfare because the effective concentration of combat power in space can be devastating to a staggering degree. Still, space is so vast, and objects move so quickly that concentration is often short-lived at best.

After Corbett wrote several naval histories, the British Admiralty asked him to develop generalized theories about naval power employment and achievement.[28] To this end, he attempted to adapt the ideas of Clausewitz to sea warfare.[29] Amazingly, Corbett effectively grafted a land warfare theory onto sea warfare, which is impressive and challenging. The main reason Corbett was largely successful in this enterprise originates from his adoption of Clausewitz's logic (and sometimes lexicon), but he refused to accept Clausewitz's precepts prima facie. Corbett adapted Clausewitz's logic and translated it into naval warfare by refuting or confirming Clausewitz's basic assumptions.[30] Corbett claimed that the overall objective of all naval warfare "must always be directly or indirectly either to secure the command of the sea or to prevent the enemy from securing it."[31] Unlike Mahan, Corbett did not believe that wars or national power could be won simply by naval forces alone. Instead, he considered naval power an element within the menagerie of national military power. "Naval strategy is ... what part the fleet must play in relation to the action of the land forces; for it scarcely needs saying that it is almost impossible that a war can be decided by naval action alone."[32] All domains function within a broader context of national military strategy. A strategy of specific domain warfare must thus always operate within general warfare. To be universally accurate, a theory of domain warfare must recognize itself as logically incomplete, only one part of a more extensive, general theory. Winning a war is inherently a multi-domain (i.e., joint) enterprise.[33]

Though Corbett might have been unable to dream of a future with four physical domains, his overall logic that command of the sea was the currency required to exploit naval power remains unassailable. Corbett held that "command of the sea, therefore, means nothing but the control of maritime communications, whether for commercial or military purposes. The object of naval warfare is the control of communications and not, as in land warfare, the conquest of territory."[34] By "lines of communication," Corbett meant not just lines of literal communication to one's leadership (e.g., telegraph wires or mail ships) but also the lines of supply, lines of lateral communications among forces, and lines of retreat.[35] Corbett's broader definition of lines of communication is elucidative and useful to examine the idea of why military victories require communication. Dissemination of information is an essential part of warfare, but if the information is not provided to the people able to exploit it, then it is functionally irrelevant. In any domain, to understand the evolution of war, one must understand how forces communicate, receive new orders, receive supplies, and preserve combat power after failure (i.e., reconstitute).

Nonetheless, the fundamental idea that communication methods may differ in different domains and that this drives much of the strategy of warfare in that domain is immutable. Therefore, Corbett's work shows that communication and reconstitution are essential requirements for any military forces that are governed uniquely for any domain. The accompanying question this work develops from Corbett's work is, therefore: "How do forces communicate and reconstitute in this domain?"

Question 3: Attack and Defense

The development of the airplane ushered in a new frontier for warfare.[36] Some early theorists claimed that the effects of tiny wooden airplanes were mostly irrelevant in a world of machine guns and battleships.[37] Other theorists, including US general Billy Mitchell, claimed that the ability to fly over the battlefield to attack the enemy directly made land and naval warfare pointless.[38] Italian general Giulio Douhet was primarily in the latter group of airpower's earliest and most fanatical adherents.[39] Unlike previous war theorists, Douhet imagined air warfare without millennia of experience in that domain.[40] After a career as an artillery officer, Douhet believed the airplane could deliver the firepower of an artillery barrage on enemy cities without first defeating the enemy's land army.[41] Further, from this postulate, Douhet held that airpower could induce sufficient fear to make the enemy surrender solely from the enemy populace's terror.[42] Douhet believed airpower alone could be decisive.[43]

The experiences of World War II largely confirmed Douhet's first claim that airpower could bypass enemy fielded forces and function as a form of flying artillery.[44] Nevertheless, civilian populations are more resilient than Douhet postulated. Aerial bombardment alone seems to spur citizens to resist, not capitulate.[45] Although incorrect about the unassailable decisiveness of airpower, Douhet was correct that airpower would become an essential element of future warfare.[46] After the militarization of the airplane in World War I, no state could hope to win a war bereft of airpower or some way to neutralize its effect.[47] The underlying awareness of Douhet that proved prescient was his recognition that attack and defense in the air *were* fundamentally different. One should not attack with air forces for maximum effect in the same way as land or naval forces, nor can one secure one's assets from attack from the air the same as from land or naval forces.[48] Thus, the method of attack and defense in a domain are essential elements of a given domain's makeup. The central question for domain theories in general, which this work distills from Douhet, is: "How does one attack and defend oneself against attack in this domain to gain benefit in this and other domains?"

Question 4: Translating Domain Power into National Strategy

Airpower enthusiasts like Douhet prophesied that airpower would become the lone, decisive arm in war. Still, the actual experiences, particularly in limited wars like in Korea and Vietnam, appeared stubbornly unwilling to conform to these beliefs. Historian Mark Clodfelter documented the fundamental problem with the belief that airpower alone could win wars: airpower has limits imposed upon it that the enemy can exploit from other domains and politics.[49] Clodfelter's revelation that airpower must operate within a more all-encompassing framework of what he denotes as "positive" and "negative" political goals explains why airpower could not simply bomb enemies into capitulation.[50] Clodfelter found that using airpower in Vietnam to win the war was often problematic because sometimes the enemy was difficult to find, sometimes the enemy resisted bombing, or sometimes political leaders did not want to accept the political blowback from collateral damage.[51] As Clodfelter posits, "the effectiveness of air power against any type of enemy depends on how well it supports the positive political goals without risking the achievement of the negative ones."[52] In essence, airpower can never achieve its Douhetian, visionary aspirations because the political nature of war places limits on the expression of airpower outside the air domain.[53] Clodfelter thus provides a convenient lens to examine how specific effects in a domain translate into other domains of war or, more broadly, into politics. He posits that any military victories in one domain must be translatable to military victories in other domains or to strategic political objectives at a higher level of strategy to have any impact on the achievement of the war's political objectives. Therefore, the final question for domain warfare developed from the work of Clodfelter is: "How can an actor translate the achievement of military objectives in this domain to the accomplishment of military or political objectives beyond this domain?"

Summation: The Four Questions Concerning Domain-Specific Theories of War

1. How do forces concentrate maximum effects for minimum losses in this domain?
2. How do forces communicate and reconstitute in this domain?
3. How does one attack and defend oneself from attack in this domain to gain benefit in this and other domains?
4. How can an actor translate the achievement of military objectives in this domain to the accomplishment of military or political objectives beyond this domain?

Chapter Conclusion

Still, the main problem in realizing theories of war is seldom a lack of accurate neologisms or buzzwords. Indeed, often the main failing of employing theories of warfare in a specific domain effectively is a failure to understand what makes that domain unique. By examining past domain theories of war from Mahan, Corbett, Douhet, and Clodfelter, this work develops four general questions that provide the interrogations necessary to illuminate the fundamental differences of a unique domain of war. The summation above outlines the questions derived from the works of Mahan, Corbett, Douhet, and Clodfelter. These four questions are not an exhaustive description of all the possible differences between warfighting domains. Instead, they provide an interrogative framework for investigating the unique nature of a domain. The timeless questions themselves are more fundamental than any transitory answers to them. The specific answers to these questions will change as time progresses, context evolves, and technology develops. Yet, the underlying utility of starting first with the correct questions is immutable.

This chapter employed a deductive logical course starting from previous military theories to distill a few unchanging elements and underlying questions that could serve as a framework to analyze warfare for any domain. The next four chapters proceed to inductively apply that framework to warfare in the space domain. Each will answer one of the questions for spacepower. Some of the precepts espoused in these next four chapters are timeless; others are based upon current weapons technology, which future advancements will invalidate. No one can predict the next revolutionary technology, especially those used in warfare; the nature of technological advancements is such that many will be unforeseen. When recognized, this work seeks to mention how technological developments could reshape space warfare.[54] These innovations, however, would not inherently invalidate the theoretical approach to employing the framework of chapter 2. I attempt to address possible far-future technological or theoretical changes that might alter the nature of space warfare throughout each of the next four chapters.[55] Nevertheless, these four chapters' main goal is to develop a holistic description regarding the derivation and deprivation of spacepower by examining what makes the space domain different now or in the near future.

3

Concentrating Spacepower

Obtaining a successful result in any battle, war, conflict, engagement, argument, or disagreement rests on sufficiently concentrating one's capabilities to overcome opposition. In war, as Clausewitz reminded us, these capabilities descend from some type of brute force—that is, combat power.[56] The main defining characteristics that differentiate the concentration of combat power in space, or really any domain, are its physical properties. For the land domain, the most rudimentary objective is to occupy key territory to either shape enemy actions or reap the benefits of occupation. Concentrating combat power on land is often best accomplished by bringing as many combatants as possible to decisive battles. The idea of massing physical combat power in space by moving many spacecraft in close proximity is not only difficult to comprehend but, given the inherent danger of proximity operations, often unwise and risky.

In this chapter, I make three main arguments to answer the question of how combat power is concentrated in the space domain. First, concentrating combat power in space locally in a physical sense is difficult owing to the sheer vastness of space as a domain. Second, space weaponry comes in two overarching types: kinetic and electromagnetic (also called nonkinetic). I argue that electromagnetic weaponry will be preferable for most engagements for the foreseeable future. The superiority of electromagnetic weaponry stems primarily from the increased speed of engagements, greater control of destructive effects, and ease of replenishment. Third, the vastness of space and the difficulty of creating space-based weapons suggest a dichotomic relationship, separating spacepower into positive and negative variants, best explaining spacepower's practical use. These three factors contribute directly to how one can effectively concentrate assets and capabilities for optimal employment of spacepower.

The Physics of Space as a Domain

Space is vast, immense beyond comprehension. Today, most human-made spacecraft exist within a small orbital envelope between Earth and its moon.

Several authors and doctrinal documents have described the four most common Earth orbital regimes detailed below as crowded or congested.[57] This is hardly so in a physical sense. Geosynchronous orbits (GEO) allow satellites to maintain a common position over a specific area on Earth. To illustrate the enormousness of the GEO orbital regime, the total surface area of all GEO is approximately 44 times that of the surface area of the earth. Highly elliptical orbits (HEO) allow spacecraft to dwell over some regions of the earth, such as the northern hemisphere, while speeding past the other hemisphere.[58] Due to their nature and mission variability, HEOs often have different orientations and orbital characteristics, making them unlikely to overlap with one another accidentally and difficult to typify monolithically. [59] Low Earth orbits (LEO), seemingly close to the earth, include all satellites that never rise above orbital altitudes of 2,000 km.[60] The total volume circumscribed by all of LEO is roughly the same as that of the entire volume of Earth. As a note, the total volume of Earth that is human-occupied (i.e., all other physical warfighting domains) accounts for less than five percent of its total volume.[61] Said another way, LEO orbits, which have the smallest total volume of any orbital plane, are more than 20 times as vast as all other warfighting domains combined. Nevertheless, LEO still is considered by space experts to be "congested" and full of fast-moving debris.[62] The final commonly denoted orbital plane, medium Earth orbits, ranging from 2,000 km to GEO, is so large that more than 280 Earths would fit inside its confines.[63] Figure 1 provides a diagram of these four orbital planes to scale. The critical idea from figure 1 is not a taxonomy of orbits. Rather, it is that space is so vast that concentrating combat power is difficult and often time resource intensive.[64] Despite more than 6,000 artificial satellites currently residing in these orbital regimes, they account for less than one-trillionth of the total volume between Earth and the moon. Additionally, the total mass of all spacecraft in orbit of the earth is approximately equal to the mass of a single US Navy destroyer.[65] The sheer physical scale of operating in space demands that the complexity of maneuver, time, and rendezvous is likely to be a common feature of space warfare for the foreseeable future until technology allows physical objects to travel at near the speed of light.[66]

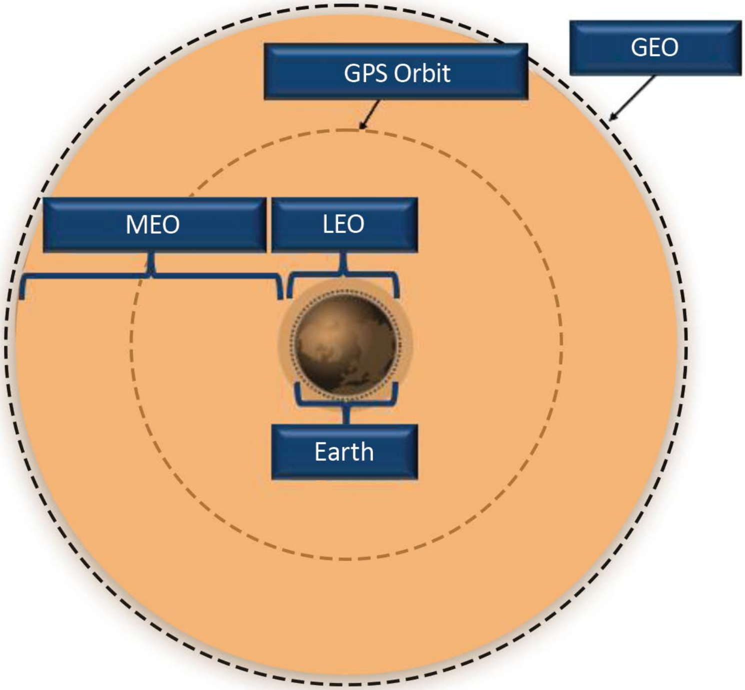

Figure 1. Two-dimensional representation of orbital regimes of Earth (to scale) (adapted from Creative Commons Image by the author)

GEO: geosynchronous orbit
LEO: low Earth orbit
MEO: medium Earth orbit

Types of Space Weaponry

Space weaponry, just like Earth-based weaponry, comes in two basic types: kinetic and electromagnetic radiation (EMR). Space weaponry can be either ground-based (*terrestrial)* or space-based (*celestial*). The two most fundamental differences between celestial and terrestrial based weaponry are (1) the energy and time required to concentrate celestially based weapons' combat power is generally less and (2) the flexibility and combat power of terrestrially based weapons are greater because of their reconfigurability and greater conceivable mass owing to not being already in orbit. In joint publications, space weaponry is referred to as methods for "Offensive Space Control" (OSC).[67]

Kinetic Weaponry

Kinetic weapons are essentially weapons that use kinetic energy (physical force) to destroy, damage, disable, disrupt, or degrade a target.[68] One convenient way to look at kinetic weaponry is that it encompasses three subtypes. First, *kinetic kill vehicles* are those that use the kinetic energy of orbital mechanics to accomplish their mission. Second, *chemical sprayers* are spacecraft that get close enough to a target and eject some chemical or other debris to accomplish an attack. Third, some satellites maneuver close enough to a target to use *robotic mechanisms* to physically attack a target by maiming, removing, or destroying part or all of the target.[69] Three unique subclasses of kinetic kill vehicles are worth mentioning: *direct ascent weapons,* which travel from the ground to intercept the target; *rendezvous in proximity operations* (RPO) vehicles, which maneuver to a target after being launched through orbital maneuvers either immediately after launch or after lying in wait for some time; and *weaponized space debris*, which uses the kinetic energy of intentional space debris or a fragmentary satellite to constitute the kinetic kill "vehicle."

All kinetic weapons must rendezvous in close proximity with their target, which, owing to the vastness of space, makes kinetic weapons' speed of target destruction inversely proportional to the proximity of the object from the weapon's initial placement. Said another way, if the space between objects is relatively large, then kinetic weapons are relatively slow to engage. Even at the highest possible speeds currently, kinetic weapons take hours to reach all of LEO when launched from Earth.[70] The main drawbacks of kinetic weaponry all stem from one core issue: a kinetic weapon, no matter the type of weapon system, must expend sufficient energy to move from its initial position to its desired target's position. In a vast space environment, the movement between different orbital regimes requires large amounts of energy because of the effects of gravity and often long periods of time. The general consequence of this is that, compared to other domains, kinetic weaponry is much more costly per use and much slower to engagements. A large time differential allows a target to potentially deploy countermeasures or maneuvers, lowering the probability of a successful engagement. If that weapon resides initially on Earth, then the time to engagement is driven mainly by the target's proximity to Earth and orbital mechanics.[71] Therefore, kinetic combat power, while often potent in space, is more difficult to concentrate than in other domains.

Because spacecraft in different orbits move so rapidly relative to one another, even seemingly minor collisions can have the physical force of large conventional munitions.[72] Thus, a space object's relative kinetic energy alone can be a weapon. Space beyond Earth's orbit is even more vast. Given it takes hours or even days to concentrate physical combat power at GEO, any concentration of physical combat power in space beyond the direct vicinity of Earth, like in the vicinity of the moon, would need to be planned and executed days or weeks in advance.[73] Currently, that timeline is several weeks or even months, but the timeline is a direct function of the efficiency and acceleration of space propulsion technologies, which will decrease the time required to move in the future.[74] Further, any adversary with robust space situational awareness (SSA) capabilities will likely notice these movements and respond accordingly, either in space or terrestrially.[75] Thus, kinetic space weapons often provide the target with hours, days, or even weeks to react by dodging, jamming, or deploying countermeasures. Moving out of a consistent orbit and position in space to concentrate is not an optimal weapon-targeting cycle. Thus, it seems that without a dramatic alteration in propulsion technologies, kinetic weapons favor the target, especially as countermeasures and passive defenses become more robust.

