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Major Robert Billard Jr., USMC

Abstract: This article explores the concept of spacesteading as it pertains to military operations. Specifically, it expands on both potential and emerging technologies that could enable logistics nodes to be positioned in geosynchronous and geostationary orbit above the Earth to enable to rapid deployment of equipment. This article proposes that space domain domination would allow for a superior alternative to existing expeditionary logistics caches such as maritime prepositioning force ships and the Marine Corps Prepositioning Program–Norway. A pair of vignettes help to illustrate the value in the military enabling logistics capabilities within the space domain. While this article largely focuses on space-based logistics applications for the U.S. Marine Corps, these efforts would have far-reaching impacts to the whole of the U.S. military and beyond.
Keywords: logistics, space operations, space logistics, maritime prepositioning force, China, space elevator, carbon nanotubes

Space-based Logistics: Future Scenarios

The year is 2050. People's Liberation Army (PLA) forces are rapidly being deployed via reusable rocket to the notional country of Orange; an African nation far from the nine-dash line that once represented the extent of China's regional hegemonic goals of the early twenty-first century. Orange has

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experienced a quick and tumultuous political deterioration due to a coup from an influential military junta. In the wake of this catastrophe, global powers rush to establish influence in the region. Joining the PLA troops are brigades' worth of rolling stock, armor, field artillery, and every other operational piece of equipment that an expeditionary force would require to conduct combat operations. The equipment was dropped via space-based logistics nodes that were made possible through China's space elevator, which was completed in 2045. The consequences of the latter would prove devastating to global adversaries as it enabled the PLA to conduct extremely rapid global deployment of personnel and equipment at a moment's notice. While logistics planners in the West are still working through load plans to outfit deploying forces, the PLA has already secured their position as the dominant ground force in Orange. Chinese space developments through the 2030s and 2040s outpaced their Western counterparts, and China emerged as the dominant spacefaring nation. As a result, a country whose military and economic ambitions had previously been granted "near-peer" status was quickly able to leapfrog the competition. With the space domain now firmly under Chinese control, global hegemony finally appears firmly within their grasp.

Militarizing Space

This scenario is not science fiction, but rather a stated goal of the China Academy of Launch Vehicle Technology, an entity belonging to China's "main space program contractor China Aerospace Science and Technology Corp."[1] Accordingly, "By 2040, it hopes to put its new-generation launch vehicles into operation, making interstellar missions, asteroid mining and space-based solar power plants possible. Five years on, it hopes to make space elevators a reality."[2] Even if this stated timeline is unreasonable, it must be taken seriously.

The United States may dominate China in every instrument of national power (outlined in *Strategy*, Joint Doctrine Note 1-18), but if a burgeoning near-peer threat were to effectively conquer the space domain first, then that adversary would possess an incredible advantage—one that would easily supplant the United States as the de facto global superpower. *Space Operations*, Joint Publication 3-14, defines the *space domain* as "the area above the altitude where atmospheric effects on airborne objects become negligible."[3] "Dominating" the space domain would entail freedom of access for space-based vehicles and equipment or uncontested access. These definitions will be important to understand going forward as dominating this domain could enable basing future technologies and subsequent military utilization of these technologies.

While both China and the United States are currently parties to the 1967 Outer Space Treaty, which governs militarization activities in space, there is no assurance that any party would adhere to its principles if it meant ending a third world war on their terms.[4] In extremis, there is not a country in the world that would not leverage the full spectrum of every possible advantage that they may possess in such a scenario. The reality is that rapid space dominance is rightfully within the purview of all spacefaring nations as such an ascendancy would effectively mitigate any shortcomings that country may otherwise have against the United States. Simply put, the United States could field the most effective military in the world, but it would be rendered useless if it can be neutralized from space. Reducing the problem set to only depict strategic weapons in space would massively undersell what space dominance can offer a country. Developments such as space elevators will drastically alter the mechanisms in which states wage future wars and will significantly reduce deployment times for personnel and equipment.

Future Marine Corps leaders will not be the ones to invest in, research, or develop the technology that will bring Marine Corps' equipment to orbit. Consequently, Marine Corps leaders will not be the ones to address the myriad scientific and engineering hurdles that must be overcome to achieve these evolutionary leaps in space technology. However, the military applications of a space elevator are impossible to ignore. The Marine Corps, and military leaders overall, must understand how they can adapt to future technologies that could shorten the timelines associated with deploying anywhere in the world.

