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A core body of scientific knowledge must serve as the foundation for national security activities in space, applied especially to domain orientation. One-to-one warfighting domain analogies are no longer viable in describing the space domain. Warfare analogies imported from the sea domain and applied to space, for example, do not work. We must establish a corpus of knowledge that marries space science with military framing. Importing principles from other domains (e.g., control of the sea or maritime law from the sea domain and applying it to space) is misguided and limiting. With a cosmic perspective, the warfighter can proceed with securing a complete standalone domain upon which to build a military theory.

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MASTER OF MILITARY STUDIES

A COSMIC PERSPECTIVE FOR THE WARFIGHTER:
WHY THE SPACE DOMAIN MUST STAND ON ITS OWN

SUBMITTED IN PARTIAL FULFILLMENT
OF THE REQUIREMENTS FOR THE DEGREE OF
MASTER OF MILITARY STUDIES

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Executive Summary

Title: A Cosmic Perspective for the Warfighter: Why the Space Domain Must Stand on Its Own

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Thesis: When considering national security aspects of the space domain, there is a certain cosmic perspective that must serve as the scientific foundational base in order to foment any military power theory, doctrine, or policy developed therein.

Discussion: This paper advocates for a core body of scientific knowledge to serve as the foundation for national security activities in space, applied especially to domain orientation. With the establishment of the Space Force in 2019, one-to-one warfighting domain analogies are no longer viable in describing the space domain. Warfare analogies imported from the sea domain and applied to space, for example, do not work. If we are to simultaneously train space operators, educate the public, and advance the United States' position as a space leader, we must establish a corpus of knowledge that marries space science with military framing. We must be space-oriented with no other domains serving as distracting places to start. While extra-domain analogies are useful in terms of studying human achievement, military abstraction, the limits of science, and other strategic frameworks, importing principles from other domains (e.g., control of the sea, or maritime law from the sea domain, as applied to space) is misguided and limiting. First, the discussion expands on Elizabeth Mendenhall's six major features of the near-Earth space environment to help caution these dangers. Second, the paper showcases Neil deGrasse Tyson and Avis Lang's alliance theory which links the relationship between astrophysics and US national security objectives in space. Finally, the paper offers a science education-based approach to synthesizing the cosmos through adult-learning concepts by introducing Jeffrey Bennett's book, *The Cosmic Perspective*. With this orientation, the warfighter can proceed with securing a complete standalone domain upon which to build a military theory.

Conclusion: Extra-domain analogies are intellectually lazy—the equivalent of fitting a square peg through a round hole, cognitively speaking. By bookending undergraduate space training with an introduction to astrophysics and cosmology, the future space warfighter will be able to harness scientific knowledge and translate domain mastery into national security advantages without relying on analogies.

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Tables

Page

Figures

Table of Contents

Page

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M.D. Sanchez
Arlington, Virginia
February 2021

Chapter 1 – Introduction: The Sea-to-Space Domain Comparison

How inappropriate to call this planet Earth when it is clearly Ocean.

– – Arthur C. Clarke, *Nature*

Outer space and human activities therein coexist with scientific and military objectives. A scientist would say space is the expanse between all matter and energy. A national security individual would call space the newest warfighting domain. Both are correct. When considering national security aspects of space, however, there is a certain cosmic perspective that must serve as a foundational base in order to foment the growth of military power theory, doctrine, and policy. This perspective exists in the scientific realm but seems to be absent as an initial point of cognitive departure for the military community. Much of the national security literature continues to misuse land and sea domains as analogies to the space domain. The goal of this paper is to show that extra-domain analogies, especially those of the sea, incorrectly import preconceptions which cannot act as substitutes for the uniqueness of space. Such preconceptions and imported artifacts muddy any endeavor to build a military theory or doctrine in the complex, unknown, and existential environment we call space. Challenges in space today and in the future will rely on a keen understanding of scientific laws and astrophysical phenomena. This body of knowledge must be unified within the operational environment due to the intersection of science, industry, and government not found elsewhere. This notion is especially significant in light of the recent establishment of US Space Command (revived in 2019), the US Space Force, and the resurgence of lunar and Martian exploration programs.

The United States Marine Corps University, in a list of suggested thesis topics for academic year 2020-21, proposes the development of a maritime strategy for space by "adapting sea power and naval warfare concepts to the space domain and national power."[1] It is not the first institution to propose such a model. In the 1996 article "The Influence of Space Power

Upon History," Colin S. Gray laments, "The influence of space power upon history is already substantial and growing, and has the potential to yield decisive advantage. Where is the theory of space power? Where is the [Alfred Thayer] Mahan for the final frontier?"[2] Gray's essay articulates technological progress in the evolution of war, and goes on to correctly identify the Gulf War as the first space war in history. But when he asks where Mahan fits into the academy, the question misleads the reader to assume that sea power is both an ideal analogy and proper foundation for developing warfighting principles in the space domain. It is not. Space is the ideal place to begin any discussion on space. Space is mired in complexity, where today's brightest thinkers share the burden of observing and understanding its shear magnitudes. These magnitudes are physical—extreme in distances, temperatures, and to-be-determined scientific findings—but also cerebral. It is therefore understandable that our minds would gravitate from the lesser-known to the usual. In a military environment, where decisions are often at the mercy of war tempo, it makes sense that principles are borrowed from other operational cognates and then projected onto a less familiar realm such as space. Our experience fighting wars from the sea, for example, are concrete, accessible, and documented. And although there may be relevant imports from the sea to space, like economic dependencies, they only seem to be useful in thought experiments. In this regard, analogies culminate early.

The sea and outer space have always had a unique relationship, especially by comparative analogy. When we observe the night sky, we may describe the expanse as a vast ocean of stars. Likewise, we attribute the shape of certain marine life to familiar objects in the night sky. For example, sea star species (starfish) are given the scientific classification name, Asteroidea.[3] Over the eons, humans have created unique relationships between the sea and space, often in philosophic, scientific, and military terms. Alexander the Great, while rampaging through India in 326 BC, is said to have invaded the land "in terms of his desire 'to reach the ends of the world and the Great Outer Sea'…"[4] It is no wonder how the term *outer space* came to be.

The history of using sea analogies to describe space traces back to ancient times. Of the 88 constellations depicted on current star charts (all of them originating in ancient Mesopotamia, Egypt, or Greece), at least a dozen of them refer to the ocean, ocean animals, or ocean gods.[5] In the 7th century BC, the Greek poet Mimne'rmus describes a west-to-east nighttime transit of the sun, saying, "The sun and stars rise and set in the Ocean."[6] In *The Iliad*, Homer speaks of "the summer star, which shines very brightly, having been bathed in the ocean."[7] In 1969, the Apollo 11 astronauts touched down in the Sea of Tranquility despite no respectable amount of water existing on the lunar surface deserving the title *sea*. There appears to be a cosmic link embedded in our collective senses originating in antiquity (at least) and extending to 20th century military strategists whom first advocated for applying sea-war concepts to space. In the 21st century, the sea-to-space comparison persists.

The idea of applying sea concepts to space, specifically in the national security context, goes back to US Navy Admiral Arleigh Burke's desire to establish a unified space command in 1959.[8] On the heels of the successful Soviet Sputnik missions in 1957-58, President Dwight D. Eisenhower recognized the need to organize a space program responsible for those activities associated with military operations (i.e., separating national security space needs from other traditional space activities). Sadly, Admiral Burke's space command idea would not see the light of day for another 26 years. The development of a space power theory based on AT Mahan and his contemporary, Sir Julian Corbett, however, has been proposed in the intervening years in works such as "Corbett in Orbit" (John Klein, 2004) and "From the Sea to Outer Space: The Command of Space as the Foundation of Spacepower Theory" (Bleddyn Bowen, 2019).[9] The analyses in these works exemplify the limitations of using existing domains to frame the space domain because they consider conducting military activity without first acknowledging requisite scientific principles which cannot be oversimplified. Artificial Earth-orbiting satellites, for example, share the domain in many unidimensional ways: launch requirements, orbit selection, deconfliction, and space environmental considerations, to name a few. Comprehension of space-specific principles is necessary for the space domain because the governing science serves to tame expectations of how military operations are conducted, especially as near-Earth satellites proliferate.[10] This notion is also indicative of the entire space enterprise as a still-foreign human undertaking, cognitively speaking—meaning, the inherent difficulties human minds encounter when thinking about space as a place are always at play. These difficulties, as well as a lack of shared experience in space, drive us to use familiar source domain analogies. Today, however, these analogies are no longer necessary, as the goals shared between scientific and military progress in space access and operations intersect and will do so as the rate of activity increases.

Chapter 2 of this paper explores the convenience of analogical thinking by revisiting John Klein's work, which considers Corbett an appropriate "historically based theoretical model" for a strategic space theory.[11] One theme that arises in articles like Klein's is the ease with which Mahan or Corbett can be repurposed by replacing key concepts and terms with the word "space" or other space-based substitutes. For example, in Klein's construction, Corbett's concept of *control of the sea* transforms into *control of space*. The idea of implementing naval blockade equivalents in space warfare also appear. The idea that one could control space is of course illogical and impossible. One could justify the existence of those terms by representing them as military strategies to upend adversarial activity or defend against them (e.g., limiting space access by controlling rocket launches). But ideas like these incorrectly and inadvertently import certain attributes of sea warfare to space when they have no place there. Trying to fit something familiar to an unknown or discomforting reality does not give room to fully exploit the potential of the unfamiliar. In a military context, this notion may hinder original thought when, say, developing tactics, techniques, or procedures for orbital operations. Removing and replacing words with *space* reduces the domain to a lesser facsimile that does not foment space-centric thinking. The chapter begins with an introduction to David Rumelhart and Donald Norman's 1980 target- and source-domain inquiry, and the idea of always-present analogical representations in human reasoning systems.

Chapter 3 takes the reader to the suddenness of the Space Race by discussing how the 1967 Outer Space Treaty forced the superpowers to agree on selecting the initial analogy for outer space. This chapter also illustrates how US and international lawyers used a high seas analogy to prescribe jurisdictional rules prior to the United Nations' first committee on space regulation in 1958. Specifically, the paper examines MJ Peterson's article, "The Use of Analogies in Developing Outer Space Law," which concludes that competing interests in treating space as a global commons rather than an appropriation led to "converging on the view that one of the underlying analogies was better than the other."[12] This notion is further discussed in Karl Leib's article, "State Sovereignty in Space: Current Models and Possible Futures," which reinforces the principles of space rights as "legal equivalent[s] of the high seas, which any state, even landlocked ones, may use."[13] The goal is not to provide further discourse on how space law should evolve, but rather to describe how current law was forced to proceed with analogical reasoning as a quick reaction to the Space Race. Such quick reactions are similar in nature to what is experienced in today's national security space arena.

The relationship between our understanding of the cosmos and military matters in space is central to Chapter 4. In this section, I summarize Neil deGrasse Tyson and Avis Lang's book, *Accessory to War*, by discussing how our knowledge of the cosmos has been a weapon of war since at least the time of Columbus. Tyson and Lang write about Columbus' successful science-based campaign to convince natives in Hispaniola to hand over their gold by threatening and spooking them with seemingly mystical powers.[14] By predicting a large, full, threatening moon on a certain calendar day and repeating the act with great accuracy, Columbus was able to easily mount a destructive offense upon the West Indies. Astronomy has had a discrete relationship with military power ever since that time, according to Tyson and Lang. Their book documents more modern examples, like the global positioning system's reliance on physics in its day-to-day operations, or the invention of adaptive optics at a US Air Force base. This advanced optical technology from the 1970s was intended to track Soviet satellites for the military, but instead became central to civilian astrophysics research when it was declassified, eventually leading to new observational techniques and the discovery of a supermassive black hole at the center of our galaxy. Tyson and Lang showcase a military-civilian astrophysics community operating in parallel, whose dependency on space access technologies—among other things—is often the same in that they are intersectional. This theme of intersectionality may help military space power theorists in the future by advocating for space as an example of domain unity.[15] Combined with General Bernard Schriever's speech in 1957, which is the first mention of the necessity for the US to achieve "space superiority," this chapter emphasizes the importance of relationship-building among science, industry, and government. Specifically, the intersectionality of all players in space (i.e., not just the military) may be the very place for new paradigms to emerge; that is to say, multiple parties may benefit from the original construction of source domain knowledge versus having to rely on extra-domain imports for their mandates.

Enter the idea of the cosmic perspective by Jeffrey Bennett et al., the main theme of Chapter 5. Bennett's book, *The Cosmic Perspective*, first published in 1998, has become the go-to textbook for non-science college majors at the undergraduate level. Bennett writes for the community learner (i.e., students of all ages with various educational goals and experiences). The author first encountered the textbook at a community college, a place where student backgrounds are perhaps more diverse than a university. This environment may also be typical of the enlisted and officer corps composition found in a military service like the Space Force. Thus, the Space Force should consider including a community learner-based approach to introducing the cosmos to its personnel by using Bennett's models. One does not need an astrophysics degree to succeed in military space operations. However, full knowledge of the space environment, or exposure to astrophysical concepts throughout one's career, will reinforce the idea of space-based thinking and decision-making. This new paradigm advances the idea of dropping other domains as a starting place in order to bolster the mastery of the space domain, which serves national security imperatives of gaining certain advantages. In the author's experience at the time of publication, Space Force members began their careers in the Air Force. In terms of doctrine development, airmindedness is likely still present especially among the ranks of senior leaders. Encountering today's officers, a few of whom have broadcasted the idea that "space is an extension of the air," are misguided due to the airminded nature of their domain development. To expel these ideas, the Space Force should start with the most fundamental topical area inherent to its domain: space.

A new, robust science-based teaching method within the Space Force should consider the influential legacies of science presented in *The Cosmic Perspective*. Specifically, there is a way to bookend Space Force training with a perspective of the universe that informs greater space orientation in a military operations context. The goal is to influence how Space Force leaders can introduce space and its grand scale with military framing. Bennett outlines unique ways to comprehend the cosmos that may enrich domain orientation. In a military learning environment, a cosmic perspective can heighten operational awareness and securely establish space as a source domain without the need for other constructs as a point of developmental departure.

The following chapters present many of the necessary aspects of space as a standalone vision impacting warfighting but also framing human understanding. In a real sense, this analysis of space manages to take the study of war to a more complete elevation ensuring a look at cognitive realities that exceed mere physical boundaries. This examination helps ensure US success in space and the endeavor of achieving better national security in not-too-distant future activities, a point which is emphasized in Chapter 6. That space is now a place for warfighting principles to exist, those principles must exist in tandem with the scientific realities of space. In this regard, space may exceed a warfighting mandate. There is a delicate approach to space because our knowledge is incomplete—not of war, but of the existential realities that limit our understanding of space as an operational domain. This notion, therefore, allows room for a certain freedom of cognitive movement in how to develop a warfighting theory, which is a positive gain to those charged with its undertaking.

Chapter 2 – The Convenience of Analogies: "Corbett in Orbit" Revisited

Analogies decide nothing, that is true, but they can make one feel more at home.
– – Sigmund Freud, *New Introductory Lectures on Psychoanalysis*

Analogies are "comparisons made between one thing and another for the purpose of explanation or clarification."[16] They are always present when a person attempts to learn a new body of knowledge.[17] They are useful and sometimes necessary when explaining complex matters. According to David Rumelhart and Donald Norman, "When we attempt to teach a child a new domain, we do not, in general, present it as an abstract piece of new knowledge. Rather, we carefully instruct the child using the knowledge already tacitly available to 'get across' the concept in question."[18] For example, consider one's approach to teaching a person with little science background (child or adult) the scale of the solar system or other cosmic distances. Imagine hearing the following: "Earth orbits the sun at a distance of $1.5x10^{11}$ meters, or about 93-million miles. The next closest star system, Alpha Centauri, is 1.5 parsecs from the earth, a distance of about $2.9x10^{13}$ miles."[19] The savviest doctoral student would have trouble visualizing such distances, let alone a child. A better technique would be writing down the distances and following with a magnitude set that is easier to grasp: "That's like putting the sun at one endzone of a football field in Washington DC, Earth on the nearest 16-yard line, and Alpha Centauri somewhere in California."[20] Rumelhart and Norman would describe the solar system scale as the target domain and the football field scale as the source domain, meaning the student is already familiar with the source material.[21] This chapter revisits John Klein's article "Corbett in Orbit" through the lens of target and source domain analysis.