Using a kinetic process to damage enemy space capabilities has other negative consequences (i.e., externalities) besides timeliness. As kinetic space weaponry involves using explosives or, more commonly, relative velocity to damage the target's space capabilities, kinetic engagements are destructive and irreversible with possible consequences for space debris. Further, attribution is relatively simplistic for states with SSA capabilities because of the ubiquity of optical or radar tracking of most large space objects by such states.[76] As the destructive potential is tremendous and the attribution is relatively simple, the use of kinetic space weaponry will rarely be unattributable or nonescalatory. A kinetic attack is likely to result in either a dramatic military or economic response and potentially an official declaration of war and international condemnation. The unintentional collision between a commercial communication satellite, Iridium, and a defunct Soviet Cosmos satellite is an example of the devastating, irreversible effects of kinetic force between space objects and the creation of considerable space debris.[77] If such a collision were purposeful, the resulting response from the target owner would probably be forceful. The military nature of an impact to the satellite owner would be much greater for a purposeful collision or with weaponized debris. Indeed, a malicious actor could use an intentional collision or series of collisions with a commercial satellite to hide a more malign intent to weaponize space debris in certain orbits, even triggering a supposedly accidental cascade of collisions fouling an entire orbit, known as the Kessler syndrome.[78]

Nevertheless, if the goal is to assuredly destroy an enemy spacecraft and any negative externalities associated with a kinetic weapon use are acceptable, direct kinetic kill offers the best approach to using physical energy to neutralize a target spacecraft because it provides more likely assured destruction and speed of engagement than other possible kinetic methods. Kinetic weapons systems that employ spacecraft for RPOs, such as chemical sprayers and robotic mechanisms, to colocate themselves with their target spacecraft and then physically damage it are an occasional novelty due to their slow speed of engagement and ease of attribution. These weapons are useful tools for surprise or preemptive strikes in limited contexts, but they will rarely form the backbone of military spacepower for a large state. RPO-centric kinetic attacks are not an efficient way to achieve the goal of neutralizing an enemy spacecraft in terms of energy expenditure, assured destruction, or reusability. Hence, kinetic RPO weapons feature all the issues with kinetic kill weaponry and risk detection by the target spacecraft before initiating an attack. While RPO-based kinetic attacks will remain a threat for the near-term future, as EMR weapons develop, RPO kinetic weapons will most likely become a weapon relegated to use for surprise or intelligence purposes rather than efficient destruction or degradation of targets.

Kinetic space weaponry does provide one case of obvious superiority over any other form of weaponry: assured destruction. Similarly, nuclear weapons provide large-scale assured threat of destruction and have become a necessary but rarely used deterrent.[79] In many ways, the use of kinetic weaponry in space is similar to that of nuclear weapons. Both spoil part of the environment by creating harmful debris while providing readily apparent attribution. Most actors may even reserve kinetic space weaponry for exigent circumstances akin to tactical nuclear weapon use or employment of large amounts of conventional terrestrial weaponry, for example, massed tank formations. The main difference between nuclear weapons and kinetic space weapons is that it will likely become increasingly more difficult to deny states access to space launch than nuclear weapons, and usually, space launch vehicles can be dual use as kinetic weapons. For example, 14 states and multiple companies have already launched spacecraft, while only eight or nine countries have nuclear weapons or nuclear weapons programs.[80]

Electromagnetic Radiation Weapons

The second basic, overarching type of space weaponry is EMR weaponry. While kinetic weapons seek to destroy or degrade a target, electromagnetic weapons use photonic energy to deceive, disrupt, deny, degrade, or destroy a target providing the user a range of options.[81] Joint Publication 3-14, *Space Operations,* provides definitions from US joint doctrine. The definitions are *deceive*: measures designed to mislead an adversary by manipulation, distortion, or falsification of evidence or information into a system, to induce the adversary to react in a manner prejudicial to its interests; *disrupt*: measures designed to temporarily impair an adversary's use of or access to a system for a period, usually without physical damage to the affected system; *deny*: measures designed to temporarily eliminate an adversary's use, access, or operation of a system for a period, usually without physical damage to the affected system; *degrade*: measures designed to permanently impair (either partially or totally) the adversary's use of a system, usually with some physical damage to the affected system; and *destroy*: measures designed to permanently eliminate the adversary's use of a system, usually with physical damage to the affected system.[82] These definitions represent a basic framework for a continuum of conflict for space operations, ranging from deception to destruction, which will be discussed further below. EMR weaponry functions by using photonic energy to neutralize the target spacecraft or ground station. EMR weaponry also has three main types. First, lasers use focused beams or pulses of light to accomplish an engagement. Second, high-power microwaves (HPM) concentrate bursts of microwave energy to damage or degrade the target's electronics. Third, radiofrequency electronic warfare (EW) employs or collects radio waves to jam, deceive, degrade, or damage a target's ability to receive external signals or conduct espionage.[83] EW is, probably for the foreseeable future, the most frequent and versatile form of space warfare because of its flexibility and the commonality of electronic hardware among spacecraft. Relatedly, space EW using cyberspace-based weapons or tools is still space warfare, albeit with a cyber component. All three of these weapon types essentially share the common characteristic of using photons, which move at the speed of light, to accomplish the engagement. Figure 2 provides a limited but elucidative illustrated taxonomy of both kinetic and EMR space weaponry as discussed in this chapter.[84]

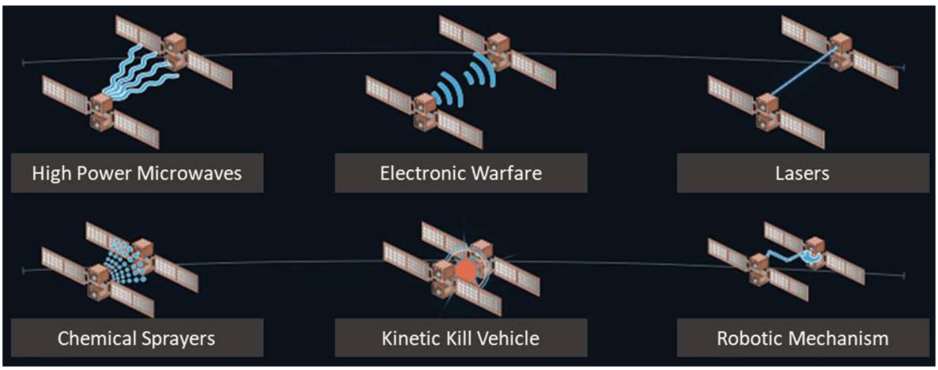

Figure 2. Common space- or ground-based weapons targeting spacecraft (adapted from Defense Intelligence Agency, "Challenges to Security in Space," 10)

Electromagnetic combat power has many benefits over kinetic weaponry in space specifically. The electromagnetic spectrum includes light waves of all possible frequencies ranging from radio waves to visible light to gamma rays.[85] Thus, EMR travels through space at the speed of light, which is approximately five thousand times faster than the fastest object ever made by humans—the Parker space probe—which only maintained that still very subluminal speed for one brief period during its orbit around the sun.[86] Concentrating EMR combat power from an operation planning or speed of engagement perspective is trivial compared to kinetic weaponry. The speed of light is invariant with respect to frequency.[87] Therefore instead of hours, days, and weeks, the photons from EMR weapons, regardless of type, take seconds to reach a target within Earth's orbit and only six hours to reach a target at the edge of the solar system. Still, EMR weapons, unlike kinetic weapons, can easily disperse and must be properly focused to exert combat power.[88] The act of focusing EMR combat power at distant ranges, beyond a few kilometers, is often the main difficulty faced by most EMR weapon systems on Earth because of atmospheric dispersion and other atmospheric effects. In a vacuum with relatively weak electromagnetic fields, however, dispersion is limited, and the ability to focus on a distant source depends primarily on the optics, antennae, or focusing apparatuses of a particular system.[89] Put simply, in space, it is much easier to focus photonic energy than in the atmosphere.

Further, an actor could use the same EMR weapon to jam, dazzle, degrade, blind, and destroy a myriad of spacecraft hardware.[90] Essentially, EMR allows the employing actor to target and attack enemy assets in a more judicious and efficient manner than kinetic ones. Unlike kinetic attacks, EMR attacks with the same asset can range from destruction to a space-based warning shot across the bow. Such an attack also only requires energy to power the EMR device, and it does not impinge upon a limited magazine of costly RPO spacecraft or missiles. Lastly, attribution of EMR weaponry is more difficult than traditional kinetic weaponry because assured attribution requires actual physical sampling of the beam of light and then triangulation of its origin. Otherwise, attribution rests on uncertain contextual information, that is, circumstantial evidence, from the engagement. To dodge or employ active countermeasures against an EMR attack, one would need to have foreknowledge of the attack to be able even to react quickly enough. The photons of an EMR attack travel at the same speed as the light absorbed by any sensor detecting an attack or relaying information about an attack's occurrence to the ground. As a result, unlike a kinetic attack from a spacecraft employing an RPO, a spacecraft housing an EMR weapon using RPO to reduce the attribution or increase the potency of an EMR weapon payload is much less novel and a significantly more dangerous threat to target spacecraft.

Another key benefit of an EMR-based weapon is that EMR weaponry is not a limited-use asset. Most types of EMR weaponry can be solely electrically driven, if designed correctly, simplifying weapon replenishment after an engagement. The process that refills the magazine of an EMR weapon can be the same as the process that produces electricity in general. A correctly designed laser, jammer, or other EMR weapon could be recharged by a ground station's power plant or a spacecraft's onboard electrical generation system endlessly. In essence, such weapons would have a nearly limitless magazine whose recharge rate would depend only upon the efficiency of electrical power generation.[91]

In summary, the main benefits of kinetic weaponry are that they provide a higher propensity for assured destruction and simplify battle damage assessments (BDA). As EMR weapons become more powerful and prolific, kinetic weaponry will become less attractive except in scenarios requiring absolute destruction or hyperaccurate BDA. EMR weapon employment in space requires less planning and rendezvous time, is more selective, and is less attributable. Thus, EMR weapons will become increasingly preferred by powerful states, smaller states, and possibly even nonstate actors. For all but the most high--intensity warfare cases, EMR weaponry of all kinds are the superior form of weaponry in space for the foreseeable future until thrust technology can accelerate a weapon to near the speed of light, spacecraft propulsion technology has markedly improved, or EMR countermeasures become so effective as to make EMR weapons themselves useless. As the world becomes more and more dependent on spacecraft, the state that develops terrestrial- and space-based EMR weaponry most effectively will become the most potent military in space because of its inherent ability to concentrate combat power efficiently.

Positive Spacepower

Viewing the accumulation and use of spacepower as dichotomous, or coming in two forms, can also help further illuminate the unique nature of the domain. On the one hand, states can possess the ability to deny space without actually possessing assets physically in space. On the other hand, states could, in theory, possess a host of space-based assets to deliver space capabilities in other domains but lack any ability to deprive space access to other actors. Essentially, the processes to use spacepower and deprive spacepower come from different sets of motivations, assumptions, and sometimes even different hardware. I denote these two possible expressions of spacepower as positive and negative spacepower. Positive spacepower is the ability to reap military benefits from space assets in space or another domain. Negative spacepower is the ability to deprive positive spacepower from others. A similar dichotomy could exist for any domain. For example, a soldier who occupies territory provides positive land power by his presence but negative land power when he kills opposing soldiers to gain or maintain the territory's occupation. Similarly, positive and negative spacepower simply function as expressions of positive and negative benefits derived from the use of space assets.

In space, this dichotomy is often necessary to understand the domain because many smaller states and actors may seek to possess only one variant of spacepower owing to cost and strategic concerns. The desire to seek only benefit or deprivation of benefit is something that is rarely true in other domains. Space-centric definitions of spacepower obviate the possibility of actors without space programs but with robust ground-based kinetic and EMR weaponry being considered space powers.[92] Neglecting the possibility of ground-based spacepower is hazardous because it creates possible paths for enemies to exploit a wholly space-centric military force, as discussed later in this section.[93]

I denote *positive spacepower* as the accumulation of benefits from physical spacecraft traversing above Earth's atmosphere. Positive spacepower is the reason that spacecraft exist in the first place, starting with Sputnik, Mercury, and Apollo.[94] Positive spacepower has been well discussed by a litany of excellent authors.[95] It can be a national asset beyond almost any comparison. The derivation of positive spacepower has given rise to the pithy observation that space is the so-called ultimate high-ground.[96] Positive spacepower provides PNT; intelligence, surveillance, and reconnaissance (ISR); missile-warning; communications; research; and numerous other benefits.[97] Indeed, as Deganit Paikowsky has shown, any state wishing to be a great power in the modern age must seek spacepower or that state will remain unrecognized as a great power by other states.[98]

Launching assets into orbit and then using those assets for a specific mission or set of missions has become commonplace for the US, the European Union, Russia, Japan, and China.[99] Nevertheless, positive spacepower is sometimes misunderstood in terms of intent. The intents of positive spacepower are to gain a national advantage and to benefit from the presence of space assets. In essence, the agglomeration and accumulation of positive spacepower function similar to market entry and resource control in other domains with the closest, though imperfect, analogy being the maritime domain. Indeed, much of the benefit of positive spacepower relates to the economic gains and military efficiencies it creates in other domains.[100] Thus, it is helpful to think of a spacepower continuum of cooperation similar to the continuum of conflict outlined earlier in this chapter (deceive, disrupt, deny, degrade, destroy) as market-like behaviors ranging from open participation (i.e., complete cooperation with unrestricted entry for any actor into the domain) to monopolization (complete competition with one actor controlling all space access). Though founded on market-like actions related to the gain of benefits from spacepower, the continuum of competition is a framework for capitalizing on military power, not solely an economic framework. The actions taken to secure one's own positive spacepower may require negative spacepower effects on the adversary. Any action undertaken to secure a benefit, even monopolization, is still classified as a positive spacepower in terms of intent, though it may require the use of negative spacepower to achieve that positive spacepower aim. Table 1 provides definitions of different terms along a continuum of competition, illustrating that powers seeking positive spacepower will choose behaviors ranging from cooperation to competition.

Table 1. Terms defining a continuum of competition in positive spacepower

Term	Definition
Open participation	Cooperative relationship characterized by a lack of competition and coercion between two or more parties
Lease	Mostly cooperative approach characterized by attempts to sell to or profit from other entrant parties and create dependent relationships in a mostly free market
Exclusive sharing	Semi-cooperative approach characterized by attempts to sell to or profit from other entrant parties and create dependent relationships that exclude specific other parties by design
Cartel	Semi-competitive approach where one or more supra-national groups attempt to control the market or a particular resource to force other actors to join the groups to increase the groups' market share
Oligopolize	Competitive approach where a small number (typically between two and eight) of actors attempt to obtain near complete control of a market or a particular resource by forcing other entrants out of the market
Monopolize	Competitive approach where a single actor attempts to obtain complete control of a market or a particular resource by forcing other entrants out of the market

From table 1, a special note about renting or leasing time on a space asset, something quite frequent, is also a form of cooperative, positive spacepower. The leasing of equipment from any actor for one's use is a commercial or political relationship like other limited alliances or military partnerships, like foreign military sales, excepting that the military proportionality and legality of targeting a leased-space asset have not yet been established internationally. In sum, cooperative and competitive behaviors in space function similarly to those terrestrially but with unique characteristics.

To further explain the continuum of competition of positive spacepower, it is necessary to first establish that the continuum's definitions are not completely predictive, based upon the actor's selection of competitive or cooperative behavior, because the strategic effect of that action could be considered as influential or meaningless with regard to competition at a political level. For example, complete control—that is, monopoly—of the market for the delivery of ISR data related to the tracking of migratory birds is unlikely to trigger conflict. Conversely, monopolization of data delivery related to stock market purchases in real-time would be a positive spacepower benefit that could trigger stiff competition or even conflict.

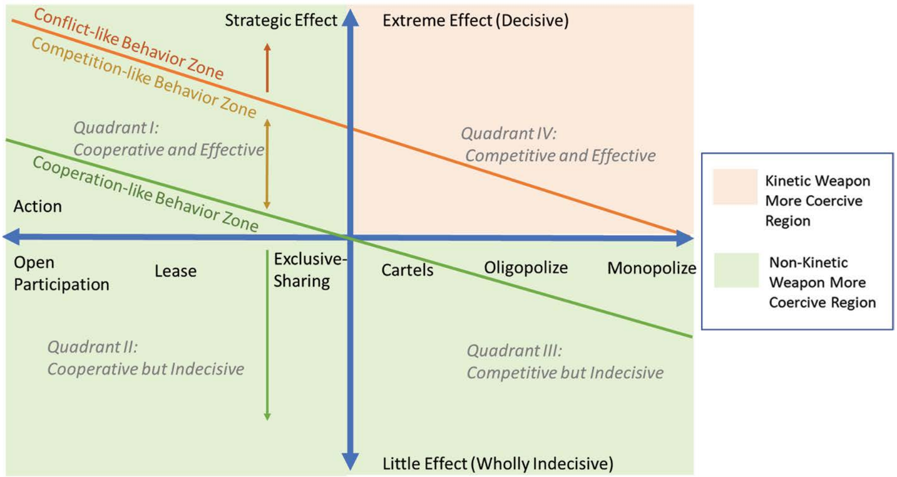

Figure 3. Framework for the continuum of competition of positive spacepower

To understand positive spacepower in a framework of a continuum of competition, the effect of an action relates to the nature of the cooperative or competitive action to predict the target's perception of the behavior. If actors conduct cooperative or competitive actions from table 1, this is the independent variable. The strategic effect of that action is determined by the target state's viewpoint regarding competition, cooperation, or even conflict. Thus, the strategic effect would be the dependent variable. The primary purpose of weapons vis-à-vis positive spacepower is not to engage in hostilities, though this may occur, but to coerce adversaries into accepting suboptimal access and market conditions. The intent of weaponry for the accumulation of positive spacepower is thus similar to a powerful fleet-in-being or air force with regard to maritime or air trade. In general, actors seem less predisposed to employ kinetic weapons for the reasons discussed below. Therefore, kinetic weapons will be more coercive than nonkinetic weapons only in the most competitive situations. Figure 3 depicts this graphically to provide a more easily interpretable continuum of competition for positive spacepower.

