Black Space versus Blue Space

A Proposed Dichotomy of Future Space Operations

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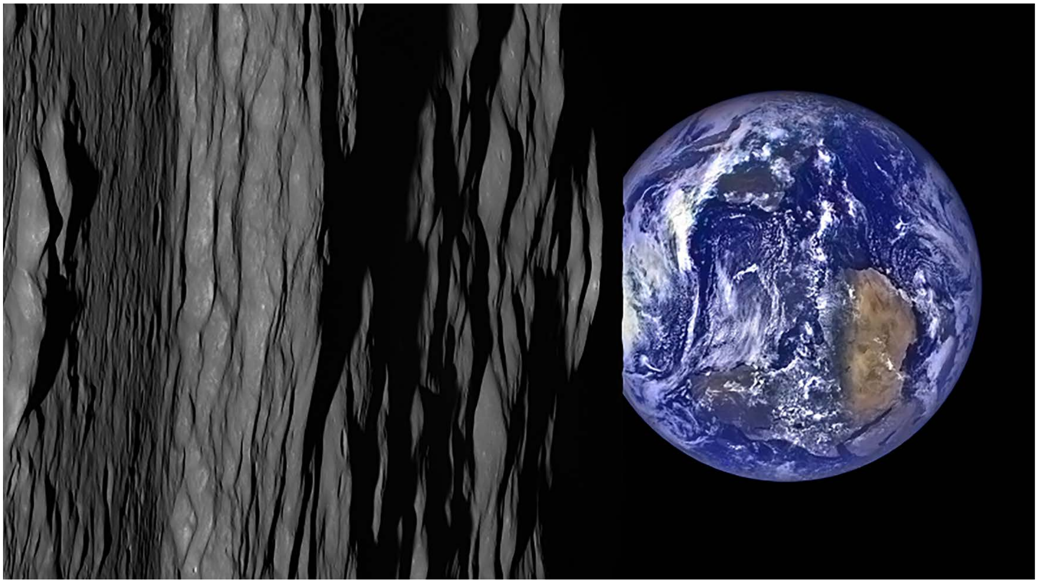

Introduction

As defined by the *National Defense Authorization Act (NDAA) for Fiscal Year 2020*, the purpose of the United States Space Force (USSF) is to "provide for freedom of operations in, from, and to the space domain for the United States" and shall include "both combat and combat-support functions to enable prompt and sustained offensive and defensive space operations and joint operations in all domains."[1] As part of the formal debut of the USSF after the signing of the NDAA into federal law, Chief of Space Operations Gen John Raymond stated the formation of the USSF serves to "[elevate] space commensurate with its importance to our national security and the security of our allies and our partners."[2]

Traditionally, Air Force space operations were ostensibly limited to near-Earth space with mission altitudes extending from low-Earth orbits (LEO) to geosynchronous (GEO) or highly-elliptical (HEO) orbits. During the 2010s, however, space operations began moving beyond this approximate altitude limit to encompass cislunar space with reinvigorated US initiatives to return to the Moon, planned commercial space projects, and cislunar injection trajectories for geosynchronous-orbiting satellites. Additionally, an increase in projects from both near-peer and emerging spacefaring nations, such as China's Chang'e 4 lunar rover mission and accompanying Lagrange-point communications relay satellite (2018–19), and Israel's attempted lunar surface mission (2019),[3] has pushed US space domain awareness and space control considerations beyond near-Earth space.