Logistics Nodes

Current prepositioned logistics nodes utilized by the United States Marine Corps, such as maritime prepositioning force (MPF) ships operated by Military Sealift Command or geographically prepositioned caches in Norway, offer mechanisms to deploy equipment to far-flung places in the world. However, they come with major constraints. These constraints include:[5]

- Space limitations[6]
- Embarkation configuration[7]
- Spare parts availability[8]

Utilizing MPF equipment requires extensive lead times and coordination for planning, ship movement, offload, equipment assembly, and then movement of equipment to the desired location. Additionally, MPF offload at a contested port may not be desirable or possible depending on the adversary's defensive posture. These problems will not disappear in space, but the space domain will offer the potential for greater flexibility and response time once the space domain has been firmly established. This point is important as extensive research and development will be required in addition to the astronomical costs and time associated with large assets in space.

A critical pacing function of winning any war has always been logistics; the Marine Corps' *Installation and Logistics 2030* specifically states, "Among the seven warfighting functions, logistics most dictates the tempo of operations and the operational reach of a unit. No other warfighting function more profoundly affects our ability to persist in contested spaces."[9] Future wars will be no different. The side that can more efficiently transport and maintain the maximum amount of personnel and equipment will have a superior advantage. When analyzing logistics through the contextual lens of a multidomain approach, space would truly be the final frontier. Domination in this realm will set a nation on the path toward global hegemony that will prove decisive. Enter "spacesteading" as a concept.

Military Spacesteading

Spacesteading is a natural extension of the concept of "seasteading." That is, the colonization of the sea (a portmanteau of the words "sea" and "homesteading") that was largely popularized by author Wayne Gramlich in a 1998 essay, though the word itself existed prior to this.[10] Applying this concept to space is not exactly novel, for example: Space historian Robert Zimmerman proposed a "Spacestead Act" in 2017 with the intent of enabling the United States to lead the world in furthering space exploration.[11] Such conversations tend to focus on individuals seeking liberty and independence from states in areas with limited or no government reach, such as international waters or outer space. In this approach, the term *spacesteading* will refer to any act of staking any orbital position around the Earth. Applying a colony approach to military logistics in space could enable an entity to cache military equipment in space stations in Earth's orbit. These stations could be unmanned, compartmentalized, and automated. Ground-based logisticians could quickly and easily identify the exact type and number of equipment needed for an operation and have it dropped from orbit to the exact location where it would be needed. Personnel could then be transported with a near nonexistent logistics train to exactly where they need to be; indeed, by the time this technology is practical it may be possible to transport personnel across the globe via rocket in a fraction of the time it currently takes. The sky is no longer the limit with the space domain, and whoever dominates this realm first will reap the benefits.

This is not to suggest that prestaging equipment in space would completely eradicate the current limitations and constraints that are experienced through other prepositioning means. Load planners, mobility personnel, operations cells, equipment owners, and all other key stakeholders would still require time to plan and train for the requirements associated with a space-based endeavor. But leveraging the fastest possible means of resupply provides an unmistakable advantage. Space-based options are also subject to a potential variety of setbacks. These could include enemy electromagnetic pulse (a.k.a. an EMP), which could stem from an enemy nuclear high-altitude burst, or even antisatellite weaponry. Considering this type of platform for logistics staging does not necessarily spell the end of existing mechanisms; however, given the extensive technological leaps that a spacesteading infrastructure presupposes, it offers a rapid response capability that would outpace existing structures.

As previously established, the Marine Corps will not be on the forward edge of the development of such emergent technologies. Nor will such technological leaps likely even consider the Marine Corps at the forefront of use-case possibilities. But once established, the Marine Corps (and other military organizations) must advocate for a relative primacy of use against other potential customers to space elevator (such as other military organizations or even private entities) to stand better poised to fight America's future potential wars and win.