Contrary to claims that economically competitive behavior in space will frequently result in conflict, as figure 3 illustrates, only actions that have major strategic effects and attempt to control the market or a subset of the positive spacepower market are likely to result in overt conflict. This aligns with the argument made by Wendy Whitman Cobb that holds that "if economic ties and commercial involvement can stem the spread of conflict on earth ... it can do so in space."[101] Cooperation breeds cooperation, and only highly competitive actions yield overt conflict. A highly destructive kinetic war in space is only in the interest of powers who do not intend to use positive spacepower. Instead, most competitive actions in space, even quite provocative ones, will likely be met with similarly competitive actions or requests for remediation by other actors. Congruent with the history of economic competition in other domains, when a power seized or intercepted foreign merchants and sailors to dominate a market, the result was typically not full-scale warfare but limited warfare or trade wars.[102] In the present day, corporate espionage—even on a state scale as the US frequently alleges China conducts—has never itself triggered a war.[103] The acquisition of positive spacepower is unlikely to yield different results than the acquisition of wealth in other domains, including cyber. Thus, even monopolistic positive spacepower behaviors are unlikely to trigger conflict on their own unless those actions have a great strategic effect in or beyond the space domain.

Seemingly, positive spacepower is only for noncombat purposes; this is illusory. Positive spacepower is not solely an auxiliary function of warfighting for noncombat purposes. Modern militaries worldwide rely on the PNT, ISR, and communications provided by positive spacepower. Additionally, the conduct of war from space relies on the construction of positive spacepower capabilities to house, assist, and reconstitute any space-borne negative spacepower capability. For example, an EW payload on a satellite is a negative spacepower asset when in use. That EW capability might also be on a dual-use positive spacepower asset for communications and remains a positive spacepower asset in-being when not in use, functioning as a deterrent. In essence, conducting effective warfighting and commercial exploitation to, in, or from space depends on the acquisition of both positive and negative spacepower capabilities.[104] Still, negative spacepower capabilities, unlike the majority of positive spacepower capabilities, can reside either on the earth or in space. Negative spacepower can uniquely be either terrestrial or celestial. Space-borne negative spacepower capabilities require an actor to also possess positive spacepower, a space asset for the negative capability to reside on. Terrestrially this is not so. A negative spacepower asset that resides solely on the ground does not necessarily provide positive spacepower.

The dichotomy of positive and negative spacepower may appear bellicose. Negative spacepower exists to make conflicts in space possible. My personal preference would be that space be a sanctuary for all states bereft of all conflict. Nevertheless, no area of human exploration, from the Americas to the air to the Arctic, has ever been free of competition and conflict.[105] Indeed, Chinese military doctrine recognizes that "space systems have become in the information age a basic support element of modern society, (and) the influence of space activity on the military is even more pronounced."[106] Thus, regardless of morality, a war in space will eventually occur because some actors benefit from space and other actors become disadvantaged as a result.[107] Said another way, because positive spacepower exists, there must be negative spacepower. If space is the ultimate high ground, then people will fight to capture those heights.

The annual global space economy is over $400 billion. [108] The derivation of positive spacepower is an extremely profitable human endeavor.[109] As Cicero held, an enemy's economy is always a factor in any conflict.[110] Because of the robust benefits of positive spacepower capabilities, the majority of the world's most potent militaries rely on positive spacepower assets and capabilities.[111] My argument is not that space *should* be a warfighting domain. Rather, space is a warfighting domain simply because humans exploit it so vigorously. If humans exploited a domain, location, object, or indeed any construct with the same vigor as they do with space, it would also naturally become an element of warfare. Thus, if any actor seeks positive spacepower, other actors will seek negative spacepower to deny the first actor complete control of the domain, and space will remain a "warfighting domain."[112]

Negative Spacepower

Negative spacepower is the deprivation of benefit from another through space. The field of negative spacepower remains unexplored, even after seven decades of military use of space.[113] Until very recently, the possibility of broad systematic warfare on space assets using both kinetic and EMR weapons was discussed openly only in niche military circles. As positive spacepower provides an intense, asymmetrical advantage in other physical domains—air, land, and sea—depriving spacepower from a state reliant upon spacepower is advantageous. Therefore, developing and preparing countermeasures for enemy use of negative spacepower should be a priority for spacefaring states. Nonspacefaring states should also begin to acquire negative spacepower capabilities because of their potency and relatively low cost compared to positive spacepower, an idea covered more fully later in this text.

Negative spacepower is a natural consequence of the unique space domain and of the complexities of concentrating combat power in space. As space assets and weapons proliferate to more actors, space warfare is becoming increasingly likely.[114] Thus, acquiring and combating the use of negative spacepower must be continuously on the mind of all US space professionals and discussed as openly as the development of positive spacepower. Open discussions of negative or "full spectrum" space wars did not occur in the US previously because of a lack of urgency and interest on the part of senior military leaders and policymakers. Happily, this issue is beginning to be resolved with the standup of the USSF in 2019.[115] The USSF has begun these discussions and done an excellent job regularizing the discussion of both countermeasures against and employment of negative spacepower.[116]

The US is undoubtedly the greatest positive spacepower in the world today. Thus, a competitor's most straightforward way to invalidate American space advantages—military, civilian, and commercial—is not to achieve equivalent positive spacepower but rather to gain sufficient negative spacepower capabilities to nullify them. The best way to invalidate an enemy's strength is not to build an equally strong force but to build an asymmetric advantage, in this case, with negative spacepower capabilities. Hoping that potential adversaries do not realize the potency of negative spacepower or space weaponry due to extreme classification and a lack of discussion by the US is a poor strategy. Instead, the USSF, US government organizations, and American companies must engage and prepare now for enemies of all sizes to build and employ space weaponry attempting to nullify the US advantage in space.

Negative spacepower should thus be the preoccupation of military forces with regard to the control of space, though not to the exclusion of maintaining positive spacepower for use in space or other domains. As a result, the primary actions that actors in space may take to exhibit negative spacepower fall along a continuum, just as was true for positive spacepower. The continuum of those actions is already well described by US joint doctrine.[117] The independent variable for positive spacepower in table 1 was strategic effect. Strategic effect is still valid for negative spacepower as the main relation between perception, action, and reaction is how effective the action was at creating a lasting strategic advantage, that is, decisiveness. Hence, figure 4 shows a negative spacepower framework utilizing the definitions outlined earlier. The implication from figure 4 is that most of the negative spacepower actions states are likely to take will occur below the threshold of war. Indeed, many states, recognizing that many deception and disruption operations are unlikely to trigger conflict, are incentivized to conduct these activities to gain military or economic advantages. A previous section showed that in many contexts, certain weapons are more versatile than others or are dual use for competition and conflict.

For example, as already noted, when either assured destruction or even pollution of an orbital regime is the goal, kinetic weapons are the most effective choice, particularly direct ascent weapons or weaponized debris. Conversely, kinetic weapons are much less adept at deception and reversible disruption, actions where nonkinetic weapons excel in comparison.

Figures 3 and 4 also include inlays denoting which quadrants in each framework are more likely to see increased benefits from the use of certain types of weapons for either conflict or competition. For most actors, the greatest benefit lies not in the possession of kinetic weaponry but of nonkinetic weaponry because these offer versatility with a lower likelihood of triggering overt war. Nevertheless, as discussed further below, current USSF and US military-strategic thinking seems hyperfocused on high-intensity space conflict with kinetic weaponry both in terms of investment and literature.

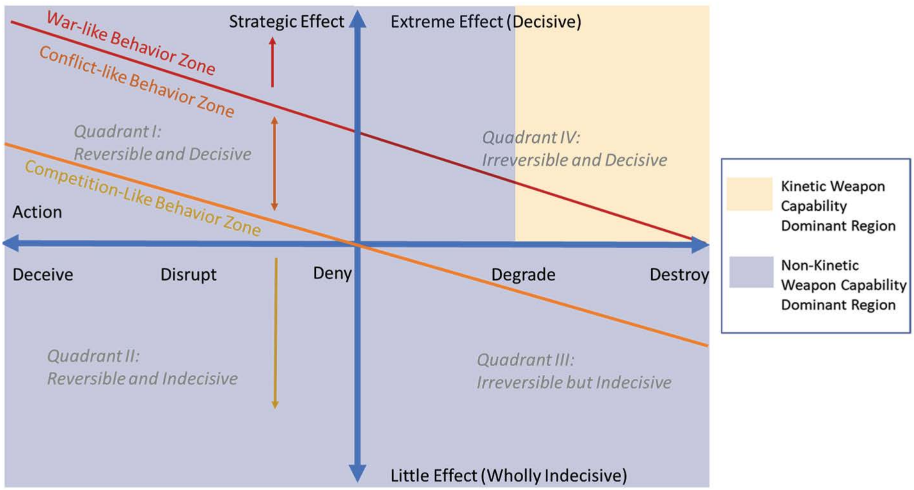

Figure 4. Framework for the continuum of conflict of negative spacepower

Positive and Negative Spacepower Applied to the Contemporary US

In terrestrial warfare, kinetic weapons dominate because they have many advantages over nonkinetic (EMR) weapons. The converse is true in space warfare for the foreseeable future. To date, much of the discussion of space warfare and militarization in the US has focused on the upper right quadrant of figure 4. A US focus on decisive, high-intensity space conflict is consistent with preparing for the "most dangerous" enemy course of action. Still, strategic and operational planning must also consider the "most likely" enemy course of action. US defense policy has not focused commensurate attention on the USSF's ability to respond to the likely threat of adversaries using nonkinetic weapons to gain strategic advantages short of overt space war. A direct kinetic attack with a direct ascent antisatellite missile against six GPS satellites is likely to trigger a war. Perpetual, nondestructive jamming of GPS signals on the ground within line of sight from a nearby country seems unlikely to trigger the same armed response but may gain the same advantage for the actor in question. This scenario seems more strategically advantageous for the US's possible foes. As an excellent first step in reorienting US space defense spending and preparation for the different nature of space warfare, the USSF's capstone doctrine document does acknowledge the utility of controlling the electromagnetic spectrum.[118] Nonetheless, the focus of space warfare defenses in the US remains on kinetic rather than nonkinetic means despite the seemingly greater utility of the latter.

The US is a mighty spacepower, reaping nearly half the space commerce economic gain, approximately $158 billion per year.[119] Many in the US understand that space assets must be protected and that positive spacepower is of massive economic and military benefit. Yet because space has often been (mis) understood through analogy or as an effect, US thinking in military and policy circles is frequently muddled. Much of the US strategic thinking about space conflates positive and negative spacepower without distinction between competition and conflict. As this work argues, conflating positive with negative spacepower limits one's ability to understand the object of both. Benefit is not the same as the denial of another's benefits. This is akin to the confusion that existed in the strategic thought relating to sea power before Corbett distinguished military sea power from maritime commerce.[120] To paraphrase Corbett, negative spacepower determines what an actor can do to another's space assets; positive spacepower determines the relationship between a state and its space assets.[121] Nonetheless, the weakness in US strategic thinking related to spacepower could be rectified easily by recognizing the difference between positive and negative spacepower and their proper contextual application.

Chapter Conclusion

This chapter's three core claims are that, first, space has unique physical, environmental properties that distinguish it from other warfighting domains. Next, space weaponry comes in two primary types: kinetic and EMR, the latter of which is predicted to be more versatile, potent, and prolific. Last, spacepower should philosophically possess both positive and negative elements. Separating spacepower into negative and positive variants is a useful construct that highlights the inherent differences of space warfare more fully.

To prepare to fight wars in the vastness of space and best gain the possible benefit from those wars, space-minded states must develop both positive spacepower in the form of space assets and negative spacepower in the form of ground and space-based EMR and kinetic weaponry. The combination of celestial and terrestrial spacepower assets provides the best answer of how to effectively concentrate combat power in and gain commercial benefit from space.

4

Communication and Reconstitution in Space

All military actions from total war to humanitarian operations must possess adequate supplies and adequate communications or risk failure.[122] Following Corbett, this work allows the word "communication" to denote both communications in the traditional sense of conveying information and in a nontraditional sense of conveying supplies (reconstitution). My argument thus parallels John Klein's celestial lines of communication (CLOC) argument, also derived from Corbett.[123] Klein argues that CLOCs may allow for the movement of physical assets as well as information conveyed by EMR, that is, light.[124] This chapter will cover both communication and reconstitution separately within the overall guise of communication.

Communication and reconstitution are literal requirements to wage modern war. Soldiers without orders or food are a starving mob. Naval ships without ammunition cannot fight. Airplanes bereft of munitions and targets cannot bomb. Spacecraft without flight commands are debris. Communications are a prerequisite for military campaigns, and space is no different.

This section makes two primary points about the nature of communication in the space domain to address how forces communicate in space effectively. First, communication of information in the space domain is mainly achieved by EMR, which shows the importance of spectrum superiority as a subset of space superiority.[125] Second, reconstitution in space primarily occurs strategically by the launch of additional spacecraft and tactically by the absorption of solar radiation. The common nature of the system of reconstitution used for nearly all spacecraft is an exploitable target for an adversary. To rectify this fault, spacecraft designers should harden spacecraft through both vertical redundancy, redundant payloads or satellites in a constellation, and horizontal redundancy, more spacecraft doing the same or a similar mission.

Lines of Communication in Space

The primary process by which spacecraft and satellites detect space phenomena, collect intelligence, or communicate with terrestrial domains is through photons, that is, EMR. As space is so vast and communication between ground stations and satellites is so frequent and necessary, the CLOCs have already followed the evolution that space weaponry will probably undergo. Physical communication between spacecraft is rare owing to its cost, sluggishness, complexity, danger, and limited utility. Instead, nearly all communication between spacecraft and the ground and spacecraft with one another is by EMR. EMR transmissions along CLOCs by radio, microwaves, infrared, and visible light are all commonplace in space and are the primary method for secure, rapid, efficient communications with spacecraft.[126] The omnipresence of photonic reconstitution and transmission for space missions is unlikely to change unless faster than light particles or effects are discovered and able to be harnessed for the same purpose.

Nevertheless, any new methods of communication would quickly supersede, rather than augment, light-based communications, which would become a backup. As light-based communications are nearly wholly ubiquitous among spacecraft and nearly all spacecraft need to relay information to Earth at some point, jamming or depriving spacecraft or ground stations of the use of the electromagnetic spectrum (EMS) is an extremely efficient and profitable avenue of attack for the employment of negative spacepower. Figure 5 shows the EMS for reference in terms of frequency and wavelength.[127] Thus, control and dominion over the EMS is an essential element of space warfare. EMS superiority would be a subset of space superiority, the ability to control part or all the EMS over a localized area for a given time. [128] EMS superiority is a powerful tool to ensure that only one's own positive spacepower assets function and that any enemy negative EMR-based spacepower assets are inert. In practice, however, EMS superiority seems nearly impossible to achieve with current technology and international laws, which specify fair use of the electromagnetic spectrum in many cases in space. [129] Like naval or air superiority, EMS superiority is temporary and only exists when contested.[130] Uncontested superiority is merely friendly dual-use or multi-use.[131] As mentioned in chapter 3, jamming is the creation of EMS noise at the same frequency as the desired signal to interfere with the communications between a specific target, sender, or receiver.[132] While jamming is temporary, it can also occur from mobile sites and affect uplinks from the earth to a satellite or influence the downlink from the satellite back to the ground.[133]

Currently, adversary terrestrially based negative spacepower assets could only be totally nullified if destroyed or severely damaged, which would require physical access or cyberattack because of the potential ability to move or rebuild the asset. In theory, EMR nullifying devices could be constructed for certain frequencies to provide more persistent EMS superiority but do not currently exist. Such devices could be a great boon for any spacefaring state.

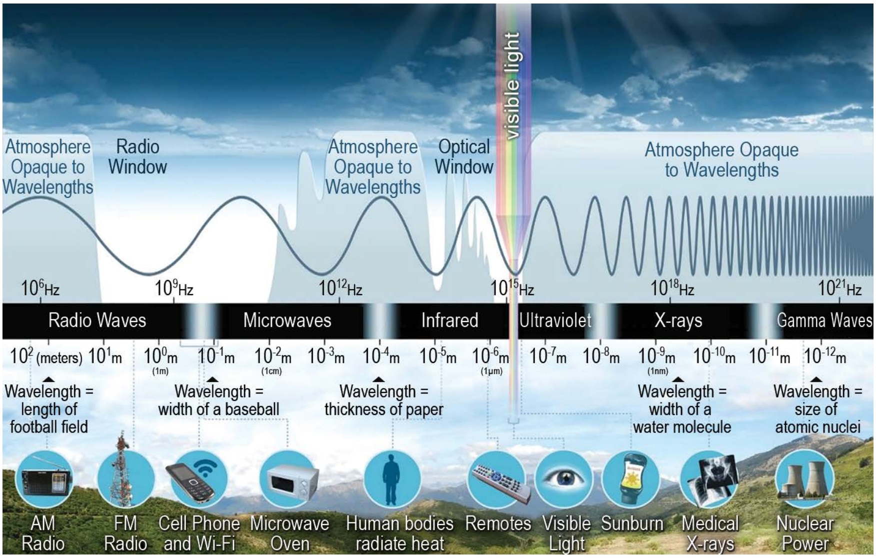

Figure 5. The electromagnetic spectrum with common applications and Earth's atmospheric opacity per frequency. (Courtesy of NASA, https://science.nasa.gov/ems/01_intro)

For higher frequencies in the visible and infrared, the primary type of photonic weapon is often called a laser. Other weapons with similar characteristics to lasers operating at the same frequencies but with different names or specific characteristics are possible. To maintain simplicity at the cost of scientific accuracy, with the word laser, I mean any visible or infrared, coherent, focused beam of light. Lasers typically function at only specific frequencies characteristic of that particular laser, though this is not universally so.[134] Laser jamming, dazzling, or damage can be blocked by filters in some cases. Still, filtering technology cannot stop high-power laser radiation from penetrating, heating, or melting the filter itself, thereby damaging the payload or degrading mission effectivity. The main reason laser weapons are not employed on Earth frequently is not their lack of utility but the possibility of stray light blinding civilians or damaging nontarget infrastructure. This drawback is much less potent in space warfare. The space domain's vastness means stray laser light is very unlikely to hit an unintended target or to scatter or refract in unexpected ways.