The US and wider international space operations, moving beyond cislunar space extending to the Moon, are poised to extend to Mars and potentially asteroids. Recently, then President Donald J. Trump issued an executive order encouraging the recovery and use of natural resources in space, thereby sanctioning the commercial mining of asteroids and potentially other celestial bodies.[4] Considered by some to still be the realm of science fiction, the conceptualizing of realistic space operations beyond the Earth's gravitational sphere of influence within the next several decades has initiated around the world. Relevant to the US and the scope of this article, the (former) Air Force Space Command released a study in 2019 outlining the findings of its "Space Futures Workshop." This report, *The Future of Space 2060 and Implications for U.S. Strategy*, pushes the bounds of legacy space operations paradigms and maps potential realities for emerging space-based economies and alterations to the international order.[5]

Influenced by this preliminary US Air Force (USAF) planning initiative, the authors advocate a new way of classifying space operations within a dichotomous structure that focuses on the location where space operations are intended and conducted with respect to the Earth or other celestial bodies (e.g., the Moon). Similar to the legacy classification paradigms of "brown-water" and "blue-water" navies in the maritime domain and the differences between local/regional and global air forces in the air domain, this article proposes the creation of a "black-space" and "blue-space" structure for space operations. This new distinction enables the functional division of current and emerging USSF missions as national space operations begin to routinely transcend the Earth's gravitational sphere of influence and the formation of acquisition lines of effort to support expanding missions aligned with an equally expanding scope of national security and strategy. The proposed structure differs from contemporary analyses that posit terms such as *blue-water space* and *brown-water space* by instead creating a description of operations truly unique to the space domain.[6]

This article will examine the proposed space operations structure by first outlining the historical foundations for differences in maritime and air domain military capabilities, specifically brown-water versus blue-water navies, and "local/

regional" versus "global" airpower. Next, the article will present the concept of black space and blue space in terms of an environment-specific definition, as well as an examination of the technical capability requirements, mission types, and national prestige and geopolitical considerations underpinning the proposed operation types. Finally, the article will explore how the USSF might support future space exploration within the black-space and blue-space operations structure.

Historical Antecedent: Brown-Water Navy versus Blue-Water Navy

Space has always had a strong tie to the oceans—from the vast emptiness to the ever-present drifting of everything. This analogy makes the employment of naval and maritime references only natural as the venture into space begins to mirror humanity's mastery of the sea. This article seeks to use the capabilities and areas of influence developed for brown-water and blue-water navies as a foundational dichotomy for the space domain to further press upon the connection. The term *brown-water navy* refers to a coastal, littoral, or inland waterway naval defense force used to protect local interests and national assets. Similarly, a *blue-water navy* is an open-ocean or international naval defense force used for the protection of commerce and national interests through the projection of national instruments of power. The operational techniques for each type of navy and their respective area or "sphere" of influence are dependent on both technology implementation and evolving national security needs.[7]

Following the American Revolution, US naval attention was bifurcated into two modes. The first represented the maintenance of an emerging blue-water capability to protect US shipping and trade routes. For example, this capability was pivotal in defeating the Barbary pirates in the Tripolitanian War (or the First Barbary War; 1801–05) and sustaining a sea line of communication between the eastern seaboard and California before the transcontinental railroad.[8] The second mode, brown-water in orientation, is exemplified by the creation of the "Revenue Cutter service," known today as the US Coast Guard (USCG),[9] which was charged with coastal defense and maritime law enforcement. Auxiliary, yet temporary brown-water capabilities, were also forged by the US Navy (USN) to combat the British during the War of 1812 in the Great Lakes and Lake Champlain and later during the Civil War along the major inland rivers such as the Mississippi.[10] The end of the 1898 Spanish-American War solidified the need to create a viable US blue-water navy with the acquisition of former Spanish territories across the Pacific Ocean and in the Caribbean Sea.[11] Nineteenth-century naval progress enabled the US to secure "command of the sea" and control its commercial and military "maritime communications" during the twentieth and early twenty-first centuries.[12]

Whether it was the Portuguese and the Spanish during the fifteenth and sixteenth centuries, the English and French during the seventeenth and eighteenth centuries, or the English and Americans in the nineteenth century, the evolution in technology became a central component to the transformation of brown-water into blue-water naval capabilities. New ship designs, the introduction of a nautical chronometer for the measurement of longitude,[13] and the eventual transition from wind to steam and then to diesel power-produced potent naval forces that could predictably and reliably be used to project national power with both increasing speed and precision. The new forms of maritime propulsion, coupled with the ability for near-instantaneous communications brought about by the invention of the radio, allowed for national spheres of influence to realistically grow beyond littoral control, and the age of global naval power became technologically practical.