Analogies are not perfect. According to Rumelhart and Norman, "Whenever one encounters a new situation, they seek to interpret it in terms of existing schemata."[22] It therefore seems reasonable that a sea-minded individual in the national security arena desires a sea-to-space analogy because of the requisite source domain knowledge. Klein acknowledges this, saying, "Maritime operations are not the same as space operations; environmental, technological, and physical factors are definitively different. Nevertheless, many of their strategic aspects are similar, and therefore they may be presumed to share certain theoretical principles."[23] For Klein, the source domain is that of Corbett's well-known naval principles transposed to a would-be space domain target. He attempts to derive a space theory "in strict keeping with Corbett's original context and strategic intent, verifying the applicability of its principles against contemporary literature."[24] Specifically, he replaces Corbettian terms with space transplants and proceeds to "test them against current expert observations and space literature to measure the theory's potential utility."[25] First, a brief summary of Corbett's principles is necessary.

Corbett based his 1907 work, *England in the Seven Years' War*, after studying Carl von Clausewitz. According to GAR Callender and James Goldrick, "this was a book which, more than any of its precursors, analysed [*sic*] the complex relationship between naval power and national policy."[26] During Corbett's era, domain analogies between the sea and land were common. In the 1911 classic, *Some Principles of Maritime Strategy*, though, Corbett cautioned against relying on domain analogies:

> You cannot argue from the one to the other, as has been to commonly done. Such phrases as the 'Conquest of water territory' and 'Making the enemy's coast our frontier' had their use and meaning in the mouths of those who framed them, but they are really little but rhetorical expressions founded on false analogy, and false analogy is not a secure basis for a theory of war.[27]

Corbett recognized that domain analogies were useful for thought experiments or general representations, but allocated two main reasons for not using them:

1. The sea cannot be conquered because it is a global commons, unlike the land domain.
2. A military force cannot subsist upon the sea as can be done on land.[28]

Corbett organized his maritime principles under three headings: *Theory of War*, *Theory of Naval War*, and *Conduct of Naval War*.[29] Klein attempts to apply Corbett's principles to space without first securing the sea and space domains as having a source-target relationship, as defined by the aforementioned Rumelhart and Norman.

Klein's article presupposes Corbett's framework is sufficient enough as an analog because it "appears to match more closely the various issues of space operations than does either air or naval theory."[30] In doing so, Klein does not offer or consider that the space domain should be allowed to stand on its own in the same way independent scientific discoveries have been made over the millennia without relying on other domain discoveries to precede. The "science" in "space science" has been, is, and will be independent of the sciences governing other domains to the degree it will not have to seek permission or wait for discoveries to be made before pursuing research. It begs the question, why then must a military activity rely on *a priori* domain experience before it continues? Klein simply uses Corbett to meet his intent. For example, he transforms Corbett's *Command of the Sea* principle to *Command of Space*, *Maritime Communications* to *Space Communications*, *Methods of Securing Control* with a space version of *blockades*, *cruisers*, and so on.[31] Table 2.1 compares Corbett and Klein:

(Continued on next page)

Table 2.1 – Examples of Corbett Repurposed for the Space Domain by Klein.	
Corbett (1911)	Klein (2004)
Command of the Sea. 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. The difference is fundamental. True, it is rightly said that strategy ashore is mainly a question of communications, but they are communications in another sense. The phrase refers to the communications of the army alone, and not to the wider communications which are part of the life of the nation.[32]	Command of Space. Command of space is the control of space communications for civil, commercial, intelligence, and military purposes. The inherent value of space is as a means of communications; therefore, space warfare must work directly or indirectly toward either securing command of space or preventing the enemy from securing it. Command of space does not mean that one's adversary cannot act, only that he cannot seriously interfere in one's actions. Additionally, the command of space will normally be in dispute.[33]
Maritime Communications. Military communications refer solely to the army's lines of supply and retreat. Maritime communications have a wider meaning. Though in effect embracing the lines of fleet supply, they correspond in strategical values not to military lines of supply, but to those internal lines of communication by which the flow of national life is maintained ashore. Consequently maritime communications are on a wholly different footing from land communications. At sea the communications are, for the most part, common to both belligerents, whereas ashore each possesses his own in his own territory. The strategical effect is of far-reaching importance, for it means that at sea strategical offence and defence tend to merge in a way that is unknown ashore. Since maritime communications are common, we as a rule cannot attack those of the enemy without defending our own. In military operations the converse is the rule. Normally, an attack on our enemy's communications tends to expose their own.[34]	Space Communications. Space communications are those lines of communications by which the flow of national life is sustained in and through space. These include strategic lines of communication, critical to a nation's survival, that serve the movement of trade, materiel, supplies, and information. By attack upon space communications, a nation can adversely affect another's civil, commercial, intelligence, and military activities, thereby reducing that nation's will to resist. The primary purpose of space warfare is to secure space communications; enemy forces that are in a position to render them unsafe must be put out of action.[35]

(Continued on next page)

Blockades.	Blockades.
In considering open blockade, three postulates must be kept in mind. Firstly, since our object is to get the enemy to sea, our position must be such as will give him an opportunity of doing so. Secondly, since we desire contact for a decisive battle, that position must be no further away from his port than is compatible with bringing him to action before he can effect his purpose. Thirdly, there is the idea of economy—that is, the idea of adopting the method which is least exhausting to our fleet, and which will best preserve its battle fitness. It is on the last point that the greatest difference of opinion has existed. A close blockade always tended to exhaust a fleet, and always must do so.[36]	[A] close blockade for space operations equates to preventing the deployment of systems from launch facilities and to interfering with communications in the vicinity of uplinks or downlinks, as well as impeding the movement of vehicles near space-based hubs. Close blockade may be achieved by physical systems or vehicles or interference measures. In Corbett's model, suppressing operations at these distribution points obliges the adversary either to submit or fight. In contrast, a more capable space power can impose an open blockade, occupying or interfering with the distant and common space lines of communication, to force an adversary into action. Like the close blockade, methods include both physical systems and interference.[37]

Klein uses two standards by which to measure the utility of his sea domain analogy; namely, a 2001 "Report of the Commission to Assess United States National Security Space Management and Organization" (aka the Space Commission Report), and Joint Publication 3-14, *Joint Doctrine for Space Operations*. The Space Commission Report and joint doctrine seem to serve as authoritative texts which grant permission to import Corbett's maritime principles. To conclude that these two documents are representative of the space literature is myopic. The plethora of scientific knowledge of the cosmos must precede military application, because its existence outdates and will survive mankind. Klein's application is thoughtful for military purposes, but disregards the astronomical magnitude of the domain, both physically and mentally. Klein's model is a forced exercise to try to fit known experience and expectations of fighting on the sea to fighting in space, an endeavor which still has yet to happen in concrete terms. The space domain is still heavily misunderstood, unknown, and recognizable to very few, which is perhaps why Klein (and others) feel it necessary to apply their knowledge of well-understood concepts to space. Though analogies may be useful frameworks to inform strategic issues in space, a theory derived from the maritime model may only be congruent with some aspects of current space-specific theory, but certainly not the whole of a military-civilian scientific body operating in parallel today. Imagine, for example, training as a naval submarine officer. Would it make sense to train, operate, and develop a new sea theory based on land maneuver warfare due to the implicit shared human experience on land? Such an idea would be rejected quickly as operationally lazy and without regard to the nature of, in this case, understanding the sea: weather, sea states, hydrology, oceanography, marine biology, and so on.

In "Treating Outer Space Like a Place: A Case for Rejecting Other Domain Analogies," Elizabeth Mendenhall argues that when we use extra-domain analogies, we inadvertently import preconceptions of law, policy, security, and other matters that fall short of material comprehension. In the spirit of Rumelhart and Norman, she would agree that analogies are useful and can succeed in certain areas. In a new or lesser-known target domain (space), since no applicable schemata may exist in terms of human experience, "the schemata used to interpret the input [could have] regions of mismatch with the input situation. In some cases, essential features of the interpreting schemata might not be present with other features in their place. Presumably, such a situation serves as a trigger for the creation of a new schema."[38]

A cognitively useful comparison between the sea and space domains may exist in the context of human achievement. The ocean and the moon serve as an example: 12 humans have walked on the moon (albeit zero since 1972); 13 humans have explored oceans depths below 35,000 feet (six in 2020 alone).[39] Only large economies tend to have large navies; only three superpowers have dominated space access since the Space Race (United States, Russia, and China). In Mendenhall's words, "the material features of space, interacting with technologies of access, shape the practices, interests, and problems that motivate the formation and operation of the outer space regime."[40] Mendenhall further contributes to the academy by describing six major features of the near-Earth space environment that are otherwise overlooked by other domain analogies: space lacks an ecology, lack of fluidity, distribution of access technology, nature of movement, infinite frontier, and existential impacts to humanity.[41] In every aspect of her analysis, Klein's model—and others like it—would fail. Table 2.2 summarizes Mendenhall:

Table 2.2 – Expanding Mendenhall's Six Major Features of the Outer Space Domain.[42]
1. Lack of Ecology – the operational space environment lacks an ecology; no ecosystems exist (so far as we know) that promote self-sustainability, renewable resources, or any other elements that would satisfy human survival needs. Though human activity is severely limited in space, similar needs for artificial satellites also cannot be satisfied by the space domain alone if they are to continue beyond their useful lifetimes.
2. Lack of Fluidity – the physical aspects of the interstellar medium cannot be experienced or used to our advantage unlike the ocean and atmosphere, both of which are governed by fluid dynamics. That is, the various states of matter on Earth are, in a way, self-contained and subject to gravity, surface tension, thermodynamics, and other planet-specific properties to the degree we can manipulate them for our gain. There is a great deal of overlap between the natural borders of other domains that do not exist in space. One could easily see, for example in naval operations, how to overcome transitioning between the land, sea, and air domains.
3. Distribution of Access Technology – oceangoing technology is ubiquitous on Earth and has been in development since the Mesolithic Age, ca. 11,500-years-ago.[43] Space access, on the other hand, requires immense infrastructure, a highly-skilled technical workforce, and a national will to deploy complex machines that are incapable of being recalled for depot-level or drydock maintenance.[44]
4. Movement – artificial near-Earth space satellites are deliberately placed in specific orbits based on their functional mission needs. They carry little onboard fuel that would allow any substantial deviation from their orbital trajectories. They also require initial conditions which demand extreme velocities not used by other military domain vehicles, and must take into account the four dimensions of space-time. A submarine or airplane may have similar difficulties with movement, but not to these ends.
5. Infinite Frontier – the universe is perhaps best described as homogenous and isotropic. The current (and best fit) model of our universe is flat with an infinite radius.[45] Where Earth frontiers have edges and soft borders, the space frontier is one that can never truly be crossed, less propulsion technology matures beyond current comprehension.[46]

(Continued on next page)

6. Existential Impacts – natural hazards on planet Earth, like weather, erosion, and sea states, have more or less been overcome through experience and technology. Naval and air operations are able to persist in what previous generations would have considered hazardous conditions. No new types of weather phenomena, volcanic eruptions, or earthquakes are likely to come into existence that could not otherwise be explained by current science. The hazards of near-Earth space are known, but to a lesser degree can they be overcome. "Low-frequency, extremely high-magnitude threat[s] to human survival," like a supernova or planet-destroying asteroid, will always be hanging over our heads. These events do not exist in Earth domains.[47]

Mendenhall's thinking inspires a closer look at the role extra-domain analogies play in international law. In places where governance necessitates guidance to construct new rules that manage target domain activities, like the 1967 Outer Space Treaty, MJ Peterson shows the missteps when dealing with new schemata. The suddenness of new governance structures, according to Mendenhall, "entails a high probability of misreading, misperception, and mistakes in problem definition and interest formation. In other words, analogies provide a poor conceptual foundation for regime building."[48] These matters are discussed in the next chapter.

Chapter 3 – Old Moon in the New Moon's Arms: The 1967 Outer Space Treaty

To break a treaty is contempt for the gods. But to outwit an enemy is not only just and glorious—but profitable and sweet.

– – Plutarch, *Parallel Lives 'Agesilaus'*

It makes sense that in the 20th century, the way in which humans waged war forced international actors to rely on quick analogies to solve security problems. How does one enforce human activity in a global commons like space, located in an unfamiliar, unpredictable environment which does not belong to any nation, civilization, or planet? On Earth, human activity is regulated by social contracts and laws, and is heavily influenced by Western ideals. International treaties, agreements, and norms shape the national security environment, and will do so for the foreseeable future. Of all the international treaties and agreements governing space activities, the 1967 Outer Space Treaty is the only one to give independence to space as a non-Earth environment which demands a structure of law not found elsewhere. It is also the only international agreement relating to space with applications inclusive of national security and peaceful operations. Finally, the treaty necessitates constant analysis over time as technology improvement and space access become more frequent, which may cause a "restrictive interpretation [of the treaty] that could undermine national security of the United States."[49] For these reasons, in addition to the nature of its early development, the Outer Space Treaty is the best place to begin the analysis. Human activity on the high seas played a central role as a source domain analogy during the treaty's initial development.

MJ Peterson, in "The Use of Analogies in Developing Outer Space Law," says that when policy decisions are being considered in the international relations community, mental constructs are "visible when actors are trying to extend interaction into new areas or to establish new modes of cooperation."[50] Such was the case when developing a first-of-its-kind space law agreement during the Space Race. Because of the unanticipated pace of Soviet achievement beginning with Sputnik I in 1957, real international concerns forced governments to confront "the problem of determining not only what they wanted to do in space but also what sorts of rules for unilateral activity and mutual interaction should prevail there."[51] Initially, the United States preferred a high seas conception of space, where the Soviets preferred to compare space to national airspace.[52] Through multilateral negotiation and "the Soviet government's shift to accepting the high seas conception," an outer space law was developed.[53] But because space was a new problem that needed a workable conception to be developed quickly, reasoning by analogy dominated the process.[54]

To reiterate Rumelhart and Norman, Peterson says humans "treat knowledge domains that are similar in some respects as similar in others, so that information from the familiar ('source') domain can be used to fill gaps in information about the unfamiliar ('target') domain."[55] When national security matters are at stake, however, additional considerations for choosing an analogy come into play. During the Space Race, for example, the US was interested in space reconnaissance "because of the large gap between what they could find out about Soviet activity and what the Soviets could find out about US activity."[56] Analogy selection was therefore further informed by "the legitimacy of satellite reconnaissance."[57] Unlike national airspace laws, where intruding aircraft may face strict punishment under internationally understood conventions, no such system exists for the high seas (coastal waters notwithstanding). Thus in 1961 the United Nations General Assembly, "Recognizing the common interest of mankind in furthering the peaceful uses of outer space," agreed to the following principles:

1. International law, including the Charter of the United Nations, applies to outer space and celestial bodies.

2. Outer space and celestial bodies are free for exploration and use by all States in conformity with international law and are not subject to national appropriation.[58]

This language made its way into the Articles I and II of the 1967 Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies (Outer Space Treaty):

> *Article I* [excerpt]
> Outer space, including the Moon and other celestial bodies, shall be free for exploration and use by all States without discrimination of any kind, on a basis of equality and in accordance with international law, and there shall be free access to all areas of celestial bodies.
>
> *Article II*
> Outer space, including the Moon and other celestial bodies is not subject to national appropriation by claim of sovereignty, by means of use or occupation, or by any other means.[59]

One issue that immediately surfaced was how to deal with the consequences of staking national claim on planetary bodies in furtherance of economic prosperity (e.g., mineral rights). This issue was especially significant in light of President John F. Kennedy's 1961 commitment to "landing a man on the moon and returning him safely to the earth."[60] In 1971, the UN "requested the Committee on the Peaceful Uses of Outer Space and its Legal Subcommittee to consider the question of the elaboration of a draft international treaty concerning the moon."[61] The Moon Treaty was not finalized until 1979, and relied once again on analogical thinking. Later, during negotiations for the Antarctic Treaty, it became clear that analogies used during Outer Space and Antarctic Treaty deliberations "failed to suggest how to regulate exploration for or exploitation of natural resources."[62] A return to sea conceptions ensued, harkening for the protection of the inherited commons of mankind, like the ocean floor. These conceptions, according to Peterson, "had less to do with mining, of which there was little immediate prospect, than with arguments over the general shape of the international economy."[63]

According to "State Sovereignty in Space: Current Models and Possible Futures," Karl Leib says one contentious provision of the Moon Treaty "was Article 11.3, which was an extension of the non-appropriation principle of the [Outer Space Treaty] to entities besides states."[64] In short, this principle states that physical surfaces including natural resources cannot "become property of any State, international intergovernmental or non-governmental organization, national organization or non-governmental entity or of any natural person."[65] In other words, no right of ownership exists on celestial bodies beyond the spacecraft used to navigate to and from such places. Without establishing further policy or law for states *and* private companies, Leib speculates "the international system will 'muddle through' and develop an ad hoc series of arrangements."[66] Given enough time, he suggests, the "inevitable danger is that states or non-government actors will make overlapping claims or violate each other's claims."[67] Until human activity makes a shift to such a degree that there is at least equal representation on Earth and other bodies like the moon, Leib says, "There is no reason to assume unilateral claims to lunar territory, whether public or private, would receive automatic deference."[68]

Both Mendenhall and Leib share common views of entity rights (or self-proclaimed rights). Given the opportunity, it seems the international community is comfortable with "fitting" their analogies within "the material realities of outer space."[69] Mendenhall says it perfectly: "This can be understood as a case of 'seeing what one wants to see.'"[70] For Earth regimes, and particularly in the national security context, we are used to normalizing intellectual slights-of-hand to side-step "accepted ideology when necessary."[71] But when it comes to space activities, scientific principles must remain in place as the intellectual building blocks. In space, there is no room for human constructs that are not built on this universal truth: space was here first. Everyone that has ever lived, everyone you have ever known or loved, water, cows, and B-52 bombers, are the result of evolutionary processes originating in the formation of stars. The central idea, in line with Mendenhall's conclusion, is that "using direct scientific evidence to construct a representation of the outer space environment is superior to relying on analogical comparisons with various planetary domains," not because of choice, but because of overwhelming scientific application of principles.[72] In the national security arena, or other places of governance, it is no longer viable to rely on traditional rules, acquired skill, or intuition to shape theory. In an environment like space, where human knowledge possibly has infinite capacity, the possibilities within the domain should be celebrated not as a detriment, but as a place for creative advantage. In this regard, "advantage" could serve both scientific and military objectives equally. Together, as viewed from a national power perspective, the US scientific-military space community could upend any other nation in terms of domain mastery and superiority with its binding relationship. But to do so, the military community must suspend the pursuit of using other domain principles and applying them to space, not just because the science is so enormous it in its scope, but because new military advantages may emerge within a higher order of respect for domain discovery.