In addition to jamming or damaging photonic communications with photonic weapons, kinetic weapons could destroy or degrade receiving apparatuses, antennae, or other payloads. Still, kinetic weapons in space, excepting only those that are the equivalent of blind shots in the dark, rely on photonic guidance both from their terrestrial control center and to track their targets before and after launch.[135] Hence, EMS superiority is a prerequisite for controlling CLOCs, whether for positive or negative spacepower, when using kinetic or photonic weapon systems. Therefore, assured space communications require mastery of the EMS, that is, spectrum superiority.

Regardless of communication method and weapon construction methodology, in space, EMS superiority is an essential subset of space superiority. Almost all lines of direct communication to and from space, as well as most means of spacecraft mission accomplishment, rely on photonic and electromagnetic access. The primary lines of communication in space are photonic. Still, physical access to spacecraft or a particular region of space, which is in constant relative motion with respect to the earth, is possible both for friendly and unfriendly craft. In a physical sense, a spacecraft should only require a minute exclusion zone around itself to ensure mission success. Also, the space surrounding a spacecraft has no intrinsic value because it is, by definition, devoid of most matter. Many spacepower advocates and theorists have highlighted that space control rests on control access to specific orbital regimes, such as those shown in figure 1.[136] Assuming that physical control of space or even control of access to space will lead to the command of space is an anachronistic approach based on terrestrial warfare, specifically naval theory, which relies on physical access to territory to either enable the movement of goods or exploitation of territory. In space, the physical "space" a spacecraft occupies relative to Earth is nonconstant, even in the case of geostationary orbits owing to drift and micro-gravity. Further, destroying all possible entry by a potential adversary to a particular orbital regime would be very difficult in practice and would often create a debris field so onerous as to deny access to that particular orbit for all users temporarily, not just the intended target. The resulting physical destruction of all spacecraft in a particular orbital regime would cease any ability by all powers to reap positive spacepower in that orbit for a period. This is, in effect, a space analog of Eisenhower's observation of the irrationality of the claim that to save the US from the Soviet Union required launching a nuclear Armageddon sure to also destroy the US.[137]

Because space is so vast, as Corbett said of the much, much smaller ocean, its natural state is uncommanded.[138] Even more so, because everything in space is almost always moving relative to the fixed position of the earth, physical space is uncommandable, perhaps not even worthy of being commanded. Corbett's primary goal in commanding the sea was to secure the lines of communication and protection of the vessels which formed those lines physically. Space superiority should be reconceptualized in terms of physical command of an exclusion zone around a spacecraft or along launch paths and photonic control of the EMS more broadly. It is these two control elements that will secure the CLOCs to and from space and which, in consequence, will deliver space superiority. Thus, space superiority rests not on control of large swaths of physical territory, as in other domains, but relies upon the dominance of the EMS to secure CLOCs and control of small exclusion zones around spacecraft to protect them physically.

Lines of Supply and Commerce in Space, Reconstitution

Corbett also discusses the reconstitution of both armies and navies and commerce via the sea as a part of controlling the sea lines of communication.[139] Currently, spacecraft reconstitute by either power generation to ensure payload endurance or by delivery of new spacecraft or supplies from the earth, but space-based shipyards or another celestial body might provide these needs in the future.[140] Most spacecraft employ solar panels absorbing photons from the sun for continuous power generation, that is, reconstitution.[141] Other power generation methods are possible, such as battery power, nuclear power, or collection of fuel from the interstellar medium. Most of these power generation methods are less attractive than solar power for a myriad of reasons ranging from political to cost.[142] Nevertheless, from a tactical sense, the near-ubiquitous reliance on photonic power generation, such as solar panels without a backup, is a flaw ripe for exploitation.

Delivery of new or additional spacecraft to a particular orbit, constellation, or mission is another method of reconstitution and is the primary method of long-term reconstitution of spacecraft. Unlike a naval ship leaving a shipyard for the open ocean, the spacecraft launch process is generally slower, more expensive, and fraught with danger. Physical reconstitution or addition of spacecraft to a mission is not currently a militarily viable option in the opening days of a conflict. With the end of the US space shuttle program, there are also almost no possible methods for repairing spacecraft which become damaged or are defective once launched.[143] Both of these are exploitable flaws in the current US space strategy.

To alleviate the challenges with the physical reconstitution of spacecraft, two avenues are the most viable. First, spacecraft launch processes must become more regularized both in terms of frequency of launches and a decrease in the overall size of spacecraft per launch. Second, spacecraft repair and shipbuilding facilities either in specific orbital regimes or the ability to move between them should be a priority to ensure costly spacecraft present better return on investment in terms of positive spacepower. Eventually, facilities which mine other celestial bodies or the interstellar medium and shuttle those resources back to Earth or elsewhere would be optimal; however, the space infrastructure needed to enable such novel schemes of resource acquisition is not likely to be exploitable militarily until they are viable commercially.

Space Lines of Communication Applied to the Contemporary US

Corbett and Mahan both hold that the main benefit a state reaps from the sea is not in the military realm but rather is a consequence of the military protecting commerce.[144] The main goal of seapower is not to control the sea for its own sake but to control the sea to reap economic gains. The same is true of space. Spacepower's ultimate aim is to reap its benefits, military, economic, and otherwise or stop another from doing so. The goal of seeking that benefit is to garner utility for that society. As Mahan noted about seapower, states that wish to develop in a particular domain militarily often have a commercial presence in that domain as well.[145]

Today, the use of space to enable commerce is ubiquitous across the earth. PNT, space-based communications, and mapping are all used by most citizens of developed countries daily.[146] The total space economy of the US alone is approximately $158 billion per year.[147] One of the main barriers to further commercial use of space is, however, the complexity of physical space launch and the return on investment of seeking resources in space. Simplification of both of these issues would be of great benefit to the military, but for many years, the US and other western states have relied primarily on corporations to exploit space commerce with limited government assistance. A lack of public-private synchronization is a suboptimal approach likely to allow more forward-thinking states to benefit from a more time-tested approach to commercial utilization of new domains. Thankfully, the USSF and National Reconnaissance Office are now working more actively with commercial space vendors like SpaceX and Blue Origin to regularize and commercialize space access by leveraging government funding.[148]

The main issue with sole reliance on corporations to spearhead the commercial use of space at scale is akin to aircraft production in the US before World War II. The American Wright brothers invented the aircraft but could not convince government officials in the US to fund further experiments owing to a lack of commercial utility.[149] In Europe, many military-minded governments saw the benefits of airpower as a spotting tool for artillery, that is, a competitive advantage. As a consequence, European investment in aircraft and excellence in aircraft production exceeded that of the US until just before World War II.[150] Only when the US government began to fund aircraft production for military means did aircraft manufacturers have sufficient capital to begin building large body aircraft that would be commercially viable on a large scale for cargo and passenger transport. The high costs of the Apollo and space shuttle programs drove the US to focus no longer on the development of spaceflight and launch from within government organizations, such as NASA. Since the late 2000s, the US government has relied mainly on commercial entities, such as United Launch Alliance, Northrop Grumman, Rocket Lab, SpaceX, Blue Origin, and Virgin Galactic, to create a commercially viable path to the utilization of space at scale.[151] Still, these entities did not have a market for their space launch capabilities or a customer base without government contracts. [152] Until the US government began providing both a market for these companies and financial assistance for them in the form of government contracts, their ability to significantly reduce costs and innovate remained limited because those efforts were not strictly profitable in the short-term.[153]

In the last five years, a renewed interest in military space in the US has occurred after several high-profile tests and launches by Russia and China.[154] Recently, some US government officials have realized that corporations are unlikely to reap the benefits of space without sufficient seed funding from the government. Government funding of space commercialization is an element of warfighting because the commercialization of a domain and exploitation of the domain for commercial gain are inherently the *reasons* to fight for access to a domain in the first place. Recognizing this fact, USSF doctrine officially states that "national spacepower" exists to deliver "prosperity" and "security."[155] New domains (or regions) are most efficiently harnessed for commercial gain by a dual governmental and civilian approach, which should be a military necessity for optimal use of space both in terms of reaping benefits but also in terms of securing lines of supply to and from space.

Conclusion

Understanding how forces and actors in a domain communicate in that domain is essential to understanding the conduct of competition, conflict, and war in that domain. As with all other domains, the space domain largely relies on lines of communication, both photonic and physical, to reap both positive and negative spacepower. These space lines of communications or CLOCs form the necessary linkages to allow both communication and reconstitution of assets in, through, and from space. These lines of communication for information rely almost exclusively on photonic transmission, while the lines of supply rely on both photonic and physical means. Nevertheless, directing the objective of maintaining or depriving spacepower against either securing or using these

CLOCs should be most effective. Securing the CLOCs requires four essential elements discussed above: electromagnetic superiority for communication with space assets, control of small exclusion zones around a spacecraft, efficient and redundant methods of power generation, and effective means of physical reconstitution of space assets. As with lines of communication in other domains, the use of spacepower must always proceed from the possession of these four elements to ensure continual use; deprivation of any one of these four elements can render a space capability inert.

5

Attack, Defense, Symmetry, and Asymmetry in Space

Returning to the question of "how does one attack and defend oneself from attack in space" first requires an explanation of what attack and defense mean in the context of space warfare. To date, there is not broad agreement on the definition of "attack" and "defense" in military space literature.[156] For Clausewitz, attack and defense were mostly synonymous with the positive objective of land warfare and the negative objective of land warfare, respectively.[157] Though Clausewitz's dichotomy of positive and negative aims may seem polar opposites, as Clausewitz notes, attack and defense do not represent a true polarity.[158] One may gain physical territory, and the other side may also benefit from the loss of the same physical territory. For example, the German retreat to the Hindenburg line in World War I benefited both sides.[159] Still, space warfare is not land warfare. The principles which govern space warfare might rest on the same logic as land, naval, or air warfare, but space's unique nature gives that logic a unique expression in practice. The concepts from one domain should not merely be grafted onto another. Instead, the concepts governing warfare in each domain must be worked out separately. In sum, the ideas of attack and defense must be examined separately for each warfighting domain.

The core purpose of this chapter is to understand attack and defense in the context of space warfare by first examining these concepts for that specific case starting from and adapting the work of Clausewitz. This chapter proceeds to make three core points about attack and defense in space warfare. The initial point is to define attack and defense in a space warfare context that agrees with previous doctrinal assessments of space warfare but also maintains the simplicity of language related to the typical lexicon of warfare. I aim to delineate what constitutes attack and defense in space in a typical military way and also identify the relationship of these constructs to previous space doctrine.

Next, this chapter addresses the current inherent asymmetry of negative spacepower and the inherent symmetry of positive spacepower due to specific peculiarities of the space domain. I argue that the best way to pursue negative spacepower currently is to seek asymmetric capabilities unlike those of potential adversaries. Conversely, I argue most actors must pursue positive spacepower in a similar, or symmetric, way to one another.

The observation that most actors seek negative spacepower by differentiation and positive spacepower by emulation leads to the third core argument of this chapter. This argument holds that spacepower is constantly being derived in the international system by one set of governing rules and deprived by another set of rules. Spacepower's accumulation and denial thus function as two separate elements or games of what Robert Putnam called a "two-level game" because of the specific nature of attack and defense that is characteristic of space warfare.[160] Thus, the intrinsic nature of space warfare creates systems and rules which govern attack, defense, optimal strategies, and norms in a foreseeable way, exclusive to space as a domain.

In Space Which Is it, Attack or Defense?

Neither positive nor negative spacepower is strictly synonymous with attack or defense. Positive spacepower concerns accrual of benefit; negative spacepower concerns the denial of benefit. Usually, these gains do not necessitate the seizure of benefit from another actor, although they may require the defense of resources from an aggressor. For example, the monopolization of a space communication market at a particular frequency is a positive spacepower aim, which may require negative spacepower attacks and positive spacepower defense to be achieved. Nevertheless, an essential element of any domain theory of war is answering how attacks are conceptualized, executed, and thwarted in a particular domain.

This theoretical difference is best illustrated by an example. The destruction of an enemy spacecraft to deprive overflight access to one's own territory might constitute an attack from the point of view of the receiving power but a defensive measure by the executor. The difference in lexicon between actors is chiefly due to the difference in context. For the receiver, the destruction of a spacecraft is an overt tactical attack, while for the executor, the same action is a strategic defense. Similarly, in land, naval, or air warfare, tactical actions and strategic actions can be executed and viewed differently by different actors. Because these domains of warfare have a more concrete conceptualization of the levels of warfare as tactical, operational, and strategic, the tendency to misinterpret a tactical action as a strategic action between two actors is less common and problematic.[161] The lines between strategic and tactical can blur in other domains of warfare, but in space warfare, they are inherently blurry due to the strategic import of space assets. Spacecraft, by their very existence, operate at multiple levels of war simultaneously complicating the classical ideas of attack and defense. Thus, it is crucial to reconceptualize attack and defense for a space warfare context to simplify strategic thinking.

To resolve this conundrum, United States Air Force (USAF) and US joint doctrine distinguish attack and defense in terms of space control. "Offensive space control (OSC) are those offensive operations to prevent an adversary's hostile use of US/third-party space capabilities or negate an adversary's space capabilities."[162] Defensive space control (DSC), in turn, consists of "operations conducted to preserve the ability to exploit space capabilities via active and passive actions while protecting friendly space capabilities from attack, interference, or unintentional hazards."[163] USAF doctrine is correct ontologically, but OSC and DSC are cumbersome ideas beyond the community of US military space professionals. In early 2021, the USAF reworked OSC and DSC into offensive and defensive counterspace, which are essentially the same equally complex ideas.[164] As a result, misperception of US or USSF intentions or objectives related to the planning or use of OSC and DSC is likely within the wider military community, the US government, the international community, and potential adversaries.

Returning to more traditional military terms, such as attack and defense, is possible with the adoption of a framework of positive and negative spacepower. To do so requires adapting Clausewitz's notions of attack and defense for use in a spacepower context. In this context, maintaining positive spacepower is *space defense*. The use of negative spacepower to deprive a capability from another actor is *space attack*. The defense of positive spacepower is analogous to DSC. Employing negative spacepower to attack another actor's positive spacepower is analogous to OSC. *Attack* in space is deprivation of enemy space capability. *Defense* in space is safeguarding one's own space capability. Hence, using attack and defense with relation to positive and negative spacepower recovers the original duality of Clausewitz in relation to attack and defense. Interestingly, the positive objective does not require attack nor the negative objective defense as it does under Clausewitz's framework but the *inverse* because of the unique nature of space warfare. As a note, adapting Clausewitz's framework strictly seems to have led to the problematic complexity of OSC and DSC, which attempt to graft terrestrial thinking about physical control into a space context. Instead, reorienting the terms attack and defense to a proper spacepower context simplifies the lexicon of space warfare, enables space professionals to more easily relate to other military domains, and demystifies the foundational question of how to attack and defend in space.

Symmetry and Asymmetry in Space Warfare

With the philosophical issue of space attack and defense resolved, the next issue is how to put those ideas into practice. Historically for land and naval warfare, the most powerful armies and powerful navies primarily looked similar. To this day, *ceteris paribus*, the most capable land armies outside their immediate borders are those armies with large, professionally trained forces with modern weaponry.[165] The same is true regarding the most powerful navies and air forces.[166] The most potent navies usually possess carriers and large surface fleets. The most powerful air forces currently possess fifth-generation air superiority fighters. Fundamentally, land, naval, and airpower are typically best sought symmetrically.

Still, there is a specific case where the efficiency of the symmetric gain of power on the air, land, and sea breaks down. Within a particular state's borders, power may be sought symmetrically or asymmetrically with an adversary. Inside a state's borders, the logic of a symmetric approach breaks down if one actor chooses to employ guerrilla tactics.[167] As many have noted in critiques of Mao Zedong, using irregular warfare is questionable as a tool of power projection into an unfriendly area.[168] Mao did prove, with sufficient time and patience, guerrilla tactics can lead to victory even against steep symmetric power imbalances if used from an area of the sanctuary.[169] When faced with an opponent with extreme superiority, one usually should adopt an approach of guerrilla or irregular warfare.[170] One definition of irregular warfare is "the use of violence by substate actors or groups within states for political purposes of achieving power, control, and legitimacy, using unorthodox or unconventional approaches to warfare owing to a fundamental weakness in resources or capabilities."[171] In a general context, the main objective of irregular warfare is to break down the traditional agglomeration of power by creating asymmetric advantages. The core goal of an asymmetric approach is to offset a power imbalance by finding and exploiting the enemy's weaknesses.[172]

In the land domain, weaker powers often employ guerrilla tactics or irregular warfare to offset a symmetric power imbalance. In the maritime domain, reliance on commerce raiding and hit-and-run tactics, what Mahan called *guerre de course,* is often an expression of asymmetric warfare.[173] As Jean-Luc Lefebvre states, "The recent upsurge in naval piracy demonstrates that a determined and able handful of men are capable of defying the international community with the most rudimentary resources in comparison to the types of equipment used by modern battleships."[174] A weakness of conventional airpower superiority frequently leads the weaker power to seek a more capable IAD to nullify an enemy's airpower advantage. The critical philosophical elements common to all asymmetric approaches are not a common set of methodology, tactics, or weaponry but *access and efficiency*. When a weaker power has access to its enemies' stronger forces stationed nearby and efficiency dictates the preservation of combat power, then asymmetric strategies become the optimal way to wage war.