Enamored by the prestige of wielding a blue-water navy, some nations neglected to sustain a brown-water capability and, therefore, limit their naval power. As previously described, the US has had a long history of balancing coastal protection needs with the importance of international maritime power projection. During the Vietnam War, however, the USN had no means to conduct missions in littoral and inland waters against the North Vietnamese and insurgent Viet Cong. In its place, portions of the USCG were used until the USN could transition equipment and tactics for "riverine" missions.[14] This need emerged again during recent operations in the Persian Gulf because the USN had overlooked the need to maintain a brown-water capability.[15] As with the Vietnam War, the USCG again served a deployed function during Operation Iraqi Freedom and complemented USN operations by protecting Persian Gulf shipping, coastal petroleum refineries, and Gulf oil platforms.[16] Despite its lack of a true brown-water capability, the USN has come to use its "blue-water [aircraft] carrier[s]" as an effective tool in both "influence and power projection" to provide coverage between the blue-water and brown-water arenas of maritime warfare.[17]

Historical Antecedent: Local/Regional Versus Global Airpower

As with the maritime domain, there is an observable distinction in the air domain concerning the evolution and pursuance of local, regional, and global airpower. In the present research, the term *airpower* is restricted to its classical air-centric definition and does not include the cyber and space domains as reflected in current USAF doctrine.[18] Foundationally, local and regional airpower is projected by air capabilities technologically constrained in terms of spatial range due to airframe design and fuel storage capacity. Local and regional air forces (or services) will typically operate within a radius that is intracontinental in scope without the need for aerial refueling capabilities for range enhancement. By extension, these technological constraints are a byproduct of and influenced by a given nation's geopolitical position and security considerations vis-à-vis its regional neighbors and international interests.

Historically, early aircraft were limited in range and operated within a radius measured in tens to hundreds of miles of airfields. This range continued to grow as operational requirements intensified during World War I. The British Handley Page V/1500 (HP 15) delivered a maximum range of approximately 1,300 miles (2,092 km) to bomb targets deep within Germany from Great Britain or France.[19] Aeronautical advances were rapid in the early days of aviation, with the first US transcontinental flight from New York to San Diego (approx. 2,700 mi, or 4,350 km) in 1923 in a Fokker T-2 and the first trans-Atlantic flight (approx. 3,600 mi, or 5,790 km) in 1927.[20] These advances, however, were only associated with smaller-scale aircraft featuring limitations in both weight and crew to maximize aerodynamic and engine efficiency. Commercial aviation and the record-breaking exploits during the Interwar period helped push the bounds of aeronautical engineering, with aircraft evolving in terms of maximum range, altitude, size, weight capacity, and design. The onset of World War II brought a new set of requirements, with the exigencies of global war again extending large aircraft range with B-29 bombers flying over 1,500 mi (2,410 km) sorties against targets in mainland Japan.[21] Even with such demonstrated strategic reach, Allied and Axis air forces remained fundamentally regional in reach, only approaching the prospect of "global reach" at the maximum extent of existing aircraft capabilities.