Peterson, Mendenhall, and Leib do not outright dismiss analogies. Some analogies are useful when describing space to non-technical (i.e., non-STEM educated) learners, operators, commanders, policymakers, and congressional leaders; however, there must be a common understanding of the scientific principles that govern our universe with respect to military space in order to achieve the aforementioned advantages of domain mastery. These principles are often times clearer to observe and understand from space than on Earth, which makes it a difficult educational task. The four fundamental forces in physics serve as a primary example:

gravity, electromagnetism, and the strong and weak nuclear forces, all of which govern *every* celestial body, would perhaps be more tangible if they could be framed with military implications. To talk about operations in space, we must therefore orient ourselves to space thinking in a way that heightens military space operations. The discussion on shared space technology and parallel science objectives continues in Chapter 4.

Chapter 4 – A Space-minded Warfighter: Astrophysics and National Security

Today, it is not only that our kings do not know mathematics, but our philosophers do not know mathematics and—to go a step further—our mathematicians do not know mathematics.
– – Julius Robert Oppenheimer, *The Tree of Knowledge*

The way humans observe outer space from Earth's surface has direct consequences on our way of life, particularly in military matters. In *The Art of War*, Sun Tzu suggests the best method to optimize incendiary attacks is by following lunar phases. He says, "Launching an incendiary attack has its appropriate seasons, igniting the fire the proper days. As for the seasons, it is the time of the dry spell; as for the day, when the moon is in *chi*, *pi*, *i*, or *chen*. When it is in these four lunar lodges, these are days the wind will arise."[73] Early ocean voyagers, too, looked upon the heavens to guide them in celestial navigation, relying on tools originally meant for waging war.

The spyglass, a tool first built for the land domain and whose importance was settled during early sea battles of the British Royal Navy, eventually evolved from ocean to outer space use. One could say that a spy satellite in orbit today is, in effect, a larger spyglass derivative. The optical ingredients have not changed much since the time of Galileo: a light-gathering tube assembly with a respectable aperture, a primary lens or mirror, and an image-producing eyepiece (today, an electronic relay or charged couple device connected to a computer). Optical telescopes fulfill the same major tasks for astronomy as they do for surveillance:

1. Collect light from a large area, making it possible to study very faint sources.
2. Increase the apparent angular diameter of objects and thus improve resolution.
3. Measure the position of objects.[74]

The science driving breakthroughs in military and civilian endeavors equally benefits national security as it does industry or academia. In the 20th century, when the US military first began to conceive space warfare, leaders such as General Bernard Schriever, father of Air Force

Space Command, recognized the necessity to include science and industry. Ahead of his day, he said in 1957:

> Several decades from now the important battles may not be sea battles or air battles, but space battles, and we should be spending a certain fraction of our national resources to insure [*sic*] that we do not lag in obtaining space supremacy. Besides the direct military importance of space, our prestige as world leaders might well dictate that we undertake lunar expeditions and even interplanetary flight when the appropriate technological advances have been made and the time is ripe. Thus, it is indeed fortunate that the technological advances required in support of military objectives can, in large part, directly support these more speculative space ventures… [75]

So continues the entanglement of space science and military matters. This suggestion is not meant to cast a negative light on scientific and military goals as separate from one another. Rather, it encourages the mutual benefits of learning from space which may bolster each community at the same rate irrespective of their individual goals.

In *Accessory to War*, Neil deGrasse Tyson and Avis Lang examine how the methods and tools of astrophysics serve the warfighting community and vice versa. From telescopes to radar, the intersection of science, technology, industry, and power, is fundamental to developing a proper cosmic perspective because of the limited experience shared by each space domain participant. For example, in the case of achieving national power objectives, and following that national security actors agree the object of power is power itself, it must be understood that human pursuits in space have zero effect on the space domain. None. One might consider orbital debris an immediate threat to space operations. But debris affects the earth, humans, and human constructs more so than the interstellar medium. Consider the implications of orbital debris transposed to Earth analogs: the giant Pacific Ocean garbage heap, landfills, chemical runoff, and pollution all affect climate change, ecosystems of the land and sea domains, and human survival itself. There is no equivalent in space, whose vastness is beyond comprehension for most. Our collective evolutionary experience on this planet allows us to operate comfortably with a certain degree of predictability. Earth is no longer a mystery to us. Space is the exact opposite—a place of great uncertainty which may imbue discomfort for warfighters, yet it is a place embraced by science.

Tyson and Lang contend that the road to achieving space power is "long, difficult, and costly. First comes science, then investigation, engineering, multiple failures and eventual mastery. Finally the aspirants arrive at control and, if sought, occupation and exploitation."[76] Unlike the days of the Space Race and President Kennedy's call to scientific arms, however, science today can ill-afford to play "second fiddle to military capability."[77] Consider the global positioning system and its adherence to physics. "Today's GPS is 24/7, real-time, accurate and precise down to a few meters. With input from widely available augmentation systems, those few meters can become a few centimeters. GPS is now absolutely ho-hum for most users."[78] The science behind GPS should not be overlooked by the guardians currently operating its constellation of satellites, a mission of worldly importance. Beyond giving users precise driving directions, enabling location services for dating apps, and providing the clock source for computers and smartphones, GPS also puts the "smart" in smart bombs. For this reason, as a seasoned reader is likely to hear utterances in halls of the Pentagon the importance of PNT (positioning, navigation, and timing), GPS is an ideal case study for studying the intersection of science, industry, and military needs.

The most important segment of GPS, the ground control segment network of monitors and antennas, manages "the satellites' flight paths and atomic clocks."[79] The onboard cesium clocks are so accurate that, according to the US National Institute of Standards and Technology, the International System of units now defines a one-second interval of time in accordance with the same atomic properties used aboard GPS.[80] The ground control segment is also responsible for managing the "two major relativistic influences upon its rate of timekeeping: a special relativistic correction for its orbital speed and a general relativistic correction for its orbital altitude."[81] Despite what public users of GPS may experience, the primary purpose of GPS is carrying out the mission of global time transfer, which is a way to manage national and international clock comparisons from space signals.[82] GPS must account for fractional time losses and gains due to physics. Specifically, while each GPS satellite loses -7.2 microseconds per day due to its orbital speed, the dominant time correction is due to fractional gains caused by general relativity—gravitational effects made famous by Albert Einstein.[83] Today these effects are known to exist in the lesser-known concept that unifies space and time, a proposition first mathematically developed by Hermann Minkowski, called *space-time*.

Space satellites operate in four dimensions, not three: (x, y, z, t). The first three dimensions, (x, y, z), may be familiar to the reader in describing the position of an object in space. The fourth dimension, t, introduces time as a variable dependent on gravity, one of the key findings of Einstein's general theory of relativity. Before Einstein, "time played a different and more independent role, as compared with the space coordinates."[84] Time is not independent in relativity, which was first shown by Hendrik Lorentz in the special case.[85] These statements are not meant for the astrophysicist reader, nor are they an indictment of the reader's educational credentials. Rather, they are meant to address the tendency for military and/or civilian leaders to oversimplify knowledge of the universe, especially by analogy, without recognizing, celebrating, and embracing these fundamental concepts as central to the space domain. How could a senior leader in the Air Force, for example, speak intelligently about flight operations without knowing how airplanes fly, or how weather affects their planning? How might a naval surface warfare officer plan an operation without understanding sea states? Should a submariner understand the topography of the sea floor when reading bathymetric charts? Four-dimensional space is not a new concept, yet "the non-mathematician is seized by a mysterious shuddering" upon hearing such things.[86] For the senior leader audience, there is no inaccessible mathematical trickery baked into astrophysics that is meant to deceive or separate itself from the same principles needed to master military space. In the words of Einstein, "there is no more common-place statement that that the world in which we live is a four-dimensional space-time continuum."[87] The corpus of knowledge that allows us to understand gravity, black holes, and the universe, is the very same knowledge attributed to deadly-accurate, GPS-guided munitions. Adaptive optics technology is another key example.

Most telescopes are ground-based, military and civilian alike. One issue for early military space systems tasked with tracking orbiting objects in the 1970s and 80s was blurred images caused by atmospheric turbulence. Adaptive optics was invented to correct for turbulence, thus producing a sharper image of space objects.[88] The military aggressively pursued the development of adaptive optics not just for space situational awareness imaging, but also laser weapons. Much of the developmental research occurred at the Starfire Optical Range at Kirtland Air Force Base, New Mexico, and included a team comprised of Air Force Research Lab scientists, private contractors, Massachusetts Institute of Technology-Lincoln Lab engineers, and more. The evolution of adaptive optics represents the epitome of science, industry, and military communities working together. When this technology was declassified in 1990-91, "Space scientists could now take it to their own next level."[89] They did just that, and over the next two decades committed themselves to researching, among other things, exotic phenomena in the universe, like black holes. Adaptive optics technology is what allowed Roger Penrose, Reinhard Genzel, and Andrea Ghez to jointly share the 2020 Nobel Prize in Physics "for the discovery of a supermassive compact object at the centre [*sic*] of our galaxy."[90] Same domain, same domain technology, and unequivocal gains for all participants in the space community.

Tyson and Lang do not suggest military personnel are overlooking the science because they are not scientists. Instead, their book is a consciousness-raising effort to inform why the intersection between national security and astrophysics matters. It is clear that the science is relevant, necessary, and primary to understanding any operations within the domain. Why not maximize the knowledge by embracing it as a necessary entry point to developing doctrine, policy, law, or any other strategic responsibility in the national security sense? By doing so, any non-space domain imports, like those from the sea, would exist only in hypotheticals.

The meaning of space power to a military member may be worlds away from the astrophysicist. Yet the mutual advantage for both communities, according to Tyson and Lang, "intersect surprisingly often," and should be central to the meaning of the words "space enterprise."[91] Said another way, "Cosmic discovery is often enabled even when it's not the driver—and even when the show of force is not weapons but technological bravado."[92] Why then is there a limiting disconnect between space as viewed from the scientist versus the warrior? From a military perspective, it may be due to the nature of being a space warrior, where rigid structures may not allow for creative or research-based inquiry in the quest for genesis doctrine. Since space operations represent the ultimate high ground in terms of military advantage, they must also represent the ultimate frontier for human advancement. Tyson and Lang say it better:

> Shared by both space scientists and space warriors, [space is] a laboratory for one and a battlefield for the other. The explorer wants to understand it; the solider wants to dominate it. But without the right technology—which is more or less the same technology for both parties—nobody can get to it, operate in it, scrutinize it, dominate it, or use it to their advantage and someone else's disadvantage.[93]

There is a purity to space that is, perhaps, overlooked by the national security community. The oversimplification of space may be due to the US' track record for achieving success during the Space Race, only to remain unmatched until the 21st century. We failed fast as a nation and failed early. The challenges on the horizon, which are receiving greater and greater attention (hence the establishment of the Space Force), offer a chance for the space enterprise to continue its remarkable relationship-building. A deeper knowledge of the cosmos will enrich the warfighter and allow room to consider how to exploit their knowledge even in the face of domain uncertainty. This idea reinforces what it could mean to gain a key advantage in terms of national power. Knowledge of the cosmos could ultimately be a savior for humanity and not merely a way to destroy other humans or their constructs in a future war. A cosmic perspective is the vehicle for harnessing that knowledge, and is dedicated to that principle in Chapter 5.

Chapter 5 – Departing from Analogies: A Cosmic Perspective for National Security Space

The Cosmos is all that is or ever was or ever will be.

– – Carl Sagan, *Cosmos*

Over the last decade, science, technology, engineering, and mathematics (STEM) education has been an institutional focus for the Department of the Air Force in both recruiting, retention, and public outreach campaigns. Inward-facing STEM examples include establishing higher education scholarships for military members, most recently the Dr. Heather Wilson science, technology, engineering and math Ph.D. program and the Chief of Staff of the Air Force captains' prestigious Ph.D. program.[94] Outward-facing STEM recruitment in the Air Force and Space Forces has manifested itself in various ways, most visibly in television advertisements and YouTube videos.[95] One recent campaign for the Space Force, for example, asks potential candidates whether their purpose in life is on this planet or elsewhere, as if to offer a non-Earth solution to exploring the cosmos. With regard to public outreach, the department has advocated a desire "to bring STEM and Space into elementary school classrooms."[96] These STEM-heavy campaigns seem genuine, and it is not the position of this paper to dispense with them; however, any pursuit that elevates a STEM focus in the military above, say a liberal arts education, is unlikely to gain traction, especially when balancing the military demands required of senior leaders.[97]

In the face of what seems to be a never-ending campaign to address current policymakers' and industry leaders' belief "that the United States faces a high-tech talent crisis," the Space Force should focus instead on the community learner concept for training its members.[98] A pure STEM recruitment and retention campaign is against the odds, especially in the space sciences (astronomy in particular is discussed at the conclusion of this paper). Because Space Force operations involve enlisted, officer, civilian, and contractor personnel—of various ages, rank, education, and professional experience—all working together, the community learner concept applies. The Space Force would do well to bookend its undergraduate space training courses with a special emphasis on astrophysics at an accessible level. This suggestion is not meant to alter the national security aspects of initial training programs, which are undoubtedly important. Rather, an introduction via the cosmic perspective may better orient future space operators to the most superior and secure framework upon which to build a military theory. Due to the general lack of understanding of space (as previously discussed) which increases the likelihood of source domain substitutes, a cosmic perspective can serve as a science-based, domain-forwarding paradigm in three distinct ways.

To begin, a cosmic perspective functions as a textbook, a pedagogical approach, and a way of centering thought on space as a place. First published in 1998 by Jeffrey Bennett of the University of Colorado Boulder, *The Cosmic Perspective* is the most popular college-level astronomy textbook for non-science majors in the United States.[99] It is used in large university systems, community colleges, high schools, and middle schools (there is a short *Fundamentals* version used for younger audiences with limited math skills). The outline of the book divides learning into seven parts and follows five major themes. Secondly, Bennett prescribes seven pedagogical strategies for teaching its content. Finally, the student learning opportunities informed by a cosmic perspective focus on "three linked goals for science teaching: education, perspective, and inspiration."[100] Taken together, these goals allow the warfighter the capacity for source domain enrichment that would otherwise be missed by analogical thinking.