In the land, air, and sea domains, access to conventional or symmetric adversary assets is restricted to a conflict zone by geography, law, politics, and technology. Therefore, asymmetric approaches are only optimal in conflict areas in which a power imbalance exists.[175] In any other case, powers that seek the ability to simultaneously project power across the globe and defend their own territory should seek to build conventional, symmetrical land, air, and sea forces. Warfare in space, however, does not conform to these ideas because of the domain's unique nature, which does not feature the same terrestrial geography, law, politics, or even technology.

In terms of access, most areas of the globe have line-of-sight access to all LEO spacecraft at some point during the day. From a military perspective, designers intend military MEO, GEO, and HEO spacecraft to loiter over conflict zones. The physical access for an actor wishing to attack space assets from the ground is often recurring or even consistent by design. Efficiency also creates an entirely different methodology for the building of space assets. In terrestrial warfare, assets that possess negative power are often those that provide positive power. For example, a naval carrier simultaneously provides positive seapower by guarding a trade lane but negative seapower when attacking an enemy craft attempting to gain that trade lane. The example of a naval carrier providing both positive and negative power in one asset is usually invalid in space. All space assets are severely constrained by the energy expended, and thus cost, to launch a payload to orbit. Every additional kilogram of payload adds to design, build, and launch costs, while also limiting and even degrading mission life.[176]

J. F. C. Fuller described the design interplay between an asset's armaments, speed, and defense as a trade-off between guarding, moving, and hitting, respectively. Much of military design philosophy is based on similar principles of trade-offs.[177] For Fuller, military assets can be optimized by the same symmetric (guard-hit-move) process. Fuller's conception does not break down in space, but to be useful requires reformulation along asymmetric lines. In space, the idea that a single space asset could guard, hit, and move in a heavily constrained cost, mass, and energy environment seems preposterous. In lower orbits, space assets must be able to move to avoid other satellites, debris, and, most critically, forestall reentry. The ability to move expends onboard fuel limiting a satellite's operational life. In general, LEO and HEO spacepower assets can either guard and move or hit and move but rarely all three. MEO and GEO space assets could possibly do any one of the three well given the correct design, but this would limit space for other payloads. Owing to the high energy costs of reaching orbit, designers often build MEO and GEO assets with the ability to move only, leaving them incapable of guarding themselves or hitting enemy craft. Terrestrial spacepower assets can guard and hit but typically cannot quickly move owing to the extensive ground facility requirements associated with building and operating the spacecraft. Thus, assets that provide positive spacepower (guarding) are typically not the same assets that provide negative spacepower (hitting). For the sake of efficiency, this is probably the current ideal, though it could eventually be overridden by improvements in propulsion (movement) technology.

Today, the most capable negative spacepower asset is not simultaneously the most capable positive spacepower asset. In the naval domain, an aircraft carrier *is*, in many contexts, both the most capable positive and negative naval power asset concurrently. Indeed, for orbital warfare near the earth, the most capable negative spacepower assets would frequently be ground-based to ensure more capable defense, greater destructive potential, lower cost, and secure operating power. The use of EMR weaponry further simplifies the problem of access by not requiring negative spacepower assets that must launch physical payloads into orbit. Currently, ground-based kinetic kill vehicles (KKV) are the most destructive form of space attack, but this does not mean KKVs are always the most strategically optimal negative spacepower asset universally. One should not disregard a spacecraft attacking other spacecraft or less destructive ground-based weapons. In some cases, a spacecraft-based attack might be optimal; in other cases, ground-based attacks or KKVs might be optimal. The denotation of the ability of negative spacepower assets to reside on a celestial body or in another domain serves to illustrate that negative spacepower can be derived from physical assets outside the domain of space itself. Still, the surface of the earth will probably remain the most potent place for basing negative spacepower capabilities until propulsion technologies become more robust.[178]

In all domains, access to a target is a requirement for mission accomplishment. Additionally, no single power can deny all other power physical and electromagnetic access to space entirely and permanently without scuttling the use of space for oneself. In most domains, a lack of access to the opponent's sanctuary, where the opponent's symmetric military forces reconstitute and resupply, generally invalidates an asymmetric approach. Nevertheless, the prevailing legal interpretation of space sovereignty almost wholly obviates the access problem that negates the use of asymmetric approaches in most domains in many contexts.[179] If space is a sanctuary or haven for all actors simultaneously and spacecraft are sufficiently close to the earth, or an enemy spacecraft, then the problem of access that generally invalidates an asymmetric approach to warfare is not valid in most cases of orbital warfare. Logically, asymmetric approaches to warfare are almost always optimal in any orbital warfare around a celestial body that has both friendly and adversary presence. Only when a celestial body or an area of "open" space is entirely controlled by one side are symmetrical approaches to space warfare again optimal, and power projection with symmetrically designed assets again becomes more viable than with asymmetric ones. Essentially, until an actor controls a large zone of space completely where it can resupply its space assets free of harassment, enemies employing guerrilla-like tactics and asymmetric strategies are almost always optimal.

Asymmetric approaches, historically, have fared poorly against great powers until the modern age. For the most part, disadvantaged actors had difficulty finding cost-effective solutions to defeat the armor and weaponry of great powers. The historical futility of asymmetric warfare largely continued unabated until the development of dynamite and the AK-47.[180] These weapons allowed less well-trained, less economically potent forces to easily penetrate armor and concentrate firepower. In space, assets rarely feature any form of armor or other defensive measures owing to launch costs. Indeed, the focus on the accrual of positive spacepower and the diversity of possible space weaponry threats has left many spacepower assets relatively undefended or defended only for very specific threats. As a result, attacking space assets with an approach customized to defeat a particular asset, that is, an asymmetric approach, is much more viable in space than elsewhere.

For the most part, asymmetric approaches to space warfare should only be viable within the range of reasonable weapons for a given adversary and given weapon technology. Thus, the utility of asymmetric approaches in space would vary with distance from a celestial body just as it does with other domains and distance from a sanctuary. Indeed, space warfare should resume the symmetric character of other domains far enough away from any celestial body or when celestial bodies are politically unitary. To provide an example by analogy from naval warfare, far from port, cruisers or carriers are most often challenged by vessels of a similar make, an enemy cruiser or carrier. Conversely, vessels close to a port are more economically defeated by a shore battery or a submarine than by an enemy surface vessel. In space, the gravity well around a celestial body functions similarly to a port. So, ground-based or small customized space-based negative spacepower assets provide an asymmetric approach similar to the asymmetric approach of using shore batteries or submarines in naval warfare. As long as space warfare occurs primarily around a celestial body or in a gravity well, an asymmetric approach is optimal. Similarly, if a single state entirely controlled Mars and another entirely controlled Earth, any conflict between Mars and earth would require developing similar capabilities to project power to the other planet effectively, that is, space fleets. Still, an Earth-Mars conflict seems unlikely in the near-term, given that Mars has a population that is exclusively robotic drones currently. Thus, the fleet-like conditions for symmetric use of negative spacepower are likely to be in a very distant future and are not necessarily germane to space warfare of the present.

All the states of Earth currently reside within the adjacent area, or sanctuary, for Earth orbital spacecraft. In consequence, unless a single government controls all of Earth, which is unlikely and certainly undemocratic, all powers—great, medium, and emerging—seeking efficient use of resources should approach offensive space warfare asymmetrically. Gaining negative spacepower is thus a constant seeking of how best to deprive the adversary of space capabilities at the lowest possible cost to oneself by optimizing an inherent asymmetry.

Conversely, positive spacepower should remain a symmetric and typical power acquisition process in all cases. The main goal of positive spacepower's acquisition is to employ those capabilities toward some benefit in the space domain or another domain. The objective to use positive spacepower for communications, PNT, intelligence, commerce, and mining is common to all possible powers in space.[181] Therefore, the method for deriving positive spacepower among actors will primarily be symmetric unless each entity develops radically different technology. Instead of rehashing previous authors' excellent discussions of the benefits of spacepower, the main goal of this chapter with regard to positive spacepower is to describe the defense of spacepower. [182] The defense of spacepower is synonymous with DSC. As a note, the defense of any negative spacepower assets located outside the space domain should instead be viewed philosophically as a defense of a capability in the domain in which those assets reside. For example, the defense of a satellite ground station or ground-based weapon platform from land attack is a function of land power.

Two fundamental divisions of space defenses exist: passive and active. Passive defenses are defenses that operate to defend a space asset without requiring any input from an outside source to function. Active defenses are those that only operate to defend a space asset with outside input.[183] Because of launch costs and concerns over efficient weight use, designers frequently discount spacecraft defensive measures in favor of more capable primary payloads and greater fuel supply. To return to Fuller's guard-hit-move conception, the focus of spacecraft design is solely on the move portion of Fuller's trichotomy. As stated above, lone space assets probably cannot perform all three of Fuller's design trade-offs simultaneously, but two of three is probably possible for most assets. For positive spacepower assets, neglecting defensive measures in favor of primary mission payloads is fundamentally unsystematic thinking. Defensive measures on spacecraft should be an element of mission accomplishment in the same way that body armor is for a soldier, countermeasures for an aircraft, or armor for a naval vessel. Such a systematic approach is common to all domains except space; defensive measures provide more assured survival of the protected capability and are equally important as the payloads that they defend.

Designers must balance defensive measures against other elements of an overall weapon system. Focusing solely on spacecraft payload is historically akin to the over-emphasis on attack, *élan*, in the doctrine of European armies before World War I.[184] The belief in the indefatigability of attack was rectified only by artillery and machine-gun fire in European trenches with, sadly, the loss of millions of lives.[185] By World War II, tanks and aircraft proved the viability of attack-centric doctrines still required some level of defensive measures for the attackers to succeed. Weapon designers in Europe and the US realized that effective designs should balance, not exclude, defensive measures against the speed and armament of weapon systems for optimal combat performance.[186] Owing to the tyranny of launch costs, the desire to maximize positive spacepower at the cost of defense against negative spacepower has led to multiple generations of spacecraft unprepared for war. The inherent weakness of this approach, which focuses on positive spacepower without protecting it, only becomes apparent when more actors begin to seek negative spacepower in earnest, as is currently occurring.[187] In World War I, a large loss of life awakened military weapon designers to the requirements for defensive measures. A similarly large loss of spacecraft, and thus economic potential, should not have to occur to break the ignorance of risk pervading spacecraft design and acquisitions with regard to defense. Instead, by acknowledging that defense (mission assurance) is often as important as the core mission of a spacecraft (payload), military and national security spacecraft designers and operators can properly rebalance the prioritization of payload and defense into spacecraft design.

Defense of positive spacepower is an essential element for spacecraft and space capabilities endurance in conflicts. The process of defending spacecraft is largely common to all actors seeking positive spacepower. Barring significant technological differences, all spacefaring states will seek and defend positive spacepower by the same symmetric processes, in philosophical opposition to the asymmetric process of accruing negative spacepower.

Gaining Spacepower Is a Two-Level Game

The inherent asymmetry of acquiring negative spacepower and the juxtaposed symmetry of gaining positive spacepower forms, in essence, a two-level game for the simultaneous acquisition of both. Robert Putnam once observed that a two-level game exists in international relations in the creation of international agreements. At the international level, actors seek to negotiate a possible agreement within a list of possible win-sets for their respective societies.[188] At the domestic level, negotiators seek to build coalitions to produce the possible win-sets and to attain agreement on a chosen plan.[189] In terms of game theory, these two levels, or games, function simultaneously but have different optimization parameters.[190] To optimize the whole system, both games must be analyzed simultaneously and symbiotically. The core insight of this two-level game theory approach to spacepower is that only a few states will be able to seek the benefit of positive spacepower by a set of norms and principles, but *all states* will seek to deprive spacepower by a *different* set of norms and principles.

As discussed in the previous chapter, the optimal approach to depriving—negative—spacepower is asymmetric for the foreseeable future. Hence, powers should seek to build negative spacepower technologies focused on potential adversaries' current or planned positive spacepower capabilities. If a country has no plan to create or utilize positive spacepower capabilities, then extremely disruptive and destructive attacks, including space debris-creating actions, become the optimal approach. Essentially, those states' best course of action is threatening indiscriminate violence in space coupled with a strategy of coercion by universal risk.[191] If states accrue positive spacepower best symmetrically, all states should attempt to gain space capabilities by the same process and use the same photonic, physical, and legal processes to communicate with assets, employ capabilities, and access the domain. Conversely, all actors will attempt to gain negative spacepower asymmetrically. Only the negative spacepower assets that specifically offset other potential foes' current or future positive spacepower assets are economically and militarily incentivized. Great powers will often need large amounts of diverse negative spacepower assets; nonstate actors focused on extortion might only need one. This dichotomy creates a two-level system that is rife for either the development of stabilizing norms or an arms race, perhaps both, depending on how actors respond.

As states increasingly desire positive spacepower, the selectivity of their approach to violence in space should increase. States with large amounts of positive spacepower should desire more controls on space weaponry, and those states wishing to use space for positive spacepower will be more inclined to adopt a view of space as a "sanctuary" and limit the use of arms in space. By contrast, powers that have few—or no—positive spacepower capabilities designed for benefit but more space attack capabilities will desire fewer arm controls or are more likely to disregard arms control treaties that they sign. States that desire arms controls in space should focus on more pluralistic multinational beneficial, positive spacepower capabilities. Great powers restricting access to space seems likely to trigger arms races because of space "security dilemma[s]."[192] Further, an actor completely deprived of the ability to use or procure positive spacepower should logically seek to deny all other actors' space access by any possible means, even catastrophic ones such as orbital debris cascades. Contrary to the idea of perpetual space hegemony, denying other states access to space is rarely in any nation's long-term interest.

An additional consequence of the two-level nature of acquisition of spacepower is that all states wishing to defend themselves against a great power must eventually seek negative spacepower. They will do so because negative spacepower is the only possible defense against the massive unbalancing effect of an inequity in positive spacepower. All nations will soon begin to seek negative spacepower capabilities as a matter of national defense. These capabilities will range from simple jamming devices to much more elaborate KKV. Indeed, the US conduct of wars against conventional Iraqi forces in 1991 and 2003 and Afghan forces in 2001 proved that the acquisition of negative spacepower should be a necessity for state survival when facing an opponent with space superiority.[193]

Consequences of the Two-Level Spacepower Game from a US Perspective

US policy and threat reporting have acknowledged the possibility of great power conflict in space, with China and Russia the most commonly enunciated possible US foes.[194] Indeed, to date, only four states have demonstrated negative spacepower capabilities in the form of kinetic antisatellite weapons: the US, Russia, China, and India.[195] Yet, South Korea, Japan, Pakistan, Iran, and North Korea, the countries most threatened by the previous four countries, are all ambitiously seeking to gain both positive and negative spacepower.[196] The desire of threatened powers with less robust space capabilities—both positive and negative—to seek spacepower to offset their space-reliant possible foes is a harbinger of the future. In particular, the fact that the space programs of Iran and North Korea have a strong antisatellite weapon focus should give the US pause.[197] Iran's and North Korea's aspirations to gain space capabilities partially stem from a desire for asymmetric advantages against a US military reliant upon space.

Further, actors suffering from a symmetric imbalance against the US in the terrestrial domains also seek negative spacepower as a means to offset that weakness. While this once seemed fanciful, the proliferation of space weapons technologies makes this feasible. These advancements in spacepower technologies present what is likely to be a common feature of future warfare: those nations' militaries that are most susceptible to the strength of American air and naval power supremacy in the future will be the most likely to seek and use negative spacepower asymmetrically. As space is integrated across the US military's air, land, and naval power, an adversary can use negative spacepower to degrade US forces, making them less lethal or useful in any terrestrial conflict. Additionally, nonstate actors will also likely use limited negative spacepower capabilities for economic extortion or denial similar to cyber assets, like ransomware, that are currently used as a form of cyber piracy.[198] In future conflicts, the US cannot be assured of air and naval supremacy. Yet, US space supremacy is the most likely to be threatened because of the inherent benefits of spacepower and the utility of asymmetric approaches to space warfare. The USSF must begin preparing for wars, conflict, and competition in space not only with the greatest powers of the earth but also with smaller states and nonstate actors.

Chapter Conclusion

The intent of this chapter was to answer the question of how actors should attack and defend most efficiently in the space domain. The question of attack and defense with regard to space seems fairly simplistic until one realizes that broad agreement on a definition of space attack or defense is nonexistent. Therefore, the first goal of this chapter was to establish an updated lexicon for attack and defense in the space domain using the ideas of chapter 3, namely positive and negative spacepower. This work's definition for space attack is the deprivation of enemy space capability. Space defense is safeguarding one's own space capability.