Intercontinental, global airpower originated after the end of World War II with the introduction of aerial refueling. Although tested and proven during the 1920s, aerial refueling became a defined and increasingly reliable capability within the nascent USAF with the debut of the KB-29M/P and KC-97, and later the KC-135.[22] This new capability reduced aircraft range and overall mission endurance dependencies of aircraft design and fuel storage capacity. As a supporting function of Air Force operations during the Cold War and post-Cold War environments, aerial refueling provided global reach to not only the strategic attack function, as embodied by aircraft like the B-52 and B-2, but also airlift and mobility. As a salient example of global airpower, consider the combined use of the B-2 and aerial refueling platforms to conduct long-range strikes from Whiteman AFB, Missouri, to locations such as Serbia (1999), Afghanistan (2001), and Libya (2011), with recovery back in the US.[23]

For the US, the maintenance of a global airpower capability advances, in part, the *National Defense Strategy* objectives of deterrence and the sustainment of global Joint Force military advantages.[24] However, the realization of US global airpower arose due to technological innovation, capability evolution, and the requirements associated with advancing and protecting US national interests in the polar postwar order emerging after World War II. The establishment and sustainment of a global air force is not a requirement for all nations, and rather a capability ultimately influenced—similar to that of local/regional airpower—by the security considerations of a given nation. While nations such as the US and Russia maintain global airpower capabilities, they also maintain aircraft intended to function on the local/regional level for air defense, intratheater combat support, or regional power projection needs.

Competition has arisen with China's desire to enter the global airpower and naval arenas. Currently limited to regional operations in eastern Asia due to forward basing requirements and limited aerial refueling platforms, China seeks to develop longer-range bombers and tankers intended to deliver global reach for Beijing. The evolution of the People's Liberation Army Air Force aerial refueling capabilities is regarded as a "necessity to project power throughout the globe" and ensures parity with perceived Chinese geopolitical rivals.[25] By contrast, other nations do not seek global power projection and only persist in sustaining local/regional air forces to satisfy a desired regional defensive posture. Every continent now has air forces subject to limited local/regional access, such as Israel, Mexico, and Pakistan.

Proposed Space Operations Architecture

Since that fateful day in 1957 when Sputnik made its first orbit around the Earth, humanity has sought to further its operational presence in outer space. Terms describing orbital regimes, such as LEO, GEO, and HEO, have become common in both the space professional and laymen communities. Also, the global society is becoming increasingly linked to—and dependent on—space-based capabilities. As nations and commercial entities alike seek to transcend the limits of Earth's gravitational pull toward the Moon, asteroids, and beyond, a more universally accurate dichotomy is needed to classify and describe space operations. As the terms *brown-water navy* and *local/regional airpower* have developed to denote operations within "localized" terrestrial spheres of influence, the term *blue space* is proposed as a means to denote space operations within "celestial" gravitational spheres of influence associated with a given planet, moon, or planetoid.[26] More accurately, *blue space* will feature two definitions: (1) space operations occurring between the boundary of the sensible atmosphere to the outer boundary of the

Earth's gravitational sphere of influence; and (2) space operations from the surface/sensible atmospheric boundary to the edge of the gravitational sphere of influence for a celestial body (planet, moon, or planetoid).

Following the terrestrial example further, the terms *blue-water navy* and *global airpower* can be used as a basis to denote black-space operations occurring between local gravitational spheres of influence. As with blue space, the term *black space* will also feature multiple definitions: (1) space operations extending outside the Earth's gravitational sphere of influence; and (2) space operations occurring between local gravitational spheres of influence where the primary gravitational source is a star, such as the Sun; and (3) space operations occurring at the interstitial boundaries formed between two or more gravitational spheres of influence. The use of the second and third definitions of *black space* will become more important as future space missions begin to occur regularly beyond the Earth's gravitational sphere of influence.

The bulk of space operations are of the blue-space variety, except for black-space scientific exploration missions in the form of interplanetary probes, such as Voyager I and II or the more-recent Juno satellite, or lander and/or rover sojourns to celestial locales like the Moon and Mars. Due to the dual requirements of technological innovation and cost, few nations have historically pursued, developed, and maintained an active space launch capability. As the first and only spacefaring nations at the dawn of the Space Age, the US and Soviet Union conducted blue-space operations under the "big-sky" principle and governed by treaties, such as the Outer Space Treaty of 1967 and the Anti-Ballistic Missile treaty of 1972.[27] These early operations focused on the development of communication, navigation, and Earth-observation missions, all of which have a military support function. This focus meant that up until the creation of the USSF, these missions were considered an extension of the USAF's operation and acquisition processes and could be grouped under the blue-space umbrella.