The Cosmic Perspective outlines its content under seven broad topical areas and five major themes:

Table 5.1 – Outline of Broad Topical Areas and Themes from *The Cosmic Perspective.*[101]	
Seven Broad Topical Areas	Five Themes
1. Developing perspective. 2. Key concepts for astronomy. 3. Learning from other worlds. 4. A deeper look at nature. 5. Stars. 6. Galaxies and beyond. 7. Life on Earth and beyond.	1. We are a part of the universe and can therefore learn about our origins by studying the universe. 2. The universe is comprehensible through scientific principles that anyone can understand. 3. Science is not a body of facts but rather a process through which we seek to understand the world around us. 4. Astronomy belongs to everyone. 5. Astronomy affects each of us personally with the new perspectives it offers.

The most important aspect in developing a cosmic perspective is orienting the learner to the cosmos with useful scales, which is why "Developing Perspective" is the first topical area. One absent artifact from the solar system scale example in Chapter 1 is a tangible reference tool for distances in space. Space is big and mostly empty, hence the name. As such, Bennett's most useful artifact is the Voyage solar system model in Washington, DC, a 1-to-10 billion scale representation of the solar system, which provides the public a tangible, walkable exhibit (*see* illustrations and photographs in Appendix B).[102] Instead of domain analogies, which rely on source imports, visualizations of a target domain allow individuals to "make abstract ideas much more concrete."[103] Table 5.1 does not suggest military space training turn into a college astronomy course. Instead, many of the concepts introduced by the textbook are important to developing perspective of the domain. The topical areas and themes can be used as a basis for the space enterprise by broadening "astronomy" with the word "space" or "space operations" (*see* Table 5.4). These ideas are emphasized in Bennett's seven strategies for teaching, and are summarized in Table 5.2:

Table 5.2 – Seven Pedagogical Teaching Strategies from *On Teaching Science.*[104]
1. Begin with and stay focused on the big picture. 2. Always provide context. 3. Emphasize conceptual understanding. 4. Proceed from the more familiar and concrete to the less familiar and abstract. 5. Recognize and address student misconceptions. 6. Use plain language. 7. Challenge your students.

Space operations and military framing should always be at the forefront under this paradigm. The most important aspect of Bennett's seven strategies is recognizing and addressing student misconceptions of space because it is so unfamiliar in the human experience. Unfamiliarity, discomfort with new schemata, and lack of tangible references all contribute to oversimplification and incorrect analogy use. These missteps can be addressed equally through Bennett's teaching strategies which emphasize community learning. Age, experience, and background are treated equally under this paradigm as there is no evidence to suggest humans learn differently from one another. In his book *On Teaching Science*, Bennet says, "Brains are brains. We may know more as we get older, but we still learn new things in the same basic way."[105]

Application of a cosmic perspective means advocating for real science, of which the military space community is a participant even if it may not realize it. This declaration could be daunting in a classroom made up of students who previously thought they were "dumb" or "bad" at math or science. Bennett attributes these utterances to indifference, fear, "lack of comfort with or motivation for the subject matter."[106] For military framing, these biases can be overcome by setting realistic expectations and following two important guideposts in a classroom setting:

1. Always assume that your audience members know *less* than you think they should.
2. Always assume that your audience members are *more* intelligent than you think they are (or than they may think themselves to be).[107]

In a military classroom, like the Space Force's Undergraduate Space Training programs for enlistees and officers (formerly Space 100), the cosmic perspective as a paradigm culminates when each student is allowed the opportunity to achieve three linked goals for science teaching, as summarized in Table 5.3:

Table 5.3 – Three Linked Goals for Science Teaching from *On Teaching Science.*[108]
1. Education – carefully consider the educational-content goals that will support your students' long-term success. 2. Perspective – show how science provides perspective on ourselves and on our planet. 3. Inspiration – use science to inspire your students to dream of how they can personally contribute to helping all of us make a better world.

The summation of the ideas presented in Tables 5.1-5.3 is the nexus of the cosmic perspective for national security space. Every topical area, theme, strategy, and goal can be framed with operational examples in the space domain; each table can be adjusted to advance the goals of a space learning institute. For example, delivering content on our solar system, solar physics, or the solar cycle, can be taught with implications for US space assets (e.g., global military satellite communications). Or, content on stars can be tied to the necessity for star trackers used in attitude, determination, and control systems of orbiting satellites. The goal of this paper is not to prescribe an outline for new academic syllabi with precision. In the broadest sense, this paper champions the intersectionality between textual content, pedagogy, and knowledge retention during initial skills training. Graphically, these overlapping ideas are showing in Figure 5.1, where Tables 5.1-5.3 are recreated with broader space operations vice astronomy as the central subject matter:

(Continued on next page)

Adjusted Areas and Themes from *The Cosmic Perspective* Textbook

Seven Broad Topical Areas with Additional Military Framing	Five Themes for Space Operations Training
1. Developing perspective. 2. Key concepts for space. 3. Learning from other worlds. 4. A deeper look at nature. 5. Stars. 6. Galaxies and beyond. 7. Life on Earth and beyond.	1. We operate in space as part of the larger universe and can therefore advance our operational knowledge by studying it. 2. Space as a domain is comprehensible through scientific principles that anyone can understand. 3. Science is not a body of facts but rather a process through which we seek to understand the world around us. 4. Space belongs to everyone, but we are charged with a military mandate in it. 5. Space and space operations affect each of us personally and professionally with new perspectives gained from the domain.

Pedagogy Retained from *On Teaching Science*

1. Begin with and stay focused on the big picture.
2. Always provide context.
3. Emphasize conceptual understanding.
4. Proceed from the more familiar and concrete to the less familiar and abstract.
5. Recognize and address student misconceptions.
6. Use plain language.
7. Challenge your students.

Three Linked Goals from *On Teaching Science* Adjusted for Undergraduate Space Training

1. Education – carefully consider the educational-content goals that will support your students' long-term professional success.
2. Perspective – show how science provides perspective on ourselves, our planet, and how we conduct military operations.
3. Inspiration – use science to inspire your students to advocate for how they personally contribute to helping all of us make a safer, better world.

Figure 5.1 – Cosmic Perspective for National Security Space

To reiterate, the ideas presented in this paper do not advocate for a complete rewrite of current syllabi. The ideas presented here are additive, not subtractive. Clearly, space operations have been able to coexist in a domain where non-military activities also take place. With a cosmic perspective, however, future theorists and strategists will not have to lean on other domains to establish what science has been able to do for millennia: experiment, peer review, fail, succeed, and most of all, advance itself without having to borrow. The key to decisive action in space will come down not to tactics, techniques, or procedures, but rather the scientific body of knowledge upon which such military paradigms are built. Working within the same realm as the scientific community mandates an equal opportunity to harness and advance military operations, bringing it up to speed with academia, research, and industry. In the spirit of General Schriever, the confluence of space as a place to study, operate, defend, and advance our nation's goals must exist alongside the desire to gain advantages. In order to compete with 21st century adversarial space threats, it is therefore necessary for the discussion to conclude with translating the cosmic perspective into national security advantages. Onward to Chapter 6.

Chapter 6 – Advantage: Cosmic Perspective as Second Nature

Science and technology have been among the decisive influences that have improved the lot of the common people and thus made this nation fine and strong.

– – Lee A. DuBridge, *Science and National Security*

In 1954, Lee A. DuBridge, who served as science advisor to both Presidents Roosevelt and Eisenhower, asked, "What are the ways in which science promotes national security?"[109] In his article, "Science and National Security," he advocates a position of science-based advantage rooted "deeply into the national pattern of living, into the nation's industrial, social, educational, and economic systems."[110] Where scientists continue to push the boundaries of discovery, he says, they also "stand as a 'ready reserve' available to accelerate the development of military technology when emergencies arise."[111] During the Space Race era, science was pivotal in helping to fill in essential gaps in knowledge in the national security context. In the 21st century, however, scientists no longer play a "ready reserve" role. In the space domain in particular, science and military operations work in parallel not because of traditional interconnectedness via industry, access, or governance, but because of the domain in which they exploit. Issues facing all operations in space, such as solar weather, propulsion methods, orbit propagation, and the like, are the same across military and non-military organizations. In this paper, I have attempted to show that today's guardians should be armed with the tools required to fill in new gaps in space knowledge. This paper advocates for additional learning in a way that is meant to bolster scientific understanding in order heighten military awareness. A cosmic perspective acts as a cognitive vehicle that is additive in achieving military success in space. Such a perspective yields greater domain mastery, which may translate to professional military advantages, not to mention achieving national power objectives.

DuBridge says, "Both a strong military and a strong industrial technology must rest on a solid base of fundamental science."[112] This paper agrees with that statement, but adds more: Not only should fundamental science serve as a solid base for the military establishment, including tools provided by industry, it should also serve to enhance the warfighter's thinking skills. The cosmic perspective can improve the intellectual tone, stimulate the imagination, and fill in essential gaps in a way that is mutually beneficial to national security and humanity. By using the tools of education, as discussed in the previous chapter, space domain orientation can be made more accessible so that it remains untethered from extra-domain analogies. In regimes of the 20th century, science was a population that once served the needs of the military separate and distinct from the warfighter. It has now transformed into a dual-role character that can, among other things, facilitate training goals shared among 21st century military personnel. In the words of Trevor Brown, "If professional space forces find that they are able to draw from a population such as this, for whom the medium of space has become second nature, they will find it to their great advantage when they go to battle."[113]

Every student in the United States gets exposure to varying degrees of space education during their science upbringing. For some it may arrive in elementary school, for others in high school or college. The American Astronomical Society reports 161 colleges currently offer astronomy related degrees in the United States.[114] There are about 20,000 physicists and astronomers in the US, mostly in academia and the federal government. As of May 2019, the median annual salary for astronomers is $114,590.[115] Despite the educational opportunities and income potential, though, the number of overall astronomy degrees granted each year is very low. In the 2015-16 schoolyear, 469 astronomy bachelor's degrees were awarded in the US. Compare this number to the 371,109 business degrees or the 228,907 degrees in the health field granted during the same timeframe.[116] For the classes of 2014-16 combined, STEM employment positions were mostly in the private sector or colleges/universities (41% and 18%, respectively).[117] Only 3% of astronomy bachelor's degree graduates entered military service throughout that time.[118]

Astronomy remains incredibly popular as a topic for discussion, debate, entertainment including film and television, comic books, science fiction novels, and the like. Ask any elementary school-aged kid how "cool" space is, and you are likely to get an unequivocal, animated response. Whether talking about black holes, Saturn's rings, telescopes, or alien worlds, space remains a well-developed place for imagination, and will likely remain so for some time. Ask how many of your friends, relatives, and yourself included wanted to be an astronaut when they grew up? With these fascinations in mind, why then is there a such a large chasm between school-aged interest and adult-level interest in space science? Space science seems to pay well, offers extraordinary opportunities to explore and learn, and as discussed serves national security priorities. What causes someone to become turned away from space as an intellectual pursuit? Jeffrey Bennett says early inspiration—and attitudes in general—of science in the classroom are to blame. He says, "Student attitudes begin to develop at a young age. Many elementary teachers are very good at helping students develop positive attitudes toward science, but there are also far too many cases in which elementary teachers have done just the opposite."[119] It is possible to associate these inadequacies in science-based curriculum with military organizations, but perhaps a larger cultural phenomenon is at play.

In "Taking Distrust of Science Seriously," Geoffrey Kabat says large scientific distrust tends to materialize today in the form of controversy "involving a widespread misunderstanding of the science by a vocal minority."[120] Whether discussing vaccines, climate change, or pandemics, questions of staggering complexity are often reduced to binary choice-making in the public debate. Often, public debates make their way into the classroom, where scientific knowledge can be characterized as conjecture even though consensus among scientists may be overwhelming on a particular matter. Supposing today's military members enter the service with more or less equivalent non-STEM backgrounds, it is easy to see how town square attitudes may infiltrate the national security arena. The mandate to expel negative attitudes and ideas of science seems to exist. A translation of concrete science is mandatory so that the layperson can use it to gain an advantage. Robert Leonhard punctuates this sentiment: "When plans and preparations collapse and everything goes to hell during a battle, the trained fighting man is the best hope for maintaining an advantage over the enemy."[121]

There is a way to present the universe in a manner that is brief and engaging. Carl Sagan, the American astronomer and writer, is perhaps best known for his television series *Cosmos*, which was geared toward the average television viewer of the 1980s. His methods were awe-inspiring, pleasant, and appealing. His science facts were less riddled with equations and complex words, and more with easy-to-digest audiovisuals and sensitive narration. In order to more formally present the universe to the military community, the cosmic perspective offers contextual and mental tools for broad comprehension. There is a future where guardians in the Space Force, for example, no longer need domain analogies to describe their actions and discoveries, because their experience will be the equivalent of what a sea-minded individual knows about naval operations today.

There is no room for sea or airmindedness in a space organization, even though today's Space Force is operating under the Department of the Air Force. The object should not be to pursue a new version of sea or air power going forward—no AT Mahan, Julian Corbett, Giulio

Douhet, or Hap Arnold, except to inform historiography. Rather, the corpus of knowledge built around Johannes Kepler, Albert Einstein, Bernard Schriever, Jeffrey Bennett, Andrea Ghez, and others, will serve our space forces with more distinction by helping to establish a concrete domain. In science, the advantage lies within the process of constant revision, peer review, and experimentation. Does that not also describe, to a larger extent, military avenues of approach?

The cosmic perspective foments the frontiers of science, but it also allows having the wisdom and insight to apply that knowledge to assess our place in the universe. Knowledge of how space works, what works in space, and what space is, does not just belong to the scientist. It belongs to military operators, too. Dr. Tyson makes clear the attributes of the cosmic perspective:

> The cosmic perspective is humble. The cosmic perspective is spiritual—even redemptive—but not religious. The cosmic perspective enables us to grasp, in the same thought, the large and the small. The cosmic perspective opens our minds to extraordinary ideas but does not leave them so open that our brains spill out, making us susceptible to believing anything we're told. The cosmic perspective opens our eyes to the universe, not as a benevolent cradle designed to nurture life but as a cold, lonely, hazardous place. The cosmic perspective shows Earth to be a mote, but a precious mote and, for the moment, the only home we have. The cosmic perspective finds beauty in the images of planets, moons, stars, and nebulae but also celebrates the laws of physics that shape them. The cosmic perspective enables us to see beyond our circumstances, allowing us to transcend the primal search for food, shelter, and sex. The cosmic perspective reminds us that in space, where there is no air, a flag will not wave—an indication that perhaps flag waving and space exploration do not mix. The cosmic perspective not only embraces our genetic kinship with all life on Earth but also values our chemical kinship with any yet-to-be discovered life in the universe, as well as our atomic kinship with the universe itself.[122]

The attributes of the cosmic perspective seem conceptual, and for the most part, as presented in this paper, they are. The executive level reader may wonder how to address cognitive gaps in the national security space context with concrete so-called "next steps." These concerns are addressed in the following pages as recommended actionable primaries.

Chapter 7 – Recommendations and Concluding Thoughts

What is a service chief or other senior space leader to make of the cosmic perspective? This paper does not presuppose that the chief of space operations or the US Space Command commander have the capacity to translate the cosmic perspective into tangible solutions. This idea is not meant to suggest they are incapable of such an exercise, rather that they are unlikely to have the time to meet the challenge of translating the conceptual into the actionable. Other matters may seemingly take priority, namely the central missions of organizing, training, and equipping a force in order to meet the administration's agenda. Offered here, then, are three actionable recommendations a national leader may use to implement the cosmic perspective. First, at the service level, a service chief may be able to establish new resident and non-resident professional military education structures at various levels, which feature the cosmic perspective as a central guide. Second, at the joint level, they may be able to work with other service chiefs and leaders to implement new space orientation opportunities across each branch including joint service schools. Finally, at the executive branch level, it may be possible to work with the administration's functionaries to establish service programs which could benefit military and non-military activities, especially in matters of education and recruitment.