Next, this chapter sought to examine the inherent duality of spacepower with reference to symmetric and asymmetric approaches to the domain. It was deduced that gaining positive spacepower is most efficiently approached symmetrically, with every actor seeking similar assets to achieve similar goals. Conversely, the main method of gaining negative spacepower will remain asymmetric for the foreseeable future as actors try to strike specific enemy vulnerabilities and design weaknesses. This asymmetric approach to negative spacepower might nullify all possible enemy space advantages universally via catastrophic nuclear or massive debris-generating attacks. Frequently, however, actors will specifically tailor attacks to particular scenarios for the sake of efficiency in terms of cost versus benefit.

Finally, this chapter proposed that a two-level game exists for possessing and employing spacepower. Currently, only a small subset of 14 of nearly 200 states have the drive, ambition, capability, and economic prowess to gain positive spacepower by launching their own space assets.[199] These states will likely be very selective in their approach to violence in space. Therefore, one level of the two-level game is primarily concerned with the acquisition of positive spacepower for a small group of nations, requiring the defense of those space assets. The other level of the two-level game is primarily concerned with negative spacepower acquisition for all nations and, thus, attack of adversary space capabilities. The technological threshold for entry into this second game is significantly lower. There will be many more entrants into the negative dimension of the spacepower game than the positive dimension. Still, each entrant must acknowledge that the relative inequality of the two-level nature of spacepower necessitates stalwart defense of space assets because any power not wishing to or unable to gain positive spacepower is unlikely to adopt an extremely selective approach to violence in space. Space warfare's two-level nature thus powerfully reinforces the necessity for countermeasures, active defenses, and passive defensive measures as more participants enter only one aspect, the attack element, of the two-level spacepower game.

6

Achieving Political and Military Goals with Spacepower

As Clausewitz adeptly reminds us, all forms of military power, or even national power, are a subset of politics.[200] All domain theories of warfare must answer how the accomplishment of military objectives in that domain translate to the accomplishment of goals in other domains or in superseding the realm of politics. The main objective of any military strategy should be to enhance the likelihood of success, respecting what Mark Clodfelter called positive political goals while not risking what he called negative political goals.[201] Per Clodfelter, positive political goals are those political effects that an actor wants to occur as a result of an action. Negative political goals are those political effects an actor does not want to occur as a result of an action.[202] A positive political goal is something to be achieved by military force (e.g., bombing targets to force capitulation), while a negative political goal is something to be avoided in the use of military force (e.g., a rule of engagement on selecting targets).

Clodfelter's ideas of positive and negative political goals are not necessarily directly related to positive and negative spacepower. The achievement of positive or negative political goals through spacepower is a consequence of practical applications of *both* positive and negative spacepower. For example, a rule of engagement limiting the use of specific space weapons and limiting what payload may be placed in orbit would be a negative political goal with both positive and negative spacepower elements. The inherent logic of positive and negative political goals holds regardless of the domain and transcends all domains of warfare. The sole purpose of any military effort should be to translate military objective accomplishment into political objective accomplishment.[203] Militaries achieve objectives to convert military prowess into political capital, a form of currency conversion or perhaps even arbitrage.[204] Put simply, as USSF doctrine holds, the acquisition of spacepower should never be an end unto itself.[205]

The Politico-Military Relationship between Space and Other Domains

Translating both positive and negative spacepower into the accomplishment of political goals follows a similar path as other domains but with one caveat: space is in a literal, physical, and metaphorical sense above all other domains. Space is often, as some claim, the ultimate "high ground."[206] A crucial benefit provided from leveraging that position of height is the assured interlinkages provided to forces in other domains. That control of space itself garners a positional advantage in all other domains is not a universal truth about space but rather a common feature of most modern militaries' force design and equipment.

Essentially, a high position over a battlefield is useful for intelligence gathering or to offer a greater range to artillery or missile weapons by exploiting the gravitational advantage of a high position. By analogy, control of the space high ground is only useful if it can be exploited. Today, most military exploitation of space functions to provide a bridge or conduit to, from, and through space to other domains. The current incarnation of positive spacepower is highly reliant on the effects provided in other domains to be beneficial to a military or an actor in general. In theory, a modern military could abandon the use of space or solely rely on space for all military missions. In either case, fully abandoning or embracing space is inefficient. Nevertheless, the rhetorical drumbeat of space as the ultimate high ground and the potency of complete space supremacy are double-edged propositions, because in the advocacy for space as a decisive advantage the reality may fall short of the promise, as was the case for many early airpower theorists.[207]

The belief that space can supersede or overmatch all the other domains of warfare is questionable and may be perilous for space professionals to adopt. Such analogous claims were dangerous to twentieth-century airpower advocates, who claimed that wars could be won with airpower alone, as in World War II, Korea, and Vietnam.[208] The logical end of over-advocacy for a single domain without acknowledging its inherent relationship to other domains is undesirable regardless of whether military or political leaders agree or disagree with that advocacy. On the one hand, politicians might adopt the views of spacepower zealots that space is the only viable warfighting domain, which is likely to end in military failure. On the other hand, leaders may intuit the myopic nature of this claim and wrongly label well-minded independent space service advocates as irrational fanatics, as happened to Billy Mitchell. Further, as chapter 5 illustrated, embracing a monolithic view of warfare in any domain is an exploitable flaw that an asymmetric approach by an enemy can leverage. As military space forces develop globally, striking a balance between advocacy for space as a warfighting domain and advocacy for space as an element within a cogent approach to warfare is essential to avoid both exploitation by the enemy and the mislabeling of space force advocates as zealots or fanatics. The best path of advocacy for spacepower is adopting an approach that acknowledges the limits of spacepower but also champions its inherent strengths.

Space advocacy is not without merit. Now that there is a US Space Force, however, the main focus of advocacy should be for coequal status with other military branches and promotion of USSF capabilities that can deliver political-objective accomplishment. The current USSF capabilities most able to be converted into the achievement of political goals or military goals in other domains are those that provide PNT, ISR, and communication to warfighters in other domains via positive spacepower. The primary purpose of current spacepower assets vis-à-vis warfighting directly is to deceive, disrupt, deny, degrade, or destroy adversary spacepower assets. Eventually, space-based warfighting capabilities may become more potent than the same capabilities terrestrially, but advocating that this exists before it does was a heritage of the twentieth-century USAF that the USSF should not repeat.

The nearly assured access and increased range of space assets provide such a boon that ignoring them would be imprudent, wasteful, and inefficient. Conversely, relying solely on space assets to project military power is currently unfeasible technologically and inefficient in practice. Space assets, just as naval ships, can never occupy physical territory on the ground.[209] At best, space assets will be able to coordinate disparate ground elements, provide PNT, and, eventually, damage adversary assets in other domains. As a result, a crucial military benefit provided by spacepower and spacepower superiority is related to military mission accomplishment in other domains. Currently, spacepower is an enabler, albeit a critical one, for military actions in other domains. Thus, spacepower as a theoretical concept must be concerned with the ability of spacepower to shape events and operations in other domains at present.

Eventually, spacepower will become superior to other forms of power in terms of precision munition delivery and bombardment simply because of the greater access, greater destructive potential, and lower energy requirement for persistent loitering in certain orbits compared to air, land, and naval forces. To take advantage of the height of space, one must first pay a large cost to overcome gravity at launch. The cost to launch space assets naturally disadvantages any large accumulation of mass on a spacecraft, such as large weapon or ordnance delivery systems. Until spacecraft have precision munition delivery superior to air, land, and naval craft, at comparable cost and scale, these will remain the preferred method for ordnance delivery for most actors, including great powers. Paraphrasing Corbett, space will remain primarily an enabler as long as humans live upon the earth and not above it.[210]

Positive and Negative Political Goals in Space

Clodfelter argued that the main constraint on the successful use of military power to achieve military objectives in the air and other domains was the interplay between positive political goals, the government's objectives for a military action, and negative political goals, the government's constraints on the use of force to achieve those objectives.[211] Positive spacepower and negative spacepower are not necessarily synonymous with positive and negative political goals, respectively. For example, a power might employ positive spacepower to assure negative political goals through monitoring of any adversary's weapons programs. Conversely, a power might employ negative spacepower to destroy an enemy's group of geostationary communication satellites to gain assured military and economic dominance over a region or to induce coercion, a positive political goal. An actor could also employ both positive and negative spacepower to gain positive and negative political objectives simultaneously. To reemphasize for clarity, positive and negative political goals and positive and negative spacepower are related but not synonymous concepts. The employment of positive and negative spacepower concerns the accomplishment of military objectives. The accomplishment of military objectives, in turn, leads to the achievement of positive or negative political goals.[212]

Because the weaponization of space is such a complex issue both legally and logistically, the use of the framework of positive and negative political goals becomes intrinsically valuable. What constitutes a space-based weapon or ground-based space weapon is still open to interpretation due to dual-use concerns and unclear legal precedents about what constitutes a weapon or an act of warfare in space.[213] Further, current treaties on the weaponization of space assets are still interpreted differently by diverse actors.[214] Some actors hold that only nuclear weapons are legally banned in space.[215] At the same time, some hold that all weaponization should be permanently banned in space.[216] In the long term, both positions are probably untenable. Eventually, space will be weaponized in all its forms. The likely eventuality of space weaponization does not, however, demand that every actor should rush to weaponize space as swiftly and completely as possible. Instead, there is marked benefit in maintaining negative political goals in space if those rules of engagement (ROE) have broad international agreement.[217] The main benefits of ROEs in space are both a decrease in the likelihood of catastrophic attacks poisoning entire orbital regimes and decreasing the possibility of nuclear weapons use in space to produce electromagnetic pulses (EMP), which would temporarily render all electronics over a large area of Earth inert.[218] Still, negative political goals in space warfare should be limited to the greatest extent possible, essentially those rules or norms that avoid catastrophic consequences for all actors seeking positive spacepower. A ban on the use of nuclear EMPs and on the intentional weaponization of space debris would be examples of reasonable negative political goals for space warfare. Currently, this paradigm would probably limit negative political goals in a space context to barring the first use and presence of nuclear weapons and abiding by current norms of space weaponization. As Clodfelter related for the Vietnam War, an increasing number of negative political goals markedly constrained the ability of military forces to achieve positive political goals in South Vietnam.[219]

The quintessential benefit provided by spacepower, in terms of positive political goals, is the ability to provide assets perpetually or intermittently above a battlefield or area of interest, largely out of reach of most land, naval, and air weapons. The current, primary methods to exploit space access militarily have already been discussed, including communication between and within domains, intelligence and information gathering, PNT, and missile warning. Each of these is an essential function of positive spacepower, and each of these provides a benefit that no other domain can provide a modern military as efficiently or effectively.[220] Indeed, these four missions should form the core of the mission set for any independent space force currently. Yet, these are not the only possible missions to be conducted in space. Eventually, political and economic objectives in space and other domains will drive actors to expand beyond the earth and to develop precision weapon delivery, both kinetic and photonic, from space. A highly weaponized space domain with colonies beyond Earth is an inevitable, though distant, future as long as the human race survives extinction.[221]

In the future, the space domain will be seen as less of a force multiplier for other domains and more as an independent domain, as it is. Yet, the fundamental differences between space and other domains do not intrinsically mean that advocating spacepower supremacy over other domains is the most politically or militarily expedient strategy to employ spacepower or develop spacepower doctrine. Extant USSF capabilities focus on force multiplication of other domains and not independent space warfare, something unlikely to change in the near term. Rather than advocating for more independent space warfighting capabilities, such as bombing from space, an independent-minded space force should first show value to national leaders by becoming integral to warfighting in other domains. Nevertheless, whether space forces act primarily as force multipliers for military forces in other domains or as independent elements in a joint approach to warfare does not preclude the universal truth that space warfare exists to achieve positive political goals without hazarding negative ones.

The positive political goals in space should translate to the use of positive and negative spacepower in the form of ensuring capabilities remain intact (defense) or depriving enemy capability (attack). Using attack and defense in reference to spacepower as derived in the preceding chapter allows Clodfelter's connection of political goals to military objectives to be adopted nearly intact. Figure 6 provides an updated version of Clodfelter's framework, which includes space and cyber operations.[222] Space operations largely follow the same logical path as other physical domains of warfare in figure 6's framework but with a unique character, a common theme of this work.[223]

The method to translate military objective accomplishment in space is thus primarily the same process used in other domains and features many of the same pitfalls. Targeting and target prosecution in space at a tactical level should largely descend from target elimination providing military benefit. Creating an operational campaign plan, essentially a series of tactical decisions and plans executed in concert, proceeds from the outlined military objectives provided by military leadership. Determining what must be targeted, when, why, and how, should all be analyzed and determined contextually based upon the overall aims to be achieved. During space campaign operational planning, an effect denoted here as *strategic discontinuity* is most likely to occur. Strategic discontinuity is the mismatch between the operational and tactical objectives outlined in a war and the positive and negative political goals. In essence, a strategic discontinuity exists when the series of planned or executed tactical and operational military actions can never lead to the achievement of an actor's positive and negative political goals or both. Most modern western militaries excel at developing effective operational plans of war based upon a series of tactical plans and decisions to lead to the achievement of an operation's overall objectives, except in, perhaps, space and cyberspace.[224]

Practical Application of the Positive-Negative Political Goal Model in Space

Modern western militaries are also proficient at the execution of the tactical and operational levels of war, essentially the fighting of battles and campaigns.[225] Nonetheless, as Clausewitz chides, campaigns and battles without purpose are useless and profligate.[226] This point shows the fundamental strength of the model of figure 6. Military plans in space and other domains should never be formed from the ground-level up, but rather always from the top down. Political goals must drive military objectives and not the reverse. Examining extant military capabilities to determine the art of the possible as a first step in military planning rather than starting with desired political goals leads to poor results. The first and most important document for a military strategy is and should be the overall positive and negative war aims that inform a war or conflict's positive and negative political goals.

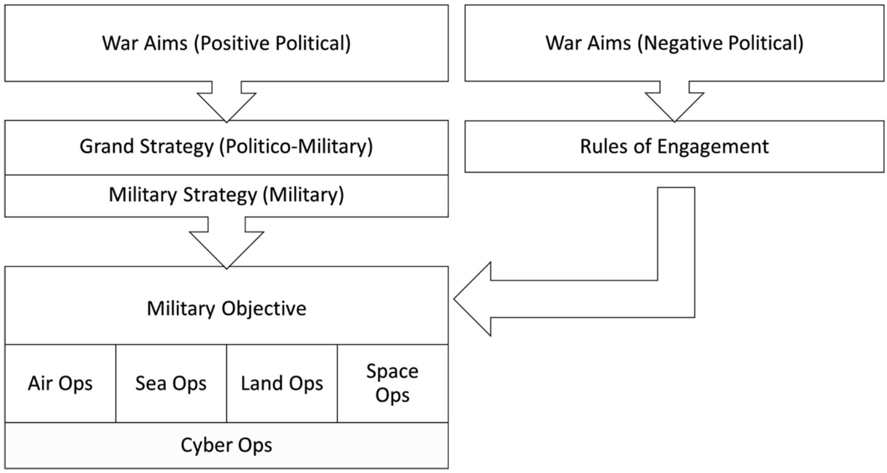

Figure 6. Model for translating military operations into political objectives (original work of the author, concept from Mark Clodfelter's *The Limits of Airpower)*

One can never remove war from its political context. Any operational plan of war must support a larger military strategy, which must, in turn, support a set of grand strategic objectives based on state policy. Space warfare will often magnify strategic discontinuities because tactical and operational decisions will often have strategic consequences due to the rarity, scarcity, and high-demand capability of many space assets. The importance of elucidating positive and negative war aims first and then developing military strategies to support those aims is essential in space warfare. The practice of dusting off old war plans and attempting to shoehorn current capabilities designed for a different war is often met with predictably poor results.[227] The weakness of previous war plans in the land, air, and sea domains, when employed in more contemporary contexts, is due, in part, to the effect of strategic discontinuities. Replicating previous war plans in the space domain is likely to be even more problematic and more dangerous due to the higher propensity for strategic discontinuities. In space warfare, it is imperative that war planning serves the function of educating and cultivating the planners, not acting as a template for a future war, aligned with Dolman's general argument in this regard.[228]

War planning and war games should not, and probably cannot, be a practical exposition of a future space war. Instead, they should be an opportunity for military leaders and staffs to prepare cognitively and create new military plans for the future. Space warfare can be both rapid and lethargic simultaneously.

As a result, planning and preparation must primarily serve to enlighten the planner and operator because it is unlikely that any previous plan will be able to capture a future political reality holistically. Space warfare planning for the foreseeable future will remain a bespoke enterprise focused on a state's available unique spacecraft defenses, singular or targeted attacks, and specific decisions to create specific battlefield conditions in space or elsewhere. The tailored nature of space conflict planning reinforces the propensity for strategic discontinuities in space war planning and the inherent need for space military professionals to cognitively train to create war plans before any conflict and then discard those plans as outdated once any conflict commences.

Chapter Conclusion

Answering how the accomplishment of military objectives in space serves military and political goals beyond the space domain starts with a recognition that all military actions exist as a subset of political discourse. Hence, any military action in space should be an expression of a broader political discourse. Military actions in space must have political intent to be war and not indiscriminate violence or destruction. The ability to achieve military objectives in and beyond space provides unique benefits to actors who possess space capabilities. Space warfare is unique but has an equivalent place to other domains of warfare. The personnel that plan and execute space warfare should, therefore, be a cadre of professionals whose focus is space warfare.

After establishing that military actions in space are a subset of a broader political discourse, this chapter adapted the airpower framework of Mark Clodfelter regarding positive and negative political goals to a spacepower context. From this hybridized spacepower-political framework, it became apparent that the achievement of political goals by military means in space rests on the ability of a military to achieve those political goals through the use (or nonuse) of military force in space. Just as in the air domain, military actions in space must support the action's political motivations—positive—without jeopardizing the actor's goals through military force employment—negative.