Space Elevator

Current technology effectively precludes the deployment of larger stores of equipment in Earth's orbit. This is largely since construction in space is extremely difficult.[12] Further, building things on Earth and then launching them into space via rocket comes with major constraints, namely that the cost is far too prohibitive to launch equipment into space. As of December 2023, one could expect to pay approximately $0.28 million per kilogram by using a popular rideshare program through SpaceX.[13] Long-term and large-scale planning to stage military equipment into orbit would require revolutionary advancements in how humans can access outer space. One such proposal has been a space elevator. Space elevators are theoretical structures that use ground stations tethered to a counterbalance in space, with elevators (or "climbers" as they are generally referred to in this context) to ascend into a spot in geosynchronous and geostationary orbit.[14] Hypothetically these climbers could transport equipment constructed on Earth, far heavier than the payload capacity of a rocket, directly into orbit through the space-based harbor.[15] As a result, a military equipment colony could be constructed on Earth, raised via a climber, and then be stationed as a geosynchronous harbor for which equipment could be stored. From there, logisticians will be able to pick and choose what stores of equipment best suit operational needs. The equipment could be compartmentalized to preclude extensive load planning and time otherwise used rearranging equipment onboard something like an MPF ship. China is already apparently pursuing such a system. According to a Chinese state-run news source,

> a "Sky Ladder" system . . . is under study, as a starting point for such a space voyage, in a bid to reduce the scale of Mars probe and transport missions. . . . Technologies like the Sky Ladder delivery system have been mentioned before, as some scientists believe it would transport humans and goods to the moon for just four percent of the current cost.
>
> Xinhua Global Service has illustrated the process in a computer graphic footage. It shows a manned or cargo space capsule travelling along a carbon nanotube "ladder" to reach a space station before it is relaunched from the space station.[16]

Additionally, Japanese construction company Obayashi has outlined a specific timeline to build a functional space elevator by the year 2050.[17] Obayashi acknowledges that "current technology levels are not yet sufficient to realize the concept, but [their] plan is realistic, and is a steppingstone toward the construction of the space elevator."[18] The plan calls for a 20-year development and construction cycle that will require an Earth port and a geostationary orbit station tethered by a cable, the latter being the main current technological constraint.[19] Accordingly, this plan will require 96,000 kilometers of carbon nanotube cabling weighing 20 tons initially, reinforced 510 times, and bearing a tensile strength of 160 gigapascals (a.k.a. GPa).[20] The current tensile strength measured GPa of carbon nanotube are considerably lower than this, though theoretical values would make this possible.[21]

Suffice it to say that this technological approach is hardly even in its infancy. There is much work to be done before this can become a reality, with a major current constraint being the development and functionality of appropriate cabling composed of carbon nanotubes. But importantly, the academic body of work surrounding space elevators indicates that it is a possibility. Further, market sources suggest that the United States may already have a head start in the practical development of carbon nanotubes. According to Future Market Insights:

- The North American carbon nanotubes market held a dominant share, accounting for 27.9 percent share in 2022.
- China's carbon nanotubes market secured an 8.1 percent global market share in 2022.[22]

Having the highest share of carbon nanotubes in the mid-twenty-first century may prove to be as decisive of an advantage as having the largest stores of uranium and plutonium did in the mid-twentieth century. Similarly, if the space race of the twentieth century, between the United States and the Soviet Union, culminated in the Moon landing, then a major milestone of the twenty-first century between the United States and China could become the question of who can develop the most—and best—carbon nanotubes the quickest.

The transformative nature of instant space accessibility with exponentially expanded space launch bandwidth, all at a fraction of the cost of current mechanisms, would represent the single most momentous revolution in transportation in millennia, greater than the opening of the Suez or Panama Canals. The first country that can embrace and harness this type of innovative approach to space logistics will hold the key to space access and dominance.

Challenges

When confronting the vast technological divide that exists between now and the time when space elevators may become a reality, it is important to study the technology through the contextual lens of military spacesteading. This contextual lens does not seek to answer the full gamut of how this technology can come into existence, but rather its utilization from a military perspective. As previously established, there are entities across the globe now that seek to develop a space elevator, and that alone warrants a thorough understanding of what possibilities that could bring to a near-peer fight. The challenges associated should not preclude planning and research. As far back as 1984, NASA explored options for space tethering in a published technical memorandum and concluded that the associated challenges "do not detract from the value of these prophetic concepts because some of those may be considered as distant goal setters that provide direction for future developments."[23]

However, there are clear technological challenges that exist, which also impede the implantation of such innovations. For example, while current orbiting objects are at risk of conjunction with each other, the existence of a stationary elevator will guarantee that there will be collisions. This challenge alone will be difficult to overcome for anyone hoping to develop a space elevator. This problem has been established for decades. For example, author Arthur C. Clarke proposed an alternative in 1966 that would try to mitigate the potential for collisions through the "Sky-Hook."[24] The Sky-Hook, accordingly, is a "satellite in low circular equatorial orbit [that] has two long tethers deployed in opposite directions. The system rotates in the orbital plan in the same sense as the Earth rotates. The tethers touch the Earth's surface during each rotation such that the velocity of the lower tether end cancels the orbital motion of the cable carrying satellite."[25] Ultimately, it was concluded that "the theoretical strength of the cable material" required was "more than two orders of magnitude greater than that of available engineer materials" of the time.[26]