Engineering/Technology Considerations. As the number of spacefaring nations grew, so did the type of blue-space operations and missions beyond near-Earth space into the black-space realm. During the 1960s, the race to the Moon introduced several new dimensions for space operations, each capable of being binned into the blue-space and black-space categories: (1) the reality of long-duration manned space flight to a different celestial body; (2) the need for a black-space rescue capability; and (3) the increased importance of material transportation to space. Unfortunately, since the Apollo missions, human spaceflight has been limited to the International Space Station (ISS) and other space stations located in LEO and, therefore, limited to blue space.

Entering into the 2020s, however, both national governments and commercial enterprises alike are seeking to end the nearly 50-year blue-space focus of human spaceflight by returning to the Moon, visiting an asteroid, and venturing out to Mars. As human spaceflight endeavors to extend its reach beyond LEO, evolving propulsion capabilities will play a deciding role in increasing long-duration space missions and extending from "blue" to "black space." Propulsion accounts for the majority of mass during current space-lift operations, with payload mass ultimately limited by the necessities of carrying sufficient propellant to attain exo-atmospheric flight and inject a given payload into a desired orbit or trajectory. Advances in propulsion technology will need to deliver higher-power densities to achieve a greater payload capacity while delivering high levels of efficient propulsive power. Even with higher efficiencies and power, future propulsion systems will still require some form of propellant management. In the same way that aerial refueling allowed for the shift from a local/regional to global airpower, orbital refueling will allow for the transition from blue to black-space operations. Once established, an orbital refueling capability will enable an expansion of space-lift capabilities to blue space and the required mission durations and speed for black-space missions, thereby ushering in an increased level of mission assurance, responsiveness, and agility.

Propulsion systems also have a role to play in spacecraft maneuverability. As spacecraft maneuverability is advanced to the point of the vehicle becoming a "free flyer," not tied to the limitations of Keplerian mechanics of motion, the ability to conduct black-space operations such as rescue and servicing will increase.[28] An extension of human spaceflight beyond the Earth's gravitational sphere of influence will necessitate the USSF to formulate doctrine and capabilities associated with the execution of rescue operations in both the blue and black-space environments. Each environment will require drastically different techniques due to the timing component of any rescue effort. In the same manner that customary international law recognizes the "affirmative obligation" of blue-water navies and general ocean-going to "render assistance to persons in distress at sea,"[29] Article V of the 1967 Outer Space Treaty[30] requires "all possible assistance" be given to astronauts in distress. In the event of a blue-space incident, such rescue missions can be conducted from a terrestrial location on Earth (or other celestial body) or a space station as long as a rescue launch is always on standby. These blue-space capabilities will resemble the current doctrine and operations conducted by the USCG, which patrols and renders aid within US littoral waters. The planning for rescue changes for the case of a black-space event, wherein such operations would require at least a vehicle or station capable of rendering assistance and aid. The time it would take to stage a terrestrial-based rescue would likely impede and negate the effectiveness of such efforts, thus making the capability of a space-based rescue increasingly relevant. Using the USN's blue-water doctrine as a foundation for this arena, the USSF would need to maintain a controlling presence in black space. The importance of something like the Lunar Gateway being located on a gravitational interstice between the Earth and the Moon would be foundational in the area of rescue.[31]

A final engineering consideration for future operations deals with the exponentially increasing factor of material cost and transportation inherent in an Earth-centric logistic system. A move to on-orbit refinement and fabrication facilities will need to be pursued to enhance development, dependability, and sustainment. This consideration will have two far-reaching effects. First, it will eliminate the long and costly procurement times for materials and equipment associated with launch and transit from Earth. Second, it will limit the dependence on Earth if material transport becomes interrupted or too distant to be considered time effective. Similarly, orbital facilities will bolster "black space" operations; once outposts on the Moon and Mars have been established, the need will arise to create facilities capable of supporting local blue-space and surface operations. The new celestial-based facilities will also have the added effect of creating additional lines of logistics that can decrease material bottlenecks and further increase exploration capabilities.