The framework of political and military goal accomplishment in space is akin to other domains of warfare in its lexicon. In practice, however, space warfare is much more likely to result in strategic discontinuities. These discontinuities result when planned and executed tactical and operational actions cannot or do not combine coherently to achieve the desired positive and negative political goals. As such discontinuities are more likely in space warfare, the importance of tying individual actions and plans to political goals is amplified in space conflicts. Each specific space conflict will remain a more tailored event than in other domains of warfare. The fact that space war plans will often be customized for each space military engagement does not excuse a lack of practice or willful ignorance in terms of planning for conflicts, in space or otherwise. Instead, the accomplishment of political goals using space warfare will demand singular adaptability and intellectual ability from space professionals honed through wargames and planning to prepare for each unique future conflict.

7

Implications and Recommendations

The broadest implication of this work is that space is distinct from other warfighting domains but not so different that past theories of warfare cannot inform the character and nature of space warfare. Analogies can help frame and develop a spacepower theory. If, however, a domain theory is applied to space incorrectly and only focuses on similarities, it will be largely ineffective.[229] One must also understand the physical environment and peculiarities of "space" to develop a viable spacepower theory, not just graft disparate pieces and parts that are similar to space from previous theories. If states go to war for fear, honor, and interest, as Thucydides claimed, then as more state and nonstate actors derive wealth, prestige, and military benefit directly from interests in space, war in space becomes increasingly likely.[230] Thus, space warfighting professionals must develop and prepare to fight conflicts in and through the space domain, which necessitates the creation of a distinct spacepower theory.

The differences that make the space domain unique have been the main focus of this work. Still, the purpose of this work was not to examine what makes space a separate warfighting domain by creating a list or taxonomy of its unique features. Instead, the focus of this work was to find the differences in the space domain, which seem to be the most important to understanding space warfare and spacepower as separate phenomena. Building on previous military theories, this work posited that the best place to start this examination was by developing a series of questions that would help delineate the space domain from other warfighting domains. Accordingly, chapter 2 provided a series of four questions based on the work of previous military theorists to assist with the development of defining characteristics of space warfare by asking the correct questions. The primary purpose of the interrogative framework developed in chapter 2 and answered in chapters 3 through 6 was to divine the foreseeable but independent core elements of space as a warfighting domain.

In answering the first question, "How do forces concentrate maximum effects for minimum losses in this domain?," chapter 3 demonstrated that the vastness of space, the sheer magnitude compared to Earth's terrestrial domain, and the relative rarity of spacecraft, at least volumetrically, presages preferable characteristics of certain types of weapons. The chapter found that the primary difficulty facing concentration of combat power in space lies within overcoming the "tyranny of time and distance" in a vast domain.[231] Weapons that overcome that challenge quickly if not instantaneously through the EMS, like lasers, jammers, and HPMs, will provide a greater benefit over those that concentrate combat power slowly by comparison, such as kinetic weapons. The current intellectual and doctrinal focus on kinetic space weaponry diminishes the US's holistic approach to space. The alarmist discourse on kinetic weapons reduces funding for nonkinetic weapon development, constrains researching US space asset defenses against nonkinetic weapons, and skews developing military and civilian space professionals who understand a realistic continuum of space conflict and competition and the distinction between the two. The US military and USSF must prepare accordingly by creating defenses against nonkinetic space weaponry and accelerating the development of its own nonkinetic space weaponry or face continual harassment by other states, eventually losing the strategic advantage. The US Department of Defense and intelligence community must begin declassifying and discussing nonkinetic capabilities in both war planning and professional military education. Without the ability to communicate, planners and would-be strategists cannot connect and relate the gamut of space capabilities beyond weaponized debris, robotic arms, and direct ascent weapons, such as laser, jamming, and other photonic threats, to appropriate US responses. Increasingly, space warfare and space commerce are fields as complex and lucrative as terrestrial warfare and commerce. Nevertheless, because the positive and negative control of space are different than the control of territory on the ground, the US and USSF must approach the space domain as a whole, consisting of both space commerce and space warfare, from a unique perspective.

Further, chapter 3 identified the concepts of positive spacepower (benefit) and negative spacepower (deprivation). Actors accrue spacepower's benefits by one set of precepts and deprive those benefits by a completely different set. The chapter then described a positive spacepower continuum of competition and a negative spacepower continuum of conflict to illuminate the result of actions in the space domain with regard to competition, conflict, and war. In sum, chapter 3 showed that the physical conditions and peculiarities of the space environment make analogizing space warfare from terrestrial domains questionable. The concentration of spacepower presents challenges foreign to other domains of warfare. Therefore, to master spacepower, one should treat it as a separate subject from other military theories to achieve maximum benefits with minimal costs.

The subject of chapter 4 was to answer "how do forces communicate and reconstitute in this domain?" and thus examine lines of communications (LOC) in space called CLOCs. CLOCs are primarily based upon the EMS because, in general, spacecraft move too quickly or are too far apart from other spacecraft to operate by any other extant communication methods. Second, CLOCs are based on the "physical" lines of communication constituted by space launch. Because CLOCs are often photonic, controlling and maintaining superiority over the EMS becomes a vital subset of space superiority. An actor or state without spectrum superiority cannot have space superiority or freedom of movement in space. Chapter 4 also demonstrated that the reconstitution or supply of spacecraft occurs primarily by either launching new assets and equipment from Earth or by spacecraft gaining power from the sun for power generation. The process of reconstitution for spacecraft is near-universal in adoption, presenting an avenue rife for exploitation in warfare. Preparing redundancy and alternate paths of reconstitution should be a primary focus for spacecraft and infrastructure design to lessen the singular nature of spacecraft reconstitution. Much as with other domains of warfare, in space, the particular methods that actors commonly use to communicate and reconstitute their spacecraft should be the primary avenues for a successful attack and the venues for an effective defense. Hence, EMS superiority and assured reconstitution of spacecraft are essential elements of successful warfighting in space. These two areas should be priorities for space warfighting professionals in the same way communications and logistics are for terrestrial warfighting professionals.

Chapter 5 explored the question: "How does one attack and defend oneself from attack in this domain?" Initially, attack and defense in space appear to be indistinguishable, at times, due to the blending of the strategic and tactical levels of space warfare. However, by defining attack and defense in the context of positive and negative spacepower, chapter 5 showed a process for regaining a set of definitions approaching the more traditional, terrestrial meaning of each term. Attack is attempting to employ negative spacepower to deprive another's positive spacepower. Defense is attempting to stop or mitigate a deprivation of one's own positive spacepower. Applying these recovered definitions of attack and defense, the chapter then investigated the process for employing attack and defense in practice by actors. The result was that spacepower's gain and loss, in general, should evolve as independent "games" from a game theory approach. The cost of depriving spacepower is significantly less than the cost of gaining spacepower. Therefore, the number of entrants into the game of possessing negative spacepower should be greater than the number of actors in the game of gaining positive spacepower. In effect, possessing spacepower functions as a two-level game.[232] As spacepower's benefits become more potent and economically concentrated, the number of states that seek only negative spacepower will increase, making space a more intensely competitive domain. Further, because actors can possess negative spacepower assets without ever leaving the earth, most actors may exclusively build weapons designed to offset another state's positive spacepower asymmetrically. Defending spacecraft and all related infrastructure, something which has been somewhat of an afterthought heretofore, will soon become a necessity.

The penultimate chapter 6 examined the question: "How can an actor translate the achievement of military objectives in this domain to the accomplishment of military or political objectives beyond this domain?" The central insight of chapter 6 was that spacepower exists primarily to connect other domains and improve commerce, diplomacy, information transfer, or warfighting in those domains currently. Spacepower is not an end unto itself, or at least it should not be. Ultimately, the process of making space war strategy and employing spacepower assets must serve the greater purpose of national political strategy. Attempting to fight wars through space alone is not likely to prove useful for the foreseeable future. Instead, the main benefit of positive spacepower is to act as a force-multiplier for other, cheaper domains. Hence, any space strategy, tactic, or mission that is not subordinate to a more extensive set of political calculations and a broader national strategy is likely to be ineffective and counterproductive. The benefits of space lie in the ability to synthesize and improve the effectiveness of national power in other domains by acting as the "ultimate high ground."[233]

This work has not presented a wholly rigorous theory of warfare in space. There are not enough historical examples of space warfare to inform the development of a general theory of space warfare. Any proposed general theory of space warfare is merely an educated guess with no data to validate it and is therefore not an actual theory because it cannot be tested, falsified, or disproved. Still, the preceding discussion leads to three primary areas for further research and policymaking. First, explorations of the fundamental differences of employing weaponry in the space domain should be an area of continued research and theoretical investigation. Second, the process for gaining and maintaining spectrum superiority, space EW, is in its theoretical and practical infancy. A major element of creating space-mindedness and building a cadre of space warfighting personnel should revolve around the improvement and honing of spectrum and photonic warfare and understanding the differences in application to the continuums of competition and conflict. Third, optimizing defense protocols and building spacecraft with attack and defense against EMS threats in mind should be an area of both research for spacecraft designers and policymaking by national security space leaders. None of these areas of study alone will constitute a general theory of space warfare. Indeed, such a theory is probably decades away, at best. Nevertheless, the process of educating space professionals to fight in the space domain cannot wait for a validated, generalized theory. To begin this process, rather than form a generalized theory of space warfare, this work has attempted to suggest a series of questions that can serve as an initial framework, a theoretical foundation, to influence future thinking, conceptualizing, doctrine, and warfighting for space.

Notes

(All notes are presented in shortened form. See bibliography for full entries.)

1. Gray, "The Post GPS-Only Era"; and Air Force Space Command and National Reconnaissance Office, "Concept of Operations for Space Warfare in Multi-Domain Conflict 2025."

2. Gagnon, McLeod, and Thompson, "Space as a War-Fighting Domain," 6.

3. Mitchell and Ehlers, *Winged Defense: The Development and Possibilities of Modern Air Power*, 3–4.

4. United States Space Force, "Space Capstone Publication: Doctrine for Space Forces," 13. The USSF capstone document does not actually define spacepower as a concept. It defines national spacepower as "the totality of a nation's ability to exploit the space domain in pursuit of prosperity and security."

5. Clausewitz, *On War*, 357–59. Clausewitz claims that positive and negative objective represent a true polarity in most cases, though in practice this does not hold for all cases. Sometimes a positive objective and a negative objective to counter it are not mutually exclusive. For example, if one state takes a city the other state may raise guerilla forces to harass the enemy, but without the explicit aim of retaking the city.

6. Arreguin-Toft, "How the Weak Win Wars: A Theory of Asymmetric Conflict."

7. Logsdon, "A Day Without Space."

8. Klein, *Space Warfare: Strategy, Principles and Policy*; Dolman, *Astropolitik: Classical Geopolitics in the Space Age*; and Logsdon, "A Day Without Space."

9. Ziarnick, *Developing National Power in Space*; Dolman, *Astropolitik*; Gray, "The Post GPS-Only Era"; and Klein, *Space Warfare: Strategy, Principles and Policy.*

10. Ziarnick, *Developing National Power in Space*, 25–26.

11. Dolman, *Astropolitik,* 180–81.

12. Olsen, *A History of Air Warfare*, 217.

13. This is wholly unlike the land or sea domain where the acquisition and use of territory for activities like farming, infrastructure building, or shipping are often much lower than the cost of maintaining a military or a navy. Further, as note 5 implied, in all modern war-fighting domains a positive and negative construction of military power and aims does not represent a true polarity, but only a seeming polarity in most cases.

14. Dolman, *Astropolitik*, 1–3; Klein, *Space Warfare: Strategy, Principles and Policy*, 1–3; and Ziarnick, *Developing National Power in Space*, 22–26.

15. "Space Capstone Publication: Doctrine for Space Forces," 13.

16. Clausewitz, *Vom Kriege*, xi. Translated from the German original "Krieg nichts ist als die fortgesetzte Staatspolitik mit anderen Mitteln" by the author. The main reason that the author chose not to use the Paret translation for this quote is that the Paret translation omits the words "state politics." To the author, the English words state politics seem to convey Clausewitz's underlying meaning more fully that war is an element of armed national discourse.

17. Gray, *The Strategy Bridge*, 1, 106.

18. Gray, 1.

19. Clausewitz, *On War*, 61.

20. Hanson, *The Western Way of War*, xv–xvii.

21. Gagnon, McLeod, and Thompson, "Space as a War-Fighting Domain."

22. Paret, Craig, and Gilbert, *Makers of Modern Strategy from Machiavelli to the Nuclear Age*, 444–45.

23. Alfred Thayer Mahan, *The Influence of Sea Power Upon History 1660-1783* (New York: Dover Publications, Inc., 1890), 1–5.

24. Paret, Craig, and Gilbert, *Makers of Modern Strategy from Machiavelli to the Nuclear Age*, 463; and Mahan, *The Influence of Sea Power Upon History 1660-1783,* 1–10. Mahan was promoted to rear admiral after retirement and his publication of this work.

25. Tolstoy, *Anna Karenina*, 1. This is functionally a form of the Anna Karenina principle. In the first line of the classic novel Tolstoy insinuates that every unhappy family is unhappy because of a lack of something, but all happy families must be "the same." In essence, a happy family (or nation) must possess no great dearth of resources in any area. This has become known as the Anna Karenina Principle.

26. Mahan, *Mahan on Naval Warfare*, xix.

27. Corbett, *Some Principles of Maritime Strategy*, x–xx.

28. Corbett, x–xx.

29. Corbett, 25–29.

30. Corbett, 341–42.

31. Corbett, 91.

32. Corbett, 15.

33. Chairman Joint Chiefs of Staff, "Joint Publication 3-0: Joint Operations," I–3.

34. Corbett, *Some Principles of Maritime Strategy*, 94.

35. Corbett, 334–35.

36. Douhet, *The Command of the Air*, 9–10.

37. Douhet, 235.

38. Mitchell and Ehlers, *Winged Defense*, 34.

39. Douhet, *The Command of the Air*, 9–10.

40. Douhet, 23.

41. Douhet, 251, 257.

42. Douhet, 224–25.

43. Douhet, 9–10.

44. O'Brien, *How the War Was Won*, 1–6.

45. Overy, *The Bombers and the Bombed*, 229–30.

46. Douhet, *The Command of the Air*, 9. Douhet's failing to acknowledge the multidomainal nature of warfare is a mistake of many zealots; in embracing their ideologies' unique character, they fail to see the overall nature of the world is determined by more than one ideology. Each domain of warfare is but a string in a greater tapestry of world politics.

47. Douhet, *The Command of the Air*, 252.

48. Douhet, 10, 52.

49. Clodfelter, *The Limits of Air Power*, 209.

50. Clodfelter, 212.

51. Clodfelter, 209–10.

52. Clodfelter, 223.

53. Clodfelter, xi. 212.

54. McNeill, *The Pursuit of Power*, ix.

55. Technological advances could require a reworking of a specific precept or possibly an entire section of this work. Readers should assure themselves that the author has missed many of the possible changes in technology and space warfare which will come in the future, but the power of starting an examination of warfare by asking the correct questions remains unassailable. The answers will change, but the questions should not. Asking the right questions means that when changes do come, the path to reformulating a theory of war can follow the same logic to different conclusions.

56. Clausewitz, *On War*, 95.

57. Dawson, *War in Space*, 46–47; and US Space Force, "Space Capstone Publication: Doctrine for Space Forces," 10.

58. Dolman, *Astropolitik*, 65–66.

59. Dolman, 66–67.

60. Wright et al., *Space Orbits Physics of Space Security: A Reference Manual*, 40–42.

61. The author performed the calculations contained on this and the preceding page to calculate volumes of orbital planes using area and positional information provided from listed citations about the location of orbital planes and the size of the earth with the assumption that a 100-kilometer volume rising 90 kilometers from the earth's surface and extending ten kilometers below the surface is roughly the human-occupied volume of the earth.

62. Biaocchi and Welser, *Confronting Space Debris*, 1; and Dawson, *War in Space*, 51.

63. Dolman, *Astropolitik* 65-6; and Wright, *Space Orbits Physics of Space Security*, 42.

64. Reesman and Wilson, "The Physics of Space War," 1.

65. Union of Concerned Scientists, "Satellite Database." The average mass of satellites in this database is 1,307 kg. The total number of active satellites is 3,372 with another 3,000 or so pieces of active space debris. Assuming that each piece of debris also has an equal mass (a gross overestimate), the total mass of all space objects in Earth orbit would be approximately 3,800 metric tons. The total weight of US Navy Arleigh Burke–class destroyer is 9,500 long tons or about 2.25 times more.

66. Reesman and Wilson, "The Physics of Space War," 1. As a note, if objects could travel faster than light this would also be impactful, but the current understanding of relativity does not allow for superluminal travel. Further, prophesied wormholes or warp drive are not technically superluminal but change the nature of locality.