To maintain the concept of a space elevator without resorting to a Sky-Hook, or some other temporary tethered device, there have been suggestions on anticollision mitigation techniques as well. Dr. Casey Handmer posited that "transverse vibrations are probably an excellent way to transmit power along the [climber] cable and to enable it to avoid collisions with satellites at lower orbits."[27] He further adds that many issues associated with corrosion, micrometeorites, etc., "can be dealt with by covering the structure in a shield like the shield on the ISS. It consists of a ceramic layer which absorbs the impact by shattering, and a metallic shield layer which can absorb lots of small impacts."[28] These two methods in combination may help mitigate a large quantity of potential issues associated with the prospect of collisions; but they would not cover every possibility. This is merely an exercise in showing that even current understanding of the problem set can provide some potential solutions that would be more readily available by the time this technology comes into existence.

Material strength of the structure is a primary concern. As previously established, carbon nanotubes are the only currently existing material that could potentially serve as construction material for such an elevator system to exist. According to NASA, however, these nanotubes are rated at a technology readiness level (TRL) of four, implying that research has been conducted to prove their feasibility but not validated in a laboratory environment.[29] Consequently there is a long way to go until they are rated at a TRL of nine where they will be proven for operation.

The point in highlighting some of these challenges as major obvious obstacles is not to dismiss the concept as an impossible fantasy, but rather to prove that this undertaking is massive. But this does not mean that the associated challenges are insurmountable. To further emphasize, the Marine Corps should not necessarily seek to identify and address the scientific and engineering constraints associated with the creation of this technology. Rather, the Marine Corps and future military logistics planners should know that logistical doctrine must evolve rapidly to take advantage of emerging technology.

Establishing New Beachheads in Space

In the 1940s, logistics nodes were established at great cost by landing support Marines on beaches across the pacific. These beachheads were staunchly defended to the death by many thousands of Marines fighting to claim islands from the Japanese. From them, additional equipment was able to flow from the sea that gained tactical superiority for the Marines in these conflicts. By the end of the war, the United States' naval dominance effectively precluded the Imperial Japanese Navy from supporting their defensive campaigns on islands like Iwo Jima. A major lesson learned from those examples was that freedom of movement and logistics throughput were significant factors in deciding the culmination of the war. So, too, would those same factors help to determine who can freely dominate space and consequently assure themselves of global hegemony.

To maximize the utility of military spacesteading operations, orbiting logistics nodes should reflect the size, scale, and scope of ground-based requirements. These stations should provide tailorable option sets that can easily detach from the node to rapidly form needed gear sets, or they should be capable of deploying to the ground as a whole. There should be multiple such stations in orbit at any given time to enable the most rapid possible deployment of gear as well as to ensure redundancy. The *International Space Station* orbits Earth every 90 minutes, according to NASA, therefore at minimum the capability to spacestead equipment will allow for equipment to be orbitally dropped in at least such a time, but the more nodes that exist in orbit the faster that equipment could be deployed to the desired location.[30] Utilizing both a geostationary approach from the harbor atop the space elevator, as well as geosynchronous stations that were built on Earth and launched thanks to the space elevator, will allow the greatest possible flexibility toward achieving logistics requirements. Aboard these stations, equipment can be stored in modular and detachable containers that can survive the delivery mechanisms from space to the ground. Mobility personnel within Marine Expeditionary Forces (MEF), in conjunction with their space operations personnel, will be equipped with load planning software that will quickly identify exactly what equipment will detach and where it will land. Timing the landing with the operations section of the MEF will ensure that gear and personnel arrive at the same time. Space logistics will become a new practical field for existing military logisticians. New subordinate specialties will come into existence. For example, space delivery personnel will complement existing air delivery Marines. These Marines will specialize in the specifics of planning for and receiving spaceborne items that will have unique considerations.