Within the organize, train, and equip missions, a service chief may have the capacity to establish how space is taught at resident and non-resident professional military education schools. One place to begin is at the post-secondary level, namely the service academics, reserve officer training corps, and enlisted training schools. For the Space Force, this idea could translate into establishing a Space Force Reserve Officer Training Corps, Space Force Department or pseudo-academy within the larger Air Force Academy, Space Force Basic Military Training, and the aforementioned Undergraduate Space Training. It seems these ideas may already be taking shape as of publication.[123] It must be emphasized, however, that implementing the cosmic perspective where space as a place may already be second nature (or close to it) is one precursor to generating reform. Current efforts to advance, for example, officer accessions are ongoing. One word of caution against targeting officers for specialized training is warranted here. As the previous chapters have mentioned, education paradigms must be addressed without regard to rank, position, experience, enlisted vs. officer status, civilian status, etc. For the military members currently midcareer, it seems appropriate to emphasize space as a place via the cosmic perspective across the services and at joint service schools.

One observation made at Marine Command and Staff College is the absence of a core space-educated military or civilian faculty member. Not one space faculty member exists, which is not so much an existential problem as it is an indication that this paper and its recommendations may have arrived at an opportune time. The chief of space operations and commandant of the Marine Corps could very well establish a space studies chair at this school and others like it. One recommendation is establishing a joint space university or college within existing schools like National Defense University. The space service chief should also implement cosmic perspective orientation programs at regular career intervals. For example, mid-field grade level officers and senior noncommissioned officers in the space career field attend Space 200 and 300 at the Peterson-Schriever Garrison to help regulate how national security strategy intersects with today's space operations. The author attended both schools in 2015 and 2019, respectively.

Since 2017, US interests in space began an upward trend of activity, innovation, and reemergence. Space Exploration Technologies (aka SpaceX) has now become a household name, and is a pivotal partner alongside the National Aeronautics and Space Administration as a rocket launch provider. New commercial companies like Blue Origin and Virgin Galactic continue their own pursuits to establish space as an entrepreneurial place for development, tourism, and science-forwarding operations. With this momentum, and in parallel with new national security space organizations like the Space Development Agency, the space service chief should reach across federal science-forwarding organizations like the Department of Education and National Science Foundation. Perhaps one way to establish a national space science consciousness-raising effort is to partner with these organizations (and others like them) to enhance America's strategy for STEM education.[124] If, in the view of the national security space enterprise, STEM recruitment is so weak that it is occurring at an alarming, threat-posing rate, now may be the time to generate national programs to address the issue. Perhaps the space service chief could establish a space leadership cadre at the executive branch level to generate such programs. The cosmic perspective could provide the conceptual backbone for all levels of space engagement and study.

Ultimately, this paper shows that extra-domain analogies do not allow a science-based approach to space comprehension. Analogies are necessary for understanding new schema, but sea-to-space analogies, for example, are not good places to initiate warfighting principles. As a species, our understanding of how to maneuver, operate, and communicate from the sea goes back centuries. Thus, there is a level of comfort with importing maritime principles to space; but such principles do not belong in space because of the divergence in material comprehension. Space is just too different and should therefore standout on its own. Moreover, science and military goals in space are nearly one in the same, which means those studying the domain should begin with the same fundamental knowledge, called here the cosmic perspective. There is a way to teach these fundamental concepts of the cosmos and at least three recommendations for implementing the cosmic perspective at the executive level appear to exist. These recommendations are centered on recruitment, retention, and training. Above all, a pedagogical approach seems to offer fresh observations that exist in science teaching paradigms in use today.

Notes

[1] Michael Ronza, *AY20 MMS Tracking Milestones* (Marine Corps University, Quantico, VA, August 3, 2020), Excel spreadsheet. Line 70 reads: "A 'Maritime Strategy' for Space – Adapting Sea Power and Naval Warfare Concepts to the Space Domain and National Power."
[2] Colin S. Gray, "The Influence of Space Power Upon History," *Comparative Strategy* 15, no. 4 (1996), 307, https://doi.org/10.1080/01495939608403082. Alfred Thayer Mahan (1840-1914), US naval officer and historian credited with publishing his influential college lectures in *The Influence of Sea Power Upon History, 1660-1783* in 1890.
[3] Christopher L. Mah and Daniel B. Blake, "Global Diversity and Phylogeny of the Asteroidea (Echinodermata)," *PLoS ONE* 7, no. 4 (2012), https://doi.org/10.1371/journal.pone.0035644.
[4] Stephen R. Grimm, "Why Study History? On Its Epistemic Benefits and Its Relation to the Sciences," *Philosophy* 92 (2017), 404, https://doi.org/10.1017/S003181911700002X.
[5] *See* Appendix A for a complete table of constellations, their English equivalents, and a highlight of those relating to the water or sea.
[6] "Ōce'anus," *The Oxford Companion to Classical Literature*, ed. M.C. Howatson, (Oxford University Press, 2011), accessed October 15, 2020, https://www.oxfordreference.com/view/10.1093/acref/9780199548545.001.0001/acref-9780199548545-e-2111.
[7] Homer, *The Iliad*, trans. Theodore Alois Buckley (London: Bell and Daldy, 1873), http://www.gutenberg.org/files/22382/22382-h/22382-h.htm.
[8] James R. Hamby and Odell A. Smith, Jr., "US Space Command - Does it Support National Military Space Requirements?" (student report, Air Command and Staff College, 1987), 4, Defense Technical Information Center, https://apps.dtic.mil/sti/pdfs/ADA182087.pdf.
[9] Sir Julian Stafford Corbett (1854-1922), British naval historian who served during World War I to the Admiralty, and is known for his essential doctrine, *Some Principles of Maritime Strategy*. *See* Julian Corbett, *Some Principles of Maritime Strategy* (London: Longmans, Green, and Co., 1911), https://www.gutenberg.org/files/15076/15076-h/15076-h.htm. *See* John J. Klein, "Corbett in Orbit," *Naval War College Review* 57, no. 1 (2004), https://digital-commons.usnwc.edu/nwc-review/vol57/iss1/7. *See* Bleddyn E. Bowen, "From the Sea to Outer Space: The Command of Space as the Foundation of Spacepower Theory," *Journal of Strategic Studies* 42, no. 3-4 (June 7, 2019), https://doi.org/10.1080/01402390.2017.1293531.
[10] According to the Union of Concerned Scientists, of the 3,372 active Earth-orbiting satellites, 2,612 of them are in low Earth orbit (LEO), or 2,000 km (~1,200 mi) in altitude. According to The Aerospace Corporation, there may be an additional "54,000 new satellites in orbit in the next decade." *See* "UCS Satellite Database," *UCSUSA.org*, last modified January 1, 2021, https://www.ucsusa.org/resources/satellite-database. *See* Sandra Erwin, "Air Force: SSA is No More; It's Space Domain Awareness," *SpaceNews.com*, November 14, 2019, https://spacenews.com/air-force-ssa-is-no-more-its-space-domain-awareness/.
[11] Klein, "Corbett in Orbit," 71.
[12] MJ Peterson, "The Use of Analogies in Developing Outer Space Law," *International Organization* 51, no. 2 (1997), 266, https://www.jstor.org/stable/2703450.
[13] Karl Leib, "State Sovereignty in Space: Current Models and Possible Futures," *Astropolitics* 13, no. 1 (2015), 6, https://doi.org/10.1080/14777622.2015.1015112.

[14] Neil deGrasse Tyson and Avis Lang, *Accessory to War: The Unspoken Relationship Between Astrophysics and the Military* (London: W.W. Norton and Co., 2018), 48.
[15] Tyson and Lang, *Accessory to War*, 318.
[16] *Oxford English Dictionary Online*, s.v. "analogy," accessed January 16, 2021, http://www.oed.com/view/Entry/7030.
[17] David E. Rumelhart and Donald A. Norman, "Analogical Processes in Learning," (technical report, University of California San Diego La Jolla Center for Human Information Processing, 1980), 6, Defense Technical Information Center, https://apps.dtic.mil/sti/pdfs/ADA092233.pdf.
[18] Rumelhart and Norman, "Analogical Processes in Learning," 6-7.
[19] Hannu Karttunen et al., *Fundamental Astronomy*, 4th ed. (Berlin: Springer-Verlag, 2003), 416.
[20] Adapted from Jeffrey Bennett et al., *The Cosmic Perspective*, 9th ed. (Hoboken, NJ: Pearson, 2020), 8. Also referenced in Jeffrey Bennett, *On Teaching Science*, (Boulder, CO: Big Kid Science, 2014), 84-85.
[21] Rumelhart and Norman, "Analogical Processes in Learning," 7.
[22] Ibid., 31.
[23] Klein, "Corbett in Orbit," 66.
[24] Ibid., 66.
[25] Ibid., 69.
[26] GAR Callender and James Goldrick, "Corbett, Sir Julian Stafford (1854–1922), naval historian," *Oxford Dictionary of National Biography*, accessed January 16, 2021, https://doi.org/10.1093/ref:odnb/32567.
[27] Corbett, *Some Principles of Maritime Strategy*, 93.
[28] Ibid., 93.
[29] Ibid., 1-2.
[30] Klein, 63.
[31] *See* Table 2.1 for examples comparing some of Corbett's principles from 1911 to Klein's 2004 article, "Corbett in Orbit."
[32] Corbett, *Some Principles*, 94.
[33] Klein, "Corbett in Orbit," 67.
[34] Corbett, *Some Principles*, 100.
[35] Klein, "Corbett in Orbit," 67.
[36] Corbett, *Some Principles*, 187.
[37] Klein, "Corbett in Orbit," 68.
[38] Rumelhart and Norman, "Analogical Processes," 31.
[39] NASA-Jet Propulsion Laboratory, "Who has Walked on the Moon?" NASA Science: Solar System Exploration, last modified March 18, 2020, https://solarsystem.nasa.gov/news/890/who-has-walked-on-the-moon/. *See* Elizabeth Montoya, "Record-Breaking Highs And Lows: Meet The NASA Astronaut That Traveled To The Deepest Point On Earth," Guinness World Records, last modified November 24, 2020, https://www.guinnessworldrecords.com/news/2020/11/record-breaking-highs-and-lows-meet-the-nasa-astronaut-that-traveled-to-the-deep-638666.
[40] Elizabeth Mendenhall, "Treating Outer Space Like a Place: A Case for Rejecting Other Domain Analogies," *Astropolitics* 16, no. 2 (2018), 100, https://doi.org/10.1080/14777622.2018.1484650.
[41] Mendenhall, "Treating Outer Space Like a Place," 106.
[42] Ibid., 106-110.

43 Hein B. Bjerck, "Settlements and Seafaring: Reflections on the Integration of Boats and Settlements Among Marine Foragers in Early Mesolithic Norway and the Yámana of Tierra Del Fuego," *Journal of Island and Coastal Archaeology* 12, no. 2 (2017), 277, https://doi.org/10.1080/15564894.2016.1190425.
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45 Ned Wright, "Cosmology Tutorial," last modified July 3, 2009, http://www.astro.ucla.edu/~wright/cosmo_03.htm.
46 Mendenhall, "Treating," 109.
47 Ibid., 109.
48 Ibid., 106.
49 Douglas S. Anderson, "A Military Look into Space: The Ultimate High Ground," *The Army Lawyer* (November 1995), 19, https://www.loc.gov/rr/frd/Military_Law/pdf/11-1995.pdf.
50 Peterson, "The Use of Analogies in Developing Outer Space Law," 245.
51 Ibid., 245.
52 Ibid., 245.
53 Ibid., 247.
54 Ibid., 247.
55 Ibid., 248.
56 Ibid., 253.
57 Ibid., 253.
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60 John F. Kennedy, "Special Message to the Congress on Urgent National Needs," (speech, Washington, DC, May 25, 1961), https://www.nasa.gov/pdf/59595main_jfk.speech.pdf.
61 United Nations General Assembly, Thirty-fourth Session, 89th Plenary Meeting, "Agreement Governing the Activities of States on the Moon and Other Celestial Bodies," December 5, 1979, https://documents-dds-ny.un.org/doc/RESOLUTION/GEN/NR0/376/95/img/NR037695.pdf.
62 Peterson, "Use of Analogies," 261.
63 Ibid., 261.
64 Leib, "State Sovereignty in Space," 13.
65 Ibid., 13.
66 Ibid., 15.
67 Ibid., 16.
68 Ibid., 16.
69 Mendenhall, "Treating Outer Space Like a Place," 99.
70 Ibid., 99.
71 Leib, 17.
72 Mendenhall, "Treating Outer Space Like a Place," 114-115.

[73] Sun Tzu, *The Art of War*, trans. Ralph D. Sawyer (Boulder, CO: Westview Press, 1994), 227. According to the translation by Lionel Giles, *chi*, *pi*, *i*, and *chen* are, respectively, the 7th, 14th, 27th, and 28th of the 28 lunar mansions; or, roughly corresponding to the constellations Sagittarius, Pegasus, Crater, and Corvus. *See* Sun Tzu, *The Art of War*, trans. Lionel Giles (Tokyo: Tuttle Publishing, 2017), 171. Traditionally "lunar mansions," now translated to "lunar lodges," are the 28 asterisms (constellations) that define the 28 regions of the sky in ancient Chinese astronomy. *See* David H. Kelley and Eugene F. Milone, *Exploring Ancient Skies: A Survey of Ancient and Cultural Astronomy* (New York, NY: Springer New York, 2011), 316.
[74] Karttunen et al., *Fundamental Astronomy*, 47.
[75] Bernard A. Schriever, "ICBM: A Step Toward Space Conquest," (speech, San Diego, CA, February 19, 1957), https://www.airforcemag.com/PDF/MagazineArchive/Documents/2007/February%202007/0207keeperfull.pdf.
[76] Tyson and Lang, *Accessory to War*, 316.
[77] Ibid., 321.
[78] Ibid., 332.
[79] Ibid., 333.
[80] One second is defined as "The duration of 9,192,631,770 periods of the radiation corresponding to the transition between two hyperfine levels of the ground state of the cesium-133 atom. The definition was added to the International System (SI) of units in 1967." *See* NIST, "Time and Frequency from A to Z," last modified July 18, 2019, https://www.nist.gov/pml/time-and-frequency-division/popular-links/time-frequency-z/time-and-frequency-z-s-so#second.
[81] Carl E. Mungan, "Relativistic Effects on Clocks Aboard GPS Satellites," *Physics Teacher* 44 (2006), 424, https://doi.org/10.1119/1.2353579.
[82] National Institute of Standards and Technology, "GPS Time Transfer," last modified October 14, 2020, https://www.nist.gov/time-distribution/gps-time-transfer.
[83] Mungan, "Relativistic Effects," 424. While a GPS satellite's speed accounts for -7.2 microseconds lost per day, general relativistic fraction time gain is about +45.6 microseconds per day.
[84] Albert Einstein, *Relativity: The Special and the General Theory - 100th Anniversary Edition*, eds. Hanoch Gutfreund and Jürgen Renn (Princeton, NJ: Princeton University Press, 2015), 69, https://doi.org/10.2307/j.ctv69tgs1.24.
[85] When comparing two reference frames in motion at a constant velocity with respect to each other, the spatial coordinates plus the time coordinate transform in what is called at *Lorentz transformation.* According to classical mechanics, the motion of an observer had to be taken into account when measuring the distance of two events. Before relativity, "the time interval between the events is the same for all observers. The world of special relativity is more anarchistic: even time intervals have different values for different observers." *See* Karttunen et al., *Fundamental Astronomy*, 402-3.
[86] Einstein, *Relativity*, 68.
[87] Einstein, *Relativity*, 68.
[88] Robert Duffner, *Adaptive Optics Revolution: A History* (Albuquerque, NM: University of New Mexico Press, 2009), 19.
[89] Tyson and Lang, *Accessory*, 155.