67. Joint Chiefs of Staff, "Joint Publication 3-14: Space Operations," II–2.

68. Defense Intelligence Agency, "Challenges to Security in Space," 9–10.

69. Defense Intelligence Agency, 10.

70. Reesman and Wilson, "The Physics of Space War," 1–7.

71. Reesman and Wilson, 4–9.

72. Dawson, *War in Space*, 49.

73. Reesman and Wilson, "The Physics of Space War," 7–8.

74. Reesman and Wilson, 5.

75. Baird, "Maintaining Space Situational Awareness and Taking It to the Next Level," 61–62.

76. Baird, 58–61.

77. Biaocchi and Welser, *Confronting Space Debris*, 2; and Dawson, *War in Space*, 50–51.

78. Dawson, *War in Space*, 49.

79. Brodie, *Strategy in the Missile Age*, viii.

80. Dawson, *War in Space*, 13; and Paikowsky, *The Power of the Space Club*, 12.

81. Defense Intelligence Agency, "Challenges to Security in Space," 10, 19-20, 26-27.

82. Joint Chiefs of Staff, "JP 3-14," II–2.

83. Defense Intelligence Agency, 10–11.

84. Defense Intelligence Agency, 10–11.

85. Elert, "Electromagnetic Spectrum."

86. NASA Jet Propulsion Laboratory (JPL), "The Fastest Man-Made Objects in the Universe."

87. Jackson, *Classical Electrodynamics*, 523–24.

88. Jackson, 309–16, 326.

89. Jackson, 309–16, 326.

90. Harrison et al., *Space Threat Assessment 2021*, 6–7.

91. The words stated in the above paragraph are based upon the author's decade-long experience of design of optical and radio systems.

92. Klein, *Space Warfare: Strategy, Principles and Policy*, 6.

93. Dolman, *Pure Strategy*, 37–40. This is following Dolman's argument that in Vietnam ignoring certain criteria led conceivably to the US failure. In general terms, for negligence in warfare, one can either acknowledge one's negligence or wait for the enemy to exploit it.

94. McDougall, *The Heavens and the Earth*, 361–63.

95. Dolman, *Astropolitik; Klein, Space Warfare: Strategy, Principles and Policy*; Lupton, *On Space Warfare: A Space Power Doctrine*; and Smith, "Security and Spacepower." This note is simply to establish the density of literature on positive spacepower.

96. Lutes, *Toward a Theory of Spacepower*, 104.

97. Defense Intelligence Agency, "Challenges to Security in Space," 8–9; and USSF, "Space Capstone Publication: Doctrine for Space Forces," 12–14.

98. Paikowsky, *The Power of the Space Club*, 14.

99. Dawson, *War in Space*, 13; and Paikowsky, *The Power of the Space Club*, 12.

100. Klein, *Space Warfare: Strategy, Principles and Policy*, 19, 38.

101. Whitman Cobb, *Privatizing Peace: How Commerce Can Reduce Conflict in Space*, x.

102. Copeland, *Economic Interdependence and War*, 78–85. See table 2.7 in this resource, which lays out a summary of Copeland's findings.

103. Buchanan, *The Hacker and The State*, 94–107; and Mandiant, "APT1: Exposing One of China's Cyber Espionage Units."

104. Klein, *Space Warfare: Strategy, Principles and Policy*, 7–8; and Paikowsky, *The Power of the Space Club*, 22–23.

105. Even Antarctica, which has numerous treaties governing its peaceful use and with less, but not an absolute dearth, of resources compared to other continents, has seen armed expeditions by many states' militaries to enforce claims including Chile, Argentina, the United States, the United Kingdom, Brazil, Australia, and New Zealand.

106. Shou Xiaosong, *Science of Strategy*, 179. Chinese original translated by the author. The quoted text is from section 1, subsection (1), second paragraph, second sentence, beginning with the second comma on page 179. Chinese Original: 空间系统成为信息时代，信息社会的基本支撑，空间活动对军事领域的影响更加明显. Note the slight change of punctuation with the deletion of the first comma from the original's appositive clause.

107. Klein, *Space Warfare: Strategy, Principles and Policy*, 155; and McNeill, *The Pursuit of Power*, 215.

108. Highfill, Jourard, and Franks, "Preliminary Estimates of the U.S. Space Economy"; OECD, "The Space Economy in Figures"; and OECD, *OECD Handbook on Measuring the Space Economy.*

109. Whitman Cobb, *Privatizing Peace: How Commerce Can Reduce Conflict in Space*, 6.

110. Cicero, *The Orations of Marcus Tullius Cicero*, Fifth Phillipic, Ch 5. The original Latin of the quote is: *"nervos belli, pecuniam infinitam"* or "the sinews of war are infinite money."

111. Klein, *Space Warfare: Strategy, Principles and Policy*, 163–64.

112. USSF, "Space Capstone Publication: Doctrine for Space Forces," 10.

113. An exception is McDougall, *The Heavens and the Earth: A Political History of the Space Age*. This work offers a broad history of the military use of space and is used as a reference for the interested reader.

114. Dawson, *War in Space*, 12–13.

115. "Space Capstone Publication: Doctrine for Space Forces," 23–26.

116. Burt, "Space Power in Small Wars: The End of Asymmetric Advantage?"; and USSF, "Space Capstone Publication: Doctrine for Space Forces," 23–44.

117. Joint Chiefs of Staff, "JP 3-14," II–2.

118. USSF, "Space Capstone Publication: Doctrine for Space Forces," 25–26.

119. Highfill, Jourard, and Franks, "Preliminary Estimates of the U.S. Space Economy."

120. Corbett, *Some Principles of Maritime Strategy*, 15–18.

121. Corbett, 15.

122. Chairman Joint Chiefs of Staff, "Joint Publication 4-0: Joint Logistics," I-1.

123. Klein, *Space Warfare: Strategy, Principles and Policy*, 51–59.

124. Klein, 55-7.

125. USSF, "Space Capstone Publication: Doctrine for Space Forces," 25–26. Spectrum superiority is probably rightly thought of as a subset of superiority in all military

domains, but I will leave such a claim to future theorists concerned with more than just the space domain.

126. Klein, *Space Warfare: Strategy, Principles and Policy*, 22–24.

127. NASA, "Introduction to the Electromagnetic Spectrum."

128. Klein, *Space Warfare: Strategy, Principles and Policy*, 24.

129. Klein, 10–11.

130. Corbett, *Some Principles of Maritime Strategy*, 91–94; and Klein, *Space Warfare: Strategy, Principles and Policy*, 24.

131. Klein, *Space Warfare: Strategy, Principles and Policy*, 25.

132. Reesman and Wilson, "The Physics of Space War."

133. Harrison et al., *Space Threat Assessment 2021*, 4.

134. Siegman, *Lasers*, 1–4.

135. Harrison et al., *Space Threat Assessment 2021*, 3–7; and Reesman and Wilson, "The Physics of Space War," 3.

136. Dolman, *Astropolitik*, 156–65; and Klein, *Space Warfare: Strategy, Principles and Policy*, 91.

137. Craig, *Destroying the Village: Eisenhower and Thermonuclear War*, x.

138. Corbett, *Some Principles of Maritime Strategy*, 209–10.

139. Corbett, 315.

140. By payload this work always means the broader definition of the primary mission for any possible spacecraft or element therein, which encompasses manned and unmanned craft.

141. Brown, *Elements of Spacecraft Design*, 315–16, 336.

142. Brown, 315–17.

143. Dawson, *War in Space*, 13, 28–30. Despite the existence of and open-source speculation about the X-37B its stated mission does not include spacecraft repair.

144. Corbett, *Some Principles of Maritime Strategy*, 91–95; and Mahan, *Mahan on Naval Warfare*, 1.

145. Mahan, *Mahan on Naval Warfare*, 1–3, 227.

146. Dawson, *War in Space*, 1–10.

147. Highfill, Jourard, and Franks, "Preliminary Estimates of the U.S. Space Economy."

148. Davenport, *The Space Barons: Elon Musk, Jeff Bezos and the Quest to Colonize the Cosmos*, 4, 267.

149. Olsen, *A History of Air Warfare*, 24.

150. Olsen, 24–25.

151. Whitman Cobb, *Privatizing Peace: How Commerce Can Reduce Conflict in Space*, 107.

152. Davenport, *The Space Barons*, 4, 53, 139, 126.

153. Beames, "Elon Musk Was Right."

154. Dawson, *War in Space*, 18–27; Harold, *Defeat, Not Merely Compete*; and Weichert, "Preparing for a Russian 'Space Pearl Harbor.'"

155. USSF, "Space Capstone Publication: Doctrine for Space Forces," 13.

156. Dawson, *War in Space*; Dolman, *Astropolitik*; and Klein, *Space Warfare: Strategy, Principles and Policy*. All three of these authors use the ideas of attack and defense throughout their works but offer no broad definition for the terms in a space-centric context.

157. Clausewitz, *On War*, 357.

158. Clausewitz, 216.

159. Asprey and Mazal Holocaust Collection, *The German High Command at War*, 304–5.

160. Putnam, "Diplomacy and Domestic Politics, 427.

161. Dolman, *Pure Strategy*, 14; and Gray, *The Strategy Bridge*, 20–21. The citations here are used here to establish that a wealth of literature discusses the relationship between the tactical, operational, and strategic levels of warfare, but very little of this literature is space focused.

162. Curtis E. LeMay Center for Doctrine Development and Education, "Annex 3-14 Counterspace Operations: Space Service Support." As a note to the reader, this document does not have page numbers.

163. Curtis E. LeMay Center for Doctrine Development and Education.

164. Curtis E. LeMay Center for Doctrine Development and Education. From the January 25, 2021, update.

165. Mearsheimer, *The Tragedy of Great Power Politics*, 135; and Paret, Craig, and Gilbert, *Makers of Modern Strategy from Machiavelli to the Nuclear Age*, 866.

166. Olsen, *A History of Air Warfare*, 378–81.

167. Mao, *Mao on Warfare*, 189.

168. Kalyvas, *The Logic of Violence in Civil War*, 195–97.

169. Mao, *Mao on Warfare*, 191–93.

170. Guevara, Loveman, and Davies, *Guerrilla Warfare*, 2004, 55.

171. Jordan et al., *Understanding Modern Warfare*, 226.

172. In military writings, asymmetric warfare can refer to either a difference in overall power between actors or a difference in tactics and strategy. In this work, I use the former definition to refer to an asymmetric power imbalance. The latter definition I employ for symmetry versus asymmetry with regard to employment of a tactical or strategic approach. I use symmetry or asymmetry to refer to a difference in the methods two actors seek or employ spacepower either tactically or strategically. This is distinguishable in the text from a difference between power in terms of space asset accumulation termed an asymmetric power balance or imbalance in this work.

173. Mahan, *Mahan on Naval Warfare*, 33.

174. Lefebvre, *Space Strategy*, 108.

175. Kalyvas, *The Logic of Violence in Civil War*, 192–227.

176. Dawson, *War in Space*, 35–36.

177. Fuller, *The Foundations of the Science of War*, 201.

178. Asymmetry does not obviate use of KKVs but rather suggests that use of KKVs by both sides will be rare.

179. Dolman, *Astropolitik*, 112–20, 130–33; and Dembling and Arons, "The Evolution of the Outer Space Treaty," 419–56. The prevailing legal opinion is that all nations

have an equal right to access space and that space is therefore an unowned area for all nations to operate in freely.

180. Cronin, *Power to the People*, 71, 136.

181. Whitman Cobb, *Privatizing Peace: How Commerce Can Reduce Conflict in Space*, 25–29. Whitman Cobb does not mention mining, but I add that to her list simply because it is also a way that most nations could exploit space economically.

182. Dolman, *Astropolitik; Klein, Space Warfare: Strategy, Principles and Policy*; Lefebvre, *Space Strategy*; and Ziarnick, *Developing National Power in Space.*

183. Curtis E. LeMay Center for Doctrine Development and Education, "Annex 3-14 Counterspace Operations: Space Service Support."

184. Liddell Hart, *Strategy*, 339–40.

185. Liddell Hart, 343–47.

186. Liddell Hart, 347–50; and Fuller, *The Foundations of the Science of War*, 148.

187. Dawson, *War in Space*, 13–14; Reesman and Wilson, "The Physics of Space War"; *Solomone, China's Strategy in Space*, 99; and Weichert, "Preparing for a Russian 'Space Pearl Harbor.'"

188. Putnam, "Diplomacy and Domestic Politics," 435.

189. Putnam, 430–33.

190. Putnam, 433–35.

191. Schelling, *Arms and Influence*, 123.

192. Johnson-Freese, *Space as a Strategic Asset*, 167; and Moltz, *The Politics of Space Security*, 336, 363.

193. Olsen, *A History of Air Warfare*, 177, 275, 279, 391–93.

194. Mattis, "Summary of the 2018 National Defense Strategy of The United States of America1; Harrison et al., *Space Threat Assessment 2021*, 8–17; and Defense Intelligence Agency, "Challenges to Security in Space," 13–30.

195. Tellis, "India's ASAT Test: An Incomplete Success," 1.

196. Khan and Khan, "Space Security Trilemma in South Asia," 4–5; Dawson, *War in Space*, 13; Defense Intelligence Agency, "Challenges to Security in Space," 31–32; Harrison et al., *Space Threat Assessment 2021*, 17–24; and Paikowsky*, The Power of the Space Club*, 12, 21, 66.

197. Harrison et al., *Space Threat Assessment 2021*, 17–24; and Defense Intelligence Agency, "Challenges to Security in Space," 31–32.

198. Buchanan, *The Hacker and the State*, 279–84.

199. Dawson, *War in Space*, 13–14; and Paikowsky, *The Power of the Space Club*, 12, 20–21.

200. Clausewitz, *On War*, 40.

201. Clodfelter, *The Limits of Air Power*, 223.

202. Clodfelter, 212, 217.

203. Clodfelter, 215.

204. Gray, *The Strategy Bridge*, 134.

205. "Space Capstone Publication: Doctrine for Space Forces," 13–14.

206. Dolman, *Pure Strategy*, 149; and Fernandez, "Space Theory and Strategy," 1.

207. Fernandez, "Space Theory and Strategy," 1.

208. Biddle, *Rhetoric and Reality in Air Warfare*, 293–300; Crane, *American Airpower Strategy in Korea*, 1950–1953, 171; Clodfelter, *The Limits of Air Power*; and Pape, *Bombing to Win: Air Power and Coercion in War*, 36–37, 55.

209. Corbett, *Some Principles of Maritime Strategy*, 15.

210. Corbett, xxv.

211. Clodfelter, *The Limits of Air Power*, 211–12.

212. Clodfelter, 217.

213. Dawson, *War in Space*, 91–92; Dolman, *Astropolitik*, 128–33; and Johnson-Freese, *Space Warfare in the 21st Century*, 12.

214. Cheng, "Article VI of the 1967 Space Treaty Revisited," 32.

215. Dolman, *Astropolitik*, 128–33.

216. Johnson-Freese, *Space Warfare in the 21st Century*, 58.

217. Whitman Cobb, *Privatizing Peace: How Commerce Can Reduce Conflict in Space*, 8.

218. Dawson, *War in Space*, 46–49; Hebert, "Regulation of Space Weapons," 4; Moltz, *The Politics of Space Security*, 124; and Klein, *Space Warfare: Strategy, Principles and Policy*, 75.

219. Clodfelter, *The Limits of Air Power*, 206–7, 216–7.

220. USSF, "Space Capstone Publication: Doctrine for Space Forces," 13–19, 38.

221. Astute evaluations on the timeliness of this future are beyond both the scope of this work and its author, but such a future's occurrence barring human extinction is as assured as any future event can be. This statement could be said another way as, on a long enough timeline space will become weaponized and humans will leave Earth to populate other worlds simply because neither time nor the human race has ended.

222. Clodfelter, *The Limits of Air Power*, 217.

223. As shown in figure 6, cyber operations, which this work does not seek to investigate in-depth, are essential to all domains of warfare but only exist as a construct outside of physical domains. Cyber assets must exist simultaneously with a physical component of that asset in residing in another domain. Computer networks have physical architecture. Signals must travel through wires, air, or space between physical assets. Figure 6 illustrates the foundational importance of cyber operations to connect all other domains by placing cyber operations below all other domain operations to serve as a conduit within and between domains. Cyber operations are essential to modern warfighting and should be seen as a separate domain; however, this domain only exists in the presence of other domains. The cyberspace domain can never be analyzed in absentia from other domains. Cyberwarfare and cyberpower should be an active field of study, but the unique nature of the cyber domain necessitates an approach that is more symbiotic and integrated than in other domains forcing this study to largely neglect cyberpower as a unique phenomenon for brevity. Still, the questions developed in chapter 2 could help frame any future analysis.

224. Gray, *The Strategy Bridge*, 20, 80, 212.

225. Gray, 212, 223, 238.

226. Clausewitz, *On War*, 213, 628.

227. Rosen, *Winning the Next War*, 259-60.

228. Dolman, *Pure Strategy*, 28–30.

229. Khong, *Analogies at War: Korea, Munich, Dien Bien Phu, and the Vietnam Decisions of 1965*, 14.

230. Strassler, Crawley, and Hanson, *The Landmark Thucydides*, 43.

231. Grau and Kipp, "The Tyranny of Time and Distance," 1.

232. Putnam, "Diplomacy and Domestic Politics," 427.

233. Fernandez, "Space Theory and Strategy," 1.

Abbreviations

BDA	battle damage assessment
CLOC	celestial lines of communication
DOD	Department of Defense
DSC	defensive space control
EMP	electromagnetic pulse
EMR	electromagnetic radiation
EMS	electromagnetic spectrum
EW	electronic warfare
GEO	geosynchronous orbit
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
HEO	highly elliptical orbits
HPM	high-power microwaves
IAD	integrated air defense
INS	inertial navigation system
ISR	intelligence, surveillance, and reconnaissance
JPL	Jet Propulsion Laboratory
KKV	kinetic kill vehicle
LEO	low Earth orbit
LOC	lines of communications
MEO	medium Earth orbit
OSC	offensive space control
PNT	position, navigation, and timing
ROE	rules of engagement
RPO	rendezvous in proximity operations
SSA	space situational awareness
USAF	United States Air Force
USG	United States Government
USSF	United States Space Force

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