While much focus has been on replicating the capabilities of the MPF program, pivoting toward space-based approaches could completely revolutionize even the most standard resupply missions that the Marine Corps conducts while deployed. More basic, albeit critical, resupply functions such as Class I (food and water), Class III (oil), Class V (ammunition), and even Class IX (repair parts) could easily be dropped to forward deployed units in a fraction of the time and a fraction of the cost to current methods. Further, when operating in an extremely hostile environment where an ever-present threat of improvised explosive devices, conventional mines, or even antiair threats prevent safe resupply to outstations, space-based resupply could prove to be the difference between life and death.

Orange Redux: Possible Outcomes of Space-based Logistics Use

The year is 2050. Deposed government leaders of Orange desperately reach out to Western leaders for assistance in curtailing the violent takeover from the military junta. To stem the tide for regional influence in Africa, the White House approves a unilateral intervention plan to send in the Marines and restore the duly elected government to power. After receipt of the warning order, I MEF assesses the scale required to drop an entire MEF's worth of personnel and equipment into the influential African nation in the following 48 hours. I MEF, now no longer as constrained as much by the tyranny of distance, quickly identifies the equipment density list needed for such an operation. Thankfully, previous exercises and wargames have already identified most of what will be needed. The date is set, and Marines with their primary weapons load into Air Mobility Command's transport rockets, which can take them anywhere in the world in less than 30 minutes (this capability had already been predicted much earlier in the century).[31] The appropriate rolling stock, communications equipment, and everything else that the task force will require is already identified and ready to drop from orbit where space delivery Marines from the G-4 will meet with it to coordinate dissemination.

Thankfully, in this updated version of the events, the United States invested heavily into carbon nanotube development in the 2020s and 2030s, which enabled the country to be the first in the world to establish a space elevator with U.S. military primacy of use. While the People's Republic of China is still busy posturing diplomatically, the United States is already at work with boots on the ground favorably reestablishing the regional order of things.

At the conclusion of hostilities, the spacesteaded equipment will travel to a home station via rocket where it will receive proper maintenance and redeployment to the space station through the space elevator that originally delivered it to space.

Other Space Logistics Possibilities

The topic of space logistics is coming more into the forefront of military consciousness. Tyler Bates, writing for Air University's journal *Æther*, recommends significant space logistics paradigm shifts:

> By the early 2030s, SpOC [Space Operations Command] should have a space sustainment space delta that would oversee its own space operations squadrons responsible for on-orbit refueling and on-orbit vehicle maintenance. This will provide US and Allied forces the ability to sustain space forces across multiple orbital regimes, from low-Earth orbit to cislunar space.[32]

The prospect put forward here of refueling and maintaining equipment in space will be complementary and critical to successful space-based logistics. He expands with two other points that will also aid in this endeavor: space-to-terrestrial energy distribution and rocket logistics.[33] The former focuses on harnessing the orbital capacity to gather more sunlight for wireless transmission to Earth as an energy source while the latter describes utilizing rockets to transport gear rapidly across the Earth.[34] Harnessing solar power from the unencumbered vantage points that space offers would not only allow for microwave transmission of power, but could theoretically tap into geostationary, space-elevator based harbors to directly transmit power to the surface. Assuming the yield from such a venture would be exponentially greater than the return on investment of surface-based solar panels, the impact of this could have significant ramifications that far exceed military applications. To be sure, every function of logistics can and should be developed for space-based utilization. Refueling capacity, energy production, maintenance, and transportation will all serve as complementary capabilities in the space domain that will give the United States an edge over any near-peer competitors who seek a technological or strategic advantage.

Recommendations

Space is designated by North Atlantic Treaty Organization (NATO) as an operational domain akin to ground, maritime, air, and cyberspace.[35] Success in any domain requires extensive logistics support. Space-based logistics will be the pacing factor in determining ownership in that domain. As a result, senior military leaders and advisors would be keen to recognize the value of investing in, and utilizing, emerging technologies to advance existing prepositioning concepts. Military spacesteading is such a mechanism that will directly enable ground-based success from space-based assets. While historically space has been a domain largely dominated by intelligence and communications subject matter experts, the future will require experts from a variety of fields to develop space-based logistics platforms.

The military is an entire industry in the United States that is uniquely poised, budgeted, and equipped to invest in the type of research and development that could yield revolutionary advances in military technology such as would be required for these concepts. The benefit to society writ large would additionally be immeasurable. If the United States does not do it, then the door is open to a competitor to seize a mighty advantage that will be difficult to surmount after the fact.