[90] Specifically, one half of the prize went to Roger Penrose for discovering that black hole formation is predicted by general relativity. The other half was split between Genzel and Ghez for discovering an invisible object in the constellation Sagittarius using adaptive optics. *See* "The Nobel Prize in Physics 2020," press release, The Royal Swedish Academy of Sciences, October 6, 2020, https://www.nobelprize.org/uploads/2020/10/press-physicsprize2020.pdf.
[91] Tyson and Lang, *Accessory*, 379.
[92] Ibid., 380.
[93] Ibid., 20.
[94] Secretary of the Air Force Public Affairs, "Air Force Seeks Nominations for the Dr. Heather Wilson STEM, CSAF Ph.D. Programs," April 1, 2020, https://www.af.mil/News/Article-Display/Article/2133499/air-force-seeks-nominations-for-the-dr-heather-wilson-stem-csaf-phd-programs/.
[95] In 2020, the Space Force began a series of television and internet-based ads which combine fictionalized space stations and members in space suits mixed with clips of real operations. *See* https://youtu.be/x619VW65l1Y.
[96] Secretary of the Air Force Public Affairs, "Space Force's STEM Outreach Provides Critical Link to Force's Future," December 29, 2020, https://www.spaceforce.mil/News/Article/2458603/space-forces-stem-outreach-provides-critical-link-to-forces-future/.
[97] Joseph Kaufman argues that "endorsement of a STEM education stands in direct opposition to the leadership narrative that emerges through close textual reading and analysis of the many publications addressing leadership and leader preparation. This narrative clearly emphasizes outcomes that can only be met through a broad-based education best accomplished through a liberal arts education." *See* Joseph Gregory Kaufmann, Jr., "The Military Imperative for The Liberal Arts," Ph.D. diss., Georgetown University, 2015.
[98] Garret Messner, "Determining the Critical Leadership Attributes and Competencies in Science, Technology, Engineering, and Mathematics Educated Army Leaders that Produce Higher Quality Army Leaders," Ph.D. diss., Northcentral University, 2017. To reiterate Chapter 1, the community learner concept targets students of all ages and educational backgrounds akin to something you would find in a community college general science course for non-science majors.
[99] Bennett, email exchange with the author, November 2020. In pure sales numbers, since 1998, *The Cosmic Perspective* has sold over 2 million copies worldwide.
[100] Bennett, *On Teaching Science*, 50.
[101] Bennett et al., *The Cosmic Perspective*, xv-xxii.
[102] Debuted in 2001, the model is currently on permanent display outside the Smithsonian National Air and Space Museum along Jefferson Drive SW. *See* Appendix B for graphics of the model.
[103] Bennett, *On Teaching Science*, 22-23.
[104] Ibid., 65-104.
[105] Ibid., 20.
[106] Ibid., 59.
[107] Ibid., 58.
[108] Ibid., 50-52
[109] Lee A. DuBridge, "Science and National Security," *Science* 120, no. 3131 (December 31, 1954), 1081, https://www.jstor.org/stable/1681774.

[110] DuBridge, "Science and National Security," 1081.
[111] Ibid., 1081.
[112] Ibid., 1081.
[113] Trevor Brown, "Space and the Sea: Strategic Considerations for the Commons," *Astropolitics* 10, no. 3 (2012), 242, https://doi.org/10.1080/14777622.2012.732462.
[114] American Astronomical Society, "College Departments Offering Astronomy Related Degrees," accessed November 1, 2020, https://aas.org/learn/college-departments-offering-astronomy-related-degrees.
[115] Bureau of Labor Statistics, US Department of Labor, "Occupational Outlook Handbook, Physicists and Astronomers," accessed November 1, 2020, https://www.bls.gov/ooh/life-physical-and-social-science/physicists-and-astronomers.htm. The average median income across the US for 2019 was just north of $39,000.
[116] National Center for Education Statistics, "Digest of Education Statistics, Bachelor's Degrees Conferred by Postsecondary Institutions, By Field of Study: Selected Years, 1970-71 Through 2017-18," accessed November 1, 2020, https://nces.ed.gov/programs/digest/d19/tables/dt19_322.10.asp.
[117] Patrick Mulvey and Jack Pold, "Astronomy Degree Recipients: One Year After Degree," Statistical Research Center of the American Institute of Physics (August 2019), accessed November 1, 2020, https://www.aip.org/statistics/reports/astronomy-degree-recipients-one-year-after-degree.
[118] Ibid.
[119] Bennett, *On Teaching Science*, 54.
[120] Geoffrey C. Kabat, "Taking Distrust of Science Seriously," *EMBO Reports* 18, no. 7 (2017), 1053, https://doi.org/10.15252/embr.201744294.
[121] Robert R. Leonhard, *The New Principles of War for the Information Age* (Novato, CA: Presidio Press, 1998), 59, quoted in Trevor Brown, "Space and the Sea: Strategic Considerations for the Commons," 239-40.
[122] Neil deGrasse Tyson, "Cosmic Perspective," *Natural History* 116, no. 3 (2007), 22-5, https://naturalhistorymag.com/universe/201367/cosmic-perspective.
[123] Rachel S. Cohen, "Air Force Academy Looks to Become a Place for Space," *Air Force Magazine* (November 25, 2020), https://www.airforcemag.com/air-force-academy-looks-to-become-a-place-for-space/.
[124] US Department of Education, "Science, Technology, Engineering, and Math, including Computer Science," *Ed.gov*, last modified January 2021, https://www.ed.gov/stem.

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Appendix A

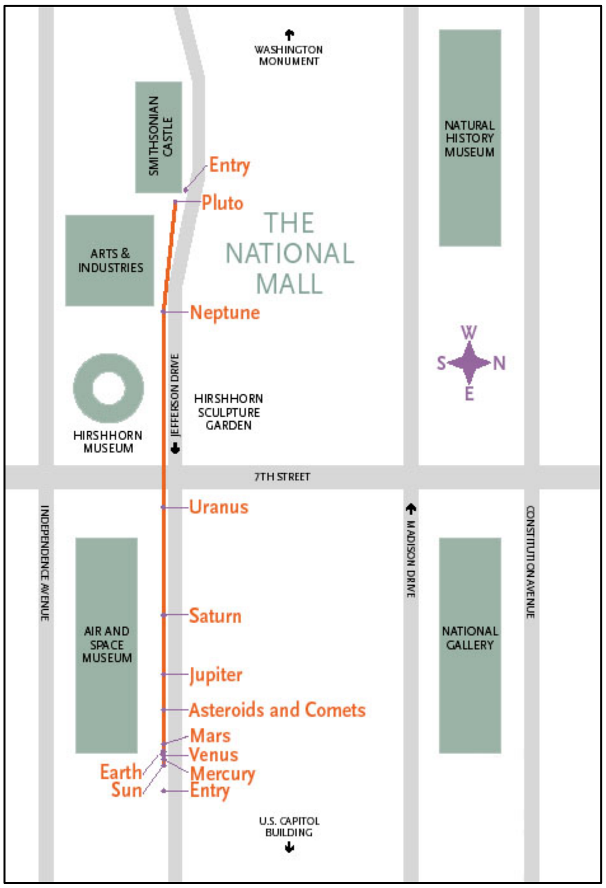
Constellation names and their English equivalents. Those referencing water, water animals, water gods, the sea, sea animals, or sea gods are highlighted **bold**.[1]

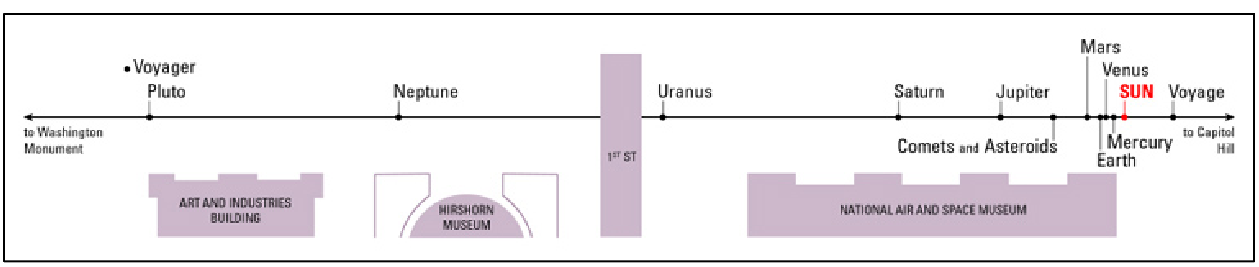
Andromeda (The Chained Princess)	Cygnus (The Swan)	Pavo (The Peacock)
Antila (The Air Pump)	**Delphinus (The Dolphin)**	Pegasus (The Winged Horse)
Apus (The Bird of Paradise)	**Dorado (The Gold Fish)**	Perseus (The Hero)
Aquarius (The Water Bearer)	Draco (The Dragon)	Phoenix (The Phoenix)
Aquila (The Eagle)	Equuleus (The Little Horse)	Pictor (The Painter's Easel)
Ara (The Altar)	**Eridanus (The River)**	**Pisces (The Fish)**
Aries (The Ram)	Fornax (The Furnace)	**Piscis Austranis (The Southern Fish)**
Auriga (The Charioteer)	Gemini (The Twins)	**Puppis (The Stern)**
Boötes (The Herdsman)	Grus (The Crane)	Pyxis (The Compass)
Caelum (The Chisel)	Hercules	Reticulum (The Reticle)
Camelopardalis (The Giraffe)	Horologium (The Clock)	Sagitta (The Arrow)
Cancer (The Crab)	**Hydra (The Sea Serpent)**	Sagittarius (The Archer)
Canes Venatici (The Hunting Dogs)	**Hydrus (The Water Snake)**	Scorpius (The Scorpion)
Canis Major (The Great Dog)	Indus (The Indian)	Sculptor (The Sculptor)
Canis Minor (The Little Dog)	Lacerta (The Lizard)	Scutum (The Shield)
Capricornus (The Sea Goat)	Leo (The Lion)	Serpens (The Serpent)
Carina (The Keel of the Ship Argo)	Leo Minor (The Little Lion)	Sextans (The Sextant)
Cassiopeia (The Queen)	Lepus (The Hare)	Taurus (The Bull)
Centaurus (The Centaur)	Libra (The Scales)	Telescopium (The Telescope)
Cephus (The King)	Lupus (The Wolf)	Triangulum (The Triangle)
Cetus (The Whale)	Lynx (The Lynx)	Triangulum Australe (The Southern Triangle)
Chameleon (The Chameleon)	Lyra (The Lyre)	Tucana (The Toucan)
Circinus (The Drawing Compass)	Mensa (The Table)	Ursa Major (The Great Bear)
Columba (The Dove)	Microsopium (The Microscope)	Ursa Minor (The Little Bear)
Coma Berenices (Berenice's Hair)	Monoceros (The Unicorn)	Vela (The Sail)
Corona Australis (The Southern Crown)	Musca (The Fly)	Virgo (The Virgin)
Corona Borealis (The Northern Crown)	Norma (The Level)	**Volans (The Flying Fish)**
Corvus (The Crow)	Octans (The Octant)	Vulpecula (The Fox)
Crater (The Cup)	Ophiuchus (The Serpent Bearer)	
Crux (The Southern Cross)	Orion (The Hunter)	

[1] Derived from Jeffrey Bennett, *The Cosmic Perspective* (Hoboken, NJ: Pearson Education, Inc., 2020), A-20, and Nick Kanas, *Star Maps: History, Artistry, and Cartography* (Cham, Switzerland: Springer, 2019).

Appendix B

Voyage scale model solar system on the National Mall in Washington, DC. On this scale, the sun is about the size of a grapefruit. Graphics courtesy of Jeffrey Bennett.





Appendix C

Interview Transcript: Major Matthew Sanchez (MS) and Dr. Jeffrey Bennett (JB).

Date: September 25, 2020.

MS: How do you as an educator try to take something as complex as space and deliver it to the public masses?

JB: The key for me is the cosmic perspective, or what astronauts call the overview. We get so caught up in thinking this is all there is down here, and so the first thing to do is shift and realize we are just a small part of a larger thing. One of the interesting things with the military, all of the early astronauts were military officers. They didn't have any real training in astronomy, space, those kinds of things. And yet when they went up there, they still all experienced that same thing of, oh my gosh, look how tiny the world is. So I think that demonstrate that there is a of universal experience if you are able to see the earth from above. What we want to do is communicate that experience to everybody who doesn't actually get to go up there personally. So that's where I would start with on space education, which is why the scale of space is so important.

MS: Do you think that as 21st century people we could probably start with, "You all know you live on Earth, so before we talk about space, we need to talk about the earth."

JB: Yeah, well, the way we approach it in our book is we start with as you said, then we set up what we know today, then we go back into the history of how we got here. The general educational principal I try to follow is going from the concrete to the abstract rather than vice versa. That's an idea that goes back to a French psychologist named Jean Piaget. Back in the 1950s he did experiments with kids and basically showed you learn how to think concretely before you can reach the level where you can think abstractly. One of the problems we have in STEM education is the tendency for people to go backwards. They say, "Here's the theory, and now I'll give you these concrete examples of how it works." But the way people learn is the other way around. You start with the concrete examples and then you generalize that into your theory. And you see that in the history of science. Newton didn't come up with his theory and then look for ways to check it. He saw all the examples around him and then realized ah-ha, there are some general principles at work here. And for that reason, we start with here's what you can experience and see and know today, and then we'll go back and do the more abstract history of how we got here and how it all ties together. So, start with here we are, this is the concrete reality that we understand right now.

MS: I'm wonder if you can speak to an outsider's perspective of okay here I am talking to a military person telling me there's a fundamental something missing in the teaching of space to space operators. How do we got about fixing that?

JB: If you don't have extra time, then you are very, very limited in what you can do. I would really focus on those scale aspects because you can do that fairly quickly particular if you've got a scale model solar system wherever you are. That'll give you that perspective and sense of things fairly quickly when you go to our Voyage model in DC, for example. You see the sun this big and you walk to Pluto in a few minutes and you realize the next star is across the United States. That kind of thing does not take very long of class time. You could do that in a couple of class periods. So, I would say that would be a kind of baseline. Everyone should kind of get that sense. Beyond that, it would be great to give the background you are talking about. The question is how do you do that unless they are going to give you an extra course, or add a couple weeks, and so on. If you can do that then it's worth doing. I would say in particular going back to that historical stuff to understand where these ideas came from. That gives people a sense of how science works. I think one of the common misconceptions about science for the general public besides all the sort of standard misconceptions, is that it's just kind of made up. People go out and say oh I have and idea, and they say oh that's real. Instead of understand that this is a long process that is checked over and over again and the evidence becomes overwhelming. That's when you realize something is in a certain way. You can't just use magical thinking and put a satellite up in orbit. It's not going to work. You have to know exactly how those laws of nature work in order to make it happen. So, if we got that idea across, that's real important as well.

MS: How do we reinforce these things? How do we reinforce at all times that the Enlightenment way of doing the scientific method is and should always be at play whenever we're making these decisions?

JB: I think that perspective, we're talking a little bit about the space perspective and the scale. I think also maybe a little bit on that time scale stuff as well, because you gave your example of North Korea: You have that immediate threat that you obviously have to deal with. But you hope that everybody is also thinking about ok well why are we in this position in the first place? What are the longer-term things we can do so that these threats won't continue to be repeated? How do you build to protect against that? I think you want to make sure that's in there. I think the military astronauts became very aware of that automatically. You want to somehow translate that experience to everyone involved so that they're thinking in that long-term, global, universal way about how do we secure a future that doesn't involved North Korea constantly threatening us and so on.

MS: What do you make of this thing, a near-Earth space force? What does it mean to you and your academic peers?

JB: I would say, semantics aside, because the semantics are confusing, I know there's been a space command for a long time down there in Colorado Springs. I've always thought of it in terms of, yeah, it's this near-Earth stuff where we have resources up in space, that if someone were to maliciously shoot them down, hack them, whatever, that would create major problems. So, you want to make sure that that is secure. So that's kind of what I think of when I'm thinking about that. You know, then there's the longer-term question of okay, now are we talking about this when we go to the moon and so on? On that, I admittedly have not thought through a lot. Other than those perspective things I would hope would come in particular, if you look for example at resources, on Earth you can understand why there are battles over resources, whether they're hot battles or cold battles. When you get to the moon, you have a situation where the resources you're interested in, metals, helium-3, whatever, there's so much of it that there's not the scarcity to battle over that [you] would have with resources on Earth. Now there is the cost and everything of getting there, and that could lead to all sorts of other things. But you'd hope that people would go, wait we don't have to be battling over this. We don't need to claim the moon, things like that; we need to figure out how does everyone share in this resource peacefully. So, I guess from a US standpoint I would look at it as I hope we have that same leadership there to be adopting this from a global perspective as being leaders of the free world as opposed to the more traditional Earth domains where only one group can have one particular domain.

MS: Putting your science educator hat on, with the Space Force coming online, is your immediate thought: What is the corpus or body of knowledge within that institution? Do you ever think or do your colleagues think, "Are they being informed by NASA scientists? Who do they have on their science advisory boards, or their technical boards?" Do they things cross your mind?

JB: Certainly, the crosses my mind. I guess I would assume that that was already built into the structure. That's just based on what I know about any of the military branches. My understanding from my friends who have been in there or are still in there is the military has been pretty good about being informed in these ways and working with NASA and having science advisors. So, I would hope that's continuing. I would tend to assume it was. It should.