Conclusions

The militarization of space is a relatively new phenomenon that has opened extraordinary avenues for those entities willing to explore them. The rapid technological developments throughout the end of the twentieth century to the present day has opened new potential avenues into transportation, energy production, resupply, and maintenance. While the term *militarization of space* may generally conjure up visions of imagery satellites, or even placing actual kinetic or strategic weapons in orbit, it cannot be overstated how important it will be to establish a logistics footprint in space.

While several logistics mechanisms have been discussed, the United States would instantly develop a national logistics center of gravity though the development of a space elevator. While the technological leap to get to its implementation would be staggering, the capabilities that this would provide will far outweigh the associated costs. The twentieth century provided such leaps in space exploration that perhaps few living in the year 1900 could have ever dreamed to be possible. This century should be no different—the Marine Corps specifically must continue to find ways to embrace and adapt not only emerging technologies, but the concept of those that do not even appear within grasp. Future logistics innovators who heed this will be well poised to transform the Marine Corps to be prepared for the future space race and its associated paradigm shifts in strategy.

Endnotes

1. Zhang Xia, "China Shoots for Stars with Plans to Build Space Elevator by 2045," YiCai Global, 17 November 2017.
2. Xia, "China Shoots for Stars with Plans to Build Space Elevator by 2045."
3. *Strategy*, Joint Doctrine Note 1-18 (Washington, DC: Department of Defense, 2018); and *Space Operations*, Joint Publication 3-14 (Washington, DC: Department of Defense, 2020).
4. Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, including the Moon and Other Celestial Bodies, United Nations, 27 January 1967.
5. *Maritime Prepositioning Force Operations*, Marine Corps Warfighting Publication 3-32 (Washington, DC: Headquarters Marine Corps).
6. *Maritime Prepositioning Force Operations*, 4-2.
7. *Maritime Prepositioning Force Operations*.
8. *Maritime Prepositioning Force Operations*.
9. *Installations and Logistics 2030* (Washington, DC: Headquarters Marine Corps, 2023).
10. Wayne Gramlich, "SeaSteading: Homesteading the High Seas," Gramlich.net, 1998.
11. Bob Zimmerman, "How President Trump Could Jumpstart Space Settlements," *Federalist*, 17 April 2017.
12. Kevin Forestell, "How to Build in Outer Space," *DOZR* (blog), 1 September 2022.
13. "SmallSat Rideshare Program," SpaceX, accessed December 2023.

14. "Space Elevator FAQ," ISEC, accessed December 2023
15. "Space Elevator FAQ."
16. Deng Xiaoci, "Chinese Rocket Manufacturer Outlines Manned Mars Mission Roadmap, Timetable," *Global Times*, 23 June 2021.
17. "The Space Elevator Construction Concept," Obayashi, 4 November 2014.
18. "The Space Elevator Construction Concept."
19. "The Space Elevator Construction Concept."
20. "The Space Elevator Construction Concept,"
21. Akira Takakura et al., "Strength of Carbon Nanotubes Depends on Their Chemical Structures," *Nature* 10, no. 3040 (2019): https://doi.org/10.1038/s41467-019-10959-7.
22. "Surging Investments by Key Players to Boost the Carbon Nanotubes Market Growth; FMI Predict Market Valuation to Cross US$ 2,428.1 Million by 2033," Future Market Insights, 17 July 2023.
23. Georg von Tiesenhausen, *Tethers in Space: Birth and Growth of a New Avenue to Space Utilization* (Washington, DC: NASA, 1984).
24. von Tiesenhausen, *Tethers in Space*.
25. von Tiesenhausen, *Tethers in Space*.
26. von Tiesenhausen, *Tethers in Space*.
27. Casey Handmer, "Space Elevator/Lift Physics," *Casey Handmer's Blog*, 30 November 2012.
28. Handmer, "Space Elevator/Lift Physics."
29. David V. Smitherman Jr., *Critical Technologies for the Development of Future Space Elevator Systems* (Huntsville, AL: Marshall Space Flight Center, NASA, 2005).
30. "Station Facts," NASA, accessed December 2023.
31. "Elon Musk Proposes City-to-City Travel by Rocket, Right Here on Earth," ABC News, 29 September 2017.
32. Tyler D. Bates, "The Next US Space Force Design: Missions and Units for the 2030s," *Æther*, 22 November 2022.
33. Bates, "The Next US Space Force Design."
34. Bates, "The Next US Space Force Design."
35. "NATO's Approach to Space," NATO, 23 May 2023.