MS: I am curious if your assumption is shared across the entire academic fields, not just astronomy and physics, but maybe engineering as well? Geology and all these sorts of things, because we touch all of them. Space science is important here, but I always like to tell people everything we do in space, we don't. It's all done here on this earth. We control it from the planet, which means we need power resources, we need real estate, we need infrastructure. So, again, this help me advance my message that it's not really the Space Force, it's the Earth-orbiting ground force, that's really what we are here.

JB: Semantics play a role. There's a lot of issues around the militarization of space. It depends on how people interpret the message, and it depends on what the actual messaging is, which is I think very uncertain at the current moment about what this all means. How other academics relate to it probably depends largely on how they think about those things. I think if you say, "Do you support making sure that space is protected for everyone, that nobody can dominate the near-Earth orbit, or prevent other people from having satellites, and prevent the shared use of resources?" then you'd get a hundred-percent agreement across academics. But if you use words like *space force*, that people don't necessarily know what they mean, then you're going to get a lot of other different reactions.

MS: I think where we've fallen short is how we tell our story and how we get at the recruiting message. We tend to contract out to large Hollywood-type production company to put together a really sexy video of the Space Force. Invariably it's a rocket being launched from the Cape, it's the X-37B doing an autonomous landing; recently, though, I've been seeing lieutenants in these commercials with space helmets on. We are not doing that. It's an erroneous misrepresentation of what we're doing. I know it looks cool, and it looks sexy, and maybe they'll show a picture of the International Space Station (which we are also not doing; we have nothing to do with that). I think we are doing a disservice by anticipating something it may not be. I'm curious if you have caught on to the recruiting campaign for the Space Force? Is it a head-scratcher for someone who is on the outside?

JB: From my point of view, I don't know if you've watched the show The Expanse, but there's a little bit of that in there. It's crossed my mind because of that science fiction show. But going back to your recruitment message, I think if you want to recruit lots of people including people with STEM backgrounds, if you want to recruit diverse sets of people and so on, I think emphasizing the fact that this is about building a peaceful, better world, and that the things you are doing will contribute to that, that's the kind of message that I think, to me, would resonate with a lot more people and particularly with the more diverse groups where you've got worries about social justice and everything else, so that this is part of it. And there are lots of great examples; you mentioned GPS. I don't think that most of the public has any awareness that GPS came out of this. Or in astronomy, adaptive optics. I think emphasizing that you'll be working on technologies and processes that will help people around the world. I've seen a lot of the military ads in the past have done a good job of talking about these things. They show military officers helping with various things around the world. I think those kinds of messages resonate with people pretty strongly and will help to explain what this is about, whereas the words right now are kind of ambiguous; people don't know what they mean.

MS: Ever since I joined the Air Force, there have been countless debates on STEM and breadth versus depth in space experience. I want to talk about the general public's understanding of space, of what it means to have technology operating in space, how we access it; how much of the sky has been surveyed? We probably know less about space than we do about our own planet. When you're trying to tell the message about how we access space, not just sending rockets and satellite bodies, but how we understand things that are billions of miles away, light years away, parsecs away – these grand scales. What about the technology about accessing those things? How do we distill this and make it accessible?

JB: You have to know what your audience knows and where they're coming from. You're going to have a lot of different backgrounds out there. One of the nice things when we're writing a college textbook is we can assume people basically have graduated from high school. When you're talking about the general public, that's not always going to be a valid assumption. We've got people who think the earth is flat out there. You have to go from where people are. You've said you've done some school visits. A very common thing will be for kids to ask you about black holes. There are so many layers of understanding before they can really understand what you're talking about with a black hole. You're really confronted with, "Okay, what am I going to say to this kid about it?" You have to make those choices based on what you think they know if you're in person you can probe that understanding a bit. I think one of the key things that I always want to get across, especially when I'm dealing with kids, is when what I'm going to tell you this answer I'm giving you to the questions is a very surface level answer. If you want to know, you're going to need to put in a lot of time and a lot of efforts, and gradually build that understanding. And those kinds of things, like black holes, they motivate people. You know it gets people excited and maybe it gives them the push they need to do well in school and to keep learning to reach the point they do have the understanding they're seeking.

MS: Putting aside astrophysics for a second, can you speak to how you teach a subject on a human cognition level?

JB: That goes back to what I mentioned about the concrete-abstract before. You need to understand the way people think and learn. And you need to see and evaluate how things are working in the classroom; you mentioned in one ear, out the other. There are better ways to teach than just standing in front of a room and lecturing at people. I don't know if you're familiar with these studies that have been done, but they put little brain detectors on people and they watch what happens. They found that in a typical lecture, the average student pays attention for the first seven minutes. If you're just talking, it doesn't even matter if you're Carl Sagan or Neil deGrasse Tyson, people start thinking about other things going on in their life. You have to find ways to engage and to keep people, bring them back to task, bring them back to what you're talking about. The advantage we have with space, I think, when you give people a chance to think about it, everybody does get fascinated. They could be as excited as you are if they spent the time thinking about it. It's just they've never had that time and that opportunity. If you can find a way in that class time that you're using, or whatever else you're doing in terms of education, to engage people and keep them thinking in this different way from what we think about in our everyday lives, then it'll start to get through to them. As soon as you get caught back up in your daily life, it's going to be off in a corner somewhere. You can bring it back when people have the chance. There's a reason that The Cosmos show is so popular when people see it. They get interested in space news and black holes and everything else.

MS: I'm curious what you think about the age of STEM here in the early part of the 21st century and what it means to you from an educator's perspective?

JB: There's a base level knowledge we would like everyone to have; a science/STEM literacy, kind of what *The Cosmic Perspective* textbook is aimed at. Right now, it's hit or miss as to whether people learn these kinds of things. If it were up to me, I would make sure everyone had a broader, general base of science literacy and math literacy than they do right now. That's easy to say, it's not so easy to do because that assumes there's going to be courses and things that teach those things. One of the questions you had on the list was about how the Space Force and encourage this kind of stuff. Taking the perspective that you have there of it's important for everyone to understand these base level things in the Space Force so that they can understand what they do day to day with satellites and everything else, you're in a position to push that into the general public as well, and into K-12 education as well. The military has a lot of resources, most of them are not going into education, but some of them do. If you can say, look we need everybody to learn these things in middle school, in high school, in order to have a cadre of people who will be qualified to come in and join this branch in the future. You can have that impact on how education moves that's more than just what your direct role is. NASA's done a lot of this also. I don't think you need to have a STEM degree, but you need to have some baseline understanding in order to work in this area.

MS: There is talk about standing up a Joint Space University. What would you think about opening those classes up to the public? To a middle school teacher, or a class, or something like that?

JB: I think that's a really interesting idea. We do have a problem in this country today where half a percent of the public has served in the military. The vast majority of people don't have any real understanding of what all their tax-payer dollars are doing and what this is all about. When it comes to the schools, the teachers, their kids, some of them are going to grow up to military officers or join the military and they don't know what that means. I think any opportunity to increase that public understanding particularly among teachers would be useful. To the extent that, again from a resource standpoint, there's just a lack of good teacher training in general in this country. We don't have the resources on the education side to provide the kind of training that ideally all teachers would be getting. If you're able to step in and add to that, that's a great thing. Looking at the NASA model, NASA has done a lot of these teacher training, teacher workshops compared to its size. If the military was doing those types of things also, that could only be good. It also builds the bridges between the public that's not military.

MS: We have a Space Force now, what does that mean for you and your peers teaching STEM courses? Do you see a need to implore the public to learn more about space?

JB: I think there's an opportunity to use it for that. I'm not sure that it's an automatic connection, but I think that there was a big push for STEM education after Sputnik in particular. You can use these opportunities to push for that again. It's not an automatic connection, but since you have the resource there – the Space Force exists, you've got your resources – then you should certainly use it to help push for those things because the education, to me, is serving the longer-term mission of: How do we build a peaceful future that's secure where you can't have a North Korea that goes and wrecks things for everybody else? If you're thinking about that kind of future, then this is all important to it.

MS: What are your thoughts on the commercialization of the not-quite-correct way of portraying the Space Force, or do you have any relationship to that idea?

JB: It is tough. Getting back to semantics and how things are presented make it really tricky. I think there is a lot of perception that this is just about militarization of space. That's not something that I think, if you're a science fiction fan, a Star Trek fan, you're looking at it from the Star Trek point of view—we want that kind of Starfleet perspective, you know, the way that they did things. It's got a military command structure to it, but you don't think of it as being militaristic. I think that even in my mind, it's not clear which direction the Space Force is intended to go right now—a lot having to do with its origins. What is the reality behind this program? I think it's going to take years to sort out. I would say what you're trying to do here, if you can shape the message in the direction that you're thinking and that you're going with this—to think of this as this larger perspective and education and understanding what all this means, and pushing it in sort of that Start Trek direction, then that's a great thing because that's the direction I would like to see it go. I do have the concern that it will go the other direction. When you talk about the new space race, that's something that, for me personally, is very concerning. The International Space Station, to me, is an example of the way things ought to go with international cooperation. But then you have the question, well how come China is not in there? They're off doing their own thing. Are we therefore getting into a position that will be hard to get out of in the future? I'd like to see the Space Force thinking about these things in terms of, instead of competing with China, get involved with China? That's a lot easier said than done, particularly when you look at China and what they're doing around the world. But those are the kinds of things that hopefully over time will get sorted out into the right direction. I think it needs that push of what Carl Sagan and Neil deGrasse Tyson, the cosmic perspective, what we're all talking about—we share this one small place and we better figure out how to make it work for all of us or else we're going to be in big trouble.

MS: Do you see maybe that sort of very broad line of thinking when it comes to learning about the cosmos?

JB: Yes, absolutely. There is the question of how do you counter that kind of thing. And it's not clear. I've been a long proponent of returning to the moon and doing it in an international, cooperative way, because to me, the fact that you can see the moon in the sky so easily—you know the space station is pretty abstract, unless you're very dedicated, you can't see it. And if you do see it, it's a dot. But the moon is very concrete and if you can look up at the moon and go, "Wow, there's Russians, Chinese, Americans, Japanese, Europeans, all working together right now up there," I tend to think that would have an impact on your day-to-day life—just for everybody to know that's going on. I could be naïve about that, maybe most people would say, "Whatever." But I think that that would have an impact and that's why I've been pushing for that for a long time in my work. I think when people start hearing about Space Force, like you said, they see the commercials with the astronauts and that's what they're thinking; or, I did watch that new Steve Carell show which was disappointing. They're off on the moon doing stuff. When people hear *space force*, they're not thinking this low Earth orbit, they're thinking people going to the moon and stuff. If that's the way people are going to think about it, if you can direct it towards, "Okay, we're not going there to dominate the moon, we're going there to figure out how to share the moon as a global resource and to make sure that it is shared and not dominated by anybody." If you can take advantage of that, push in that direction—that way in five, ten years—you want the perception of the Space Force in five, ten years to be: Whatever its origins were, now it's this force for peaceful, global cooperation.

MS: Maybe the roll of the Space Force, now, beyond controlling our satellites and interests in space, is taking a more diplomatic role. Would you agree?

JB: Yeah, and I would also emphasize what is at stake here. I'll give you something I've been working on lately for middle school kids. I've been doing a lot on climate change with them. When you're talking to kids, there's an enormous fear factor around climate change because the messaging that you hear—it's pretty obvious that it's scary—and what the kids hear a lot is their future is either going to be really, really awful, or maybe we'll find a way to make it not quite so awful. What I want to do is shift that messaging—I don't want to downplay the scare because it is scary, there is this really awful future possibility—but the alternative is not just barely getting by, there's a much more positive alternative. The way I try to frame this is, when you're thinking about kids, or for the general public, your own children, or your grandchildren, or your great-grandchildren, today's kids—they're still going to be alive in the year 2100. You have to shift your viewpoint on what affects my life or my kid's life, not to just [say], "Okay, what's going to happen with climate change by 2050, but what's going to happen by the year 2100 and beyond that. When you look at that you've got two basic paths: one path is we continue on the path we're on now and things are pretty bad; but the other path is we figure this out. We get off of fossil fuels. How do we get off of fossil fuels? Well, there's going to be all kinds of other new energy sources. What kinds of new energy sources? If you look far enough out into the future, you're talking about things like nuclear fusion or solar energy from space. Was it the Navy that just did a solar energy from space experiment that was launched in May? They sent up a test of something for sending down the beam energy. Things like that you go okay we could in 30 to 50 years, not just have stopped climate change by not using fossil fuels anymore, we could now have energy that's much more widely available at cheaper prices than we have today through these futuristic technologies. Then you say okay, so what are we going to do with that? In my mind one of the things you'd do with that is you say, first of all, you can use that energy for all kinds of things just right here on Earth. Also, you can go start mining the moon so that you go into this Star Trek mode where the earth is sort of a national park or preserve—you don't go dig up the earth anymore, you go get your resources from the moon. Get your helium-3 for fusion from the moon. You do all of these kinds of things. I would love to see Space Force being used as a way of messaging about here's where the long-term future looks like and here's what we're preparing for. We're going to make sure that in the future, in the year 2100 when you've got all these incredible resources available, the earth well-preserved, enough resource material to eradicate poverty around the world, to do all these amazing things. What we're setting up with the Space Force is making sure that that will be used for those positive purposes and not for negative, nefarious aims. If you can get that messaging across, use that with people, then you'll have widespread support, global support, in the same way that for a long time, the US military, NATO, has been seen as a global force for peace. You want that now to be seen in this wider domain. Lay the groundwork for that now when the force is young. Set up its mission in those directions. To me that would be very, very beneficial and helpful. As much as you can, try to get some of the NASA military officers to try and weigh in on these things. People like me or Neil deGrasse Tyson, we can talk, but we don't have a military background to really understand the whole cultural thing. I have a good friend Alvin Drew or Mark Kelly and Scott Kelly—these kinds of people who have both sides of this experience. If that's what your advisory board looks like, then you start to really push in those really positive directions for the long term.

Appendix D

Interview Transcript: Major Matthew Sanchez (MS) and Dr. Elizabeth Mendenhall (EM).

Date: October 9, 2020.

MS: What in your research seems to be the best way to marry up the scientific community with this national security enterprise in a way that informs the doctrine that I'm talking about, the policy I'm talking about?

EM: My first reaction is would we even want to do that? It makes me think, how can the military use science to achieve its military ends? What I'm more interested in is how can the scientific community can help shape what those ends are. Space debris, for example, in my opinion should be elevated above other space concerns because of what you were describing earlier, that it could ruin it [space] for all of us. The more debris that's up there, the harder the attribution problem gets. Debris doesn't just exist because of the collisions; it exists because of launches in the first place. The more we use space, the more debris there is, the more problems proliferate from this. In terms of how the military can leverage the scientific community like how to set up that relationship, I really am not confident in my ability to characterize what it looks like now. But one of the things that comes to mind is that [Donald] Kessler and his co-author back in the late 70s introduced the colliding debris concept of breeding space debris. It just didn't get a lot of attention until the 1990s. I'm curious as to where was the disconnect there? That seems to be a clear example of the military being able to leverage scientific knowledge and the scientific community to inform its approach to space, but it didn't seem to happen. So, I don't know the answer other than it seems like an important question to ask. I worry about assuming that the Space Force has the right goals and right outlook and that they're going to use science as opposed to putting the scientific community's approach to space more in the foreground to guide what those goals and purposes should be.

MS: My fear now is that if we don't start integrating space communities—in my mind, they should be one in the same. When you say military space or the space science community, to me, it's just space. That's the problem for people is that there's a separation between say what NASA is doing and what we [the Space Force] are doing, which fundamentally makes sense. They're a scientific independent government agency, they're not part of the military, not part of the national security enterprise. But because of the delicate nature of space, we should be married at the hip.

EM: It's funny, the whole article is: We should stop using these other domain analogies, but my mind goes to them automatically. I'm thinking, what is the equivalent distinction in the ocean realm? Is it the Navy versus NOAA? And also, what is the equivalent in the space realm of the Office of Naval Research that sponsored so much oceanography after World War II that really pushed the scientific community forward. In that case, the scientific community, they kind of knew what they were getting into in terms of how those funding systems, getting a grant through the ONR, shaped the research they could do. Because they were aware of it, it was sort of more palatable to the scientific community because they needed so much data collection and theory development. I just think that considering institutional analogies might make sense in this context because the ONR was so successful and also asking, does the distinction between the Navy and NOAA, is that as problematic in the same way? I would think that reason the answer is no, that it makes more sense to divide NOAA's activities from the Navy, has to do with features of the ocean itself, whereas space, you can't separate the sea surface from the water column from the seabed in terms of management in the same way. You're in orbit or you're not in orbit. And most of what we're interested in is in orbit.

MS: There's this fragility factor that comes into play that with space that is always, always overlooked in my perspective. It's not just necessarily to the physics. I've never been to space, but I've been trained to a high degree that I understand the physiological ramifications, the psychological ramifications of humans up there. There's nothing like it, and we need to start from that point forward before we continue the conversation.

EM: I would also add to that list the likely durability of launch costs. It's going to be hard and expensive to get there for the foreseeable future. And you said that the fragility should be emphasized. I would also emphasize the unity of the space domain in the sense that things are travelling very quickly. If something's going to stay stationary above you on Earth, it needs to be moving very fast in orbit. The placeness of spots of space is different than the placeness on land and in the atmosphere and in the ocean. Do you think that the space scientific community is put into national siloes maybe more than it needs to be because of efforts like the Space Force? I'm just thinking about things like the International Geophysical Year in the late 50s, an explicit effort to internationalize some atmospheric and marine sciences. I'm wondering if that's needed for the space community. Does the internationalization of that academic research community need some boosting and are we headed in the wrong direction? I don't know.

MS: I don't necessarily view it as an us versus them sort of thing, but I'm not in the Navy. I would imagine that the work that NOAA does with weather and bathymetric charts and the "understandingness" of the ocean domain is at least happily married to the Navy, but I don't know. I want to bring it back to training in terms of how we understand these domains. Could you be, for example, a surface warfare officer in the US Navy without fundamentally understanding what a line of bathymetry is? I think the answer is no, of course not. You need to understand how the currents work, how weather comes into play, the tidal forces… clearly you went through some kind of training. Let's say I was a philosophy major, not oceanography or marine biology. They would train me enough to become a surface warfare officer, would they not? The answer is yes, of course. And they've been doing this for a very long time. In my mind, our equivalent on the space side is probably not as adequate.

EM: That [Daniel] Deudney book I sent you would make the argument that cultural references fill in for people. People get an image of space just by growing up in the United States that is misleading about how accessible and usable and uncontrollable it is. I just want to say one more thing on the NOAA-Navy versus NASA-Space Force thing. I agree with you that there's sort of a distinction between NOAA and the Navy doesn't necessarily mean that they're not working together, that they can't have a productive relationship. One of the big differences is there are goals and purposes and focuses and I think, in the case of the ocean, it's fine that NOAA cares about marine plastic debris and the Navy does not. Marine plastics don't really affect the Navy's activities, except for maybe they can get caught up in propellers and stuff. But really, it's okay that debris is a focus of NOAA but not the Navy. But for space debris, that would not be okay. I think the question is, given the nature of the domain, can you split off goals based on military goals and environmental goals, and have two different organizations pursue those goals? In the space case, I think the answer is no you can't separate the goals as easily as might in the other case. Consider the Air Force: the Air Force probably thinks more about airspace than atmospheric currents—well at least air pollution wouldn't be so much of a concern I think.

MS: That's a very good point. It comes back to that fragility part for space. For NASA being concerned about a large debris cloud, it would have equal sorts of devastating effects on our space systems as it would them, because it's space. There's nothing you can really do about it. When it comes to space, we seem to hit existentialism very quickly, like almost immediately. If there's an accident in space, it's not a Space Force issue, it's a world issue right away. This is going to affect the way that we communicate with GPS, or maybe the way we take satellite pictures for Google Maps. It's going to affect our commerce maybe not immediately, but certainly over time.

EM: It's harder to distinguish or separate the pursuit of public interest from private interest. And by public interest I mean government interest so to include government interest. Another reason why it is okay in the case of marine debris but not space debris to separate who is focused on it, is the currents in the ocean mean that marine debris doesn't spread evenly across the ocean. But if it did that might be more of a concern for navy ships and submarines who don't want their wakes visible to everybody. Another example of how the ocean itself is the reason why debris behaves that way in a way the Navy can overlook, but debris in space does not behave that way.

MS: How can a space force advocate for a heightened, consciousness-raising effort to celebrate space science, to make it part of our blood, so that when people come to us and use analogies, we say no, you don't need to do that?

EM: When I read this question, I interpreted it differently at first about how can training occur without using other domains as a starting point for remote sensing or training in Antarctica to prepare for space. I was thinking that this question was pointing to how do we get people to study space directly from space?

MS: That is what I mean.

EM: You mean directly from the cognitive perspect ove space rather than physically being in space?

MS: Yes.

EM: I think that there is always a tendency to always put the space endeavor in the context of a more expanded version of human history. You said rightly so, because the space age is relatively recent and we got there relatively suddenly. It's natural to think of it in the course of human beings going to new places and doing new things. You put it in the context of these other frontiers, these other kinds of difficult exploration, like in the ocean. Evidence of my ambivalence about analogies overall, that in general I'm saying, my brain reaches for them! I'm thinking about analogies that we use to frame how we look at the planet as a whole. Deudney and I have a paper on this from 2014 that just goes through Earth images or Earth analogies, stuff like the pale blue dot idea or Gaya that think of Earth as a unitary system or a place that's in this larger context of space. Even the Earth rise photo from late 60s where you see the earth rise from the moon, because then that really foregrounds the Earth-space relationship and makes you think about orbital space and the gravity well and the atmosphere protecting us from radiation. I wonder if part of the problem is nationalism because the exploration of the oceans, like Magellan was Portuguese sent by the Spanish I think; the HMS Challenger in ocean exploration was a British expedition that was part of their colonial expansion, and I think maybe part of the solution—and this is probably anathema to the Space Force or the US military—is to think about the human species and the planet as a whole and how we relate to space. It takes away the ability to analogize to other domains because you're grouping them as Earth versus the context in which the earth is located. That's just my first thought, I don't have a really good answer, I want to know the answer. You probably read this, the astronauts are always like when you come back [from space] you're never the same, it changes you, it's a psychological experience. If there's some way to give that psychological experience—it's been a while, but definitely someone is saying this—about using virtual reality to put people in the perspective of space. Even then, you've got to make it really cold, you got to make it so you have your oxygen with you—you would have to include things about the physiological fragility of the human body in space, too, I think. How you capture things like the speed of travel in space, because if we were up there travelling very quickly, we wouldn't physically experience that. How do you capture the dynamics that explain why space debris is such a problem? Honestly, I have also been criticizing or I've mentioned that Deudney's book talks about cultural messages about space. I just watched that movie Gravity last year—did you see that one with Sandra Bullock and George Clooney? It's so disorienting and also it really makes space debris seem like a threat. So, analogies, they're a kind of story about oh you know this thing and the brave explorers and the scientific discoveries and stuff, so let's think about that in the space context. We're sort of doing that anyway, we're providing narrative frameworks for this place in and our activities there. So maybe expanding what narrative frameworks are available and may be readily attached to space.

MS: We love our pop culture in the Western world.

EM: I mean we're consuming it anyway, so.

MS: Exactly. As evidenced by, as soon as the Space Force emblem came out, everyone got upset because it was so strikingly similar to Star Trek of the 1970s.

EM: Oh, and I've been waiting to ask if you watched the Netflix show.

MS: I only watched the first episode. I didn't stop out of protest, I watched it as the pandemic was starting. I had to shift focus to saving my family.

EM: Right. It's evidence that this is a cultural phenomenon, that people are reacting to it, they're forming opinions about it. And it's kind of a moment for the Space Force to define itself internally, clearly, but also externally to how the American public perceives it.

MS: I do like the idea of breaking that fourth wall by putting people, say, in the same gravity trainers that the astronauts go through where they sort of spin around. I think things like those are necessary here at least to get students to understand that this is a very difficult place to operate in, here's what it does to you physiologically. When I did my space systems engineering degree, one of my favorite courses was human spaceflight physiology. It was taught to us by a doctor from Johnson Space Center, a flight doctor. I immediately thought to myself, *I went into the wrong field*! I think bringing that to the student right off the bat is necessary here, because even I didn't know that. Here I finished an astronomy degree from UCLA and I had no idea that these things are at play.

EM: If we did include that in training, what would the effect be? Presumably it would convince them [students] that sending humans to space is difficult and not maybe worth investing in in the near term. I feel like we're not sending that many astronauts to space already. Does the Space Force really have—I assume it doesn't have—visions of creating a military base in space. It still wouldn't capture key features of the space environment in terms of how objects interact. I think that would be a part of it, but that wouldn't achieve everything we'd want to achieve in training about the space environment.

MS: The answer is no, we have no intentions on putting military astronauts in space, at least not in this century. Maybe in the 22nd century, maybe a 23rd century problem. Because human activity, invariably, is Earth-bound. We are in the Anthropocene, so we love our Earth [activities].

EM: If you think about the human perspective in space, like if you did a virtual reality and you're in orbit, it could look very empty because even orbital space is quite vast and the satellites are relatively small. But you've got to capture that speed thing. Deudney calls it effective that things move so fast in orbit that they get from one place to a very faraway place very quickly. And that's why—it's only because I saw it recently that it's in my head—but I think the Gravity movie captures that nicely because things are moving so quickly. The sort of urgency that the speed entails in terms of safety risk is something that you would want to capture, not just the vastness of space.

MS: There's always been this debate since the first day I entered. Should we try to recruit this STEM-only career fields? I think you'll agree with me that the answer is no, of course not. You should recruit courageous patriots who have knowledge in all sorts of things—philosophy, art history, music—because if we are going to represent our society and be ambassadors for the US population, for the citizenry, we can't just all be space scientist. As cool as that would be, we would be missing the fundamental nature, the substance, of our population.

EM: I agree with you that yes, they are needed. And I think two particular reasons: there are national interested and shared global public interests in space, like maintaining the orbital environment, the orbital integrity. There needs to be communication happening between those two goals. You can't say the Space Force deals with the national interest goals and the rest of the government deals with the public interest goals because they're so closely connected. I don't know if that is about communications or it's about international relations, but it seems like there are social science things going on there. And then also psychology things maybe in terms of how people can understand and grasp space issues. But then also we haven't talked about this yet, but there's a public-private space actor thing going on too, especially in the 21st century. And I think considering not only what are the threats to private assets in space, but how does public military Space Force activity impact the market for private actors or their ability to get to space and do more things in space. So, like economists, it might be useful to get [them] involved. I think a theme of this conversation is you can't cordon off the Space Force from all these other interests and actors and goals and expect it to achieve its own goals because the space environment is so connected. The technology is available to advanced users whether they're public or private users. My background is international relations, that's really interesting to me that Iran has sent a satellite to space but they didn't launch it themselves. They don't have equivalent capabilities to the US and Russia still. They didn't build their own international space station. But Jeff Bezos and Elon Musk are in the top-tier group of potential space actors. I feel like a lot of times we treat it as if it's still great power struggle up there when it hasn't been that way exclusively for a long time and, in my opinion, that's the less relevant or dominant story to how things are going to turn out in orbital space compared to this public-private dynamic.

MS: You're absolutely right. Right now, Elon has supplanted SpaceX as a national security space provider via his launch systems. We as a government completely failed to realize that people like that United Launch Alliance had a monopoly that was overcharging taxpayers, etcetera. So, you're right.

EM: That's another question: Are these national actors? And also, just while it's on my radar: space ports of convenience, space flags of convenience. Again, it's an analogy. But the way the Outer Space Treaty regime is written now, it's possible. Although of course space ports have to be—the most useful ones are located in certain places. It's not like coastlines where there's a lot of access, or easy access to space. In terms of private actors, I think they're disruptive of the outer space regime, or the outer space regime is not constructed in a way that makes it clear how they will be managed or allows us easily manage them, I think.

MS: This is great because you're actually making me retreat on my thinking. If we do get to the end of the 21st century and we do see a preponderance of more commercial activity, then that means this idea of space control has gone completely out the window. In the United States military enterprise, we have this thing called the Unified Command Plan. You've probably heard of USSTRATCOM, United States Strategic Command. The eleventh one to stand up last year was US Space Command. Inside the Unified Command Plan, which dictates which geographic area each command has purview over, the current plan says Space Command is defined as 100 miles above the surface of the planet to infinity. It doesn't make any sense.

EM: It's kind of a fun teaching tool for orienting about space.

MS: It is, exactly. I caught wind of a new draft that says 100 miles above the surface of the earth to include cislunar space. Even that is a high volume to have purview over.

EM: I'm just wondering what justifies that outer border of cislunar space.

MS: In terms of Earth-orbiting regimes, we typically don't go beyond geosynchronous orbit, which is about 23,000 miles above the surface of the planet. If Jeff Bezos decides he's going to get into corporate competition with Elon and send an object to Venus or something like that, would he have to get our permission? Is that even legal? To me, whoever wrote that sentence clearly didn't understand the grand scale of the solar system and the universe in and of itself.

EM: Have you heard of the Treaty of Tordesillas? It's in the late 1400s when Spain and Portugal divided all of the global ocean between themselves. It's what this reminds me of because they just made this broad declaration of, we get everything over here but no ability to enforce it. And it quickly broke down because there were practical challenges to it immediately that they couldn't respond to. It really shows the futility but also it's counterproductive to make a claim that actually doesn't change anyone's behavior, which then makes you look weak or incapable.

Author's Biography

BIOGRAPHY

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MAJOR MATTHEW D. SANCHEZ

Maj. Matthew D. Sanchez is a student at Marine Command and Staff College, Marine Corps University, Marine Corps Base Quantico, Va. In this role, he represents the US Air Force, US Air Force Reserve, and the US Space Force, as a full-time graduate student. His research interests include space domain orientation, science-forwarding paradigms in new accession training, and science pedagogy. As a seminar-contributing student, he advocates methods for effective communication, implements the Marine Corps Planning Process, and offers a joint perspective for international, coalition, and civilian peers.

Maj. Sanchez received his commission through the ROTC program in 2007 at the University of California, Los Angeles. He is a senior space operations officer with a career spanning the air and space operations center, spacelift and range operations, experimental satellite command and control, Headquarters Air Force, and intelligence community duties.

Prior to assuming his current position, Major Sanchez was the deputy program manager for integrated mission management at the Defense Intelligence Agency, Joint Base Anacostia-Bolling, Washington, D.C.

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2011 Master of Science degree in space systems, Florida Institute of Technology, Melbourne, Fla.
2013 Squadron Officer School, Maxwell AFB, Ala.
2018 Bachelor of Arts degree in music, George Mason University, Fairfax, Va.
2020 Air Command & Staff College, by correspondence, Maxwell AFB, Ala.
2021 Master of Military Studies degree, Marine Command & Staff College, Quantico, Va. (expected)

ASSIGNMENTS
1. January 2008 - August 2008, casual status, 505th Training Squadron, Hurlburt Field, Fla.
2. August 2008 - February 2009, student, 392nd Training Squadron, Vandenberg AFB, Calif.
3. February 2009 - April 2010, range control officer, 45th Operations Support Squadron, Patrick AFB, Fla.

4. April 2010 - May 2012, range operations commander and flight commander, 1st Range Operations Squadron, Cape Canaveral AFS, Fla.
5. May 2012 - August 2013, wing executive officer, 45th Space Wing, Patrick AFB, Fla.
6. August 2013 - May 2017, mission director, assistant operations officer, and senior mission director, 3rd Space Experimentation Squadron, Operating Location-Alpha, Joint Base Anacostia-Bolling, Washington, D.C.
7. May 2017 - April 2019, IMA to the C3 Chief, Strategic Warfighter Communications, Deputy Chief of Staff for Intelligence and Cyber Effects Operations, Headquarters Air Force, the Pentagon, Arlington, Va.
8. April 2019 - August 2020, deputy program manager for integrated mission management, Defense Intelligence Agency, Joint Base Anacostia-Bolling, Washington, D.C.
9. August 2020 - present, student, Marine Command & Staff College, Marine Corps Base Quantico, Quantico, Va.

MAJOR AWARDS AND DECORATIONS

Meritorious Service Medal with one oak leaf cluster
Air Force Achievement Medal with one oak leaf cluster
Air Force Outstanding Unit Award with two oak leaf clusters

EFFECTIVE DATES OF PROMOTION

Second Lieutenant August 25, 2007
First Lieutenant October 31, 2009
Captain October 31, 2011
Major October 1, 2017