National prestige/geopolitical considerations. The advancement of technological innovation and the pursuance of scientific exploration are often tied to national prestige and the enhancement of a nation's geopolitical standing. During the early Space Age, Cold War competition between the US and Soviet Union translated into a race of culture, economic ideology, and technology beyond near-Earth space. As the first into space with both an artificial satellite and a manned space capsule, the Soviet Union sought to extend its early Space Age prestige victories by sending interplanetary probes to Venus concurrent with its lunar exploration program. From its first successful Venusian landing with VENERA-3 in 1966 to the back-to-back landings with VENERA-5 and VENERA-6 in 1969, the Soviet Union sought to declare that it "clearly demonstrates the high perfection of Soviet space science and technology, [and] the high talent of its scientists, engineers, constructors, and workers."[32] Even though losing to the Americans in the race to the Moon, the Soviet Union persisted in maintaining its presence in space and incrementally developing its space lift and space-based capabilities with the Soyuz program and Salyut series of space stations—all within LEO and the blue-space realm of operations.[33]

Despite winning the race of the Moon, the US rapidly returned its focus to blue-space operations with the programs such as Skylab and the Space Shuttle, with only minor forays into black space with interplanetary probes to Mars and the Outer Planets. Presidents John F. Kennedy and Ronald Reagan both suggested the importance of having joint/cooperative governmental capabilities "to explore the stars" while spreading the cost of such ventures.[34] This early concept of cooperation is the foundation that many spacefaring nations rely on at present. Amidst this environment of post-lunar space system development and exploration, the US became inextricably dependent on its space-based technologies for commercial, governmental, and military needs. This reliance forms the basis for an increase in US space control and defense considerations as embodied by the recent formation of the USSF. Although the US commercial space enterprise comprises the bulk of satellites in the American blue-space operations footprint, the continued use of and access to space by US stakeholders represent a matter of national security and interest. As the US pushes more into black-space operations, there will be attendant national security considerations that drive space system capability development and acquisition. This need is echoed in the recently released *Space Capstone* publication: "As the range of civil, commercial, national intelligence, and multinational space applications expands in scope and extends farther from Earth, military space forces must prepare to extend Space Security in support of these new US interests."[35]

After several decades of well-established cooperation between nations for space exploration and study, the early twenty-first century has witnessed a re-ignition of competition in space. Comparatively, new entrants into the space domain, China and India have set sights on missions to the Moon and Mars. Faced with China's LEO space station, recent and planned cislunar missions, and a planned mission to Mars in the early 2020s, as well as India's Chandrayaan-1 and Chandrayaan-2 (attempted) missions to the Moon and Mangalyaan mission orbiting Mars, the US has started to invigorate its own blue and black-space operations to expand its space presence vis-à-vis its geopolitical competitors.[36]

Additionally, missions to and operations on the International Space Station (ISS), along with evolving efforts at expanding spacecraft maneuverability and autonomy, represent a burgeoning foundation in future near-Earth blue-space area of operation for the USSF and allied space programs. The recent launch of the crewed SpaceX Dragon capsule to the ISS on 30 May 2020 adds a new dimension to blue-space operations with the potential for privately owned commercial flights. Coupled with plans for commercial space tourism and mining operations, the security of national interests in space will only increase, thus requiring a persistent US presence in both blue and black space. To this end, the Lunar Gateway "will uphold the US position as a leader in spaceflight and allow the United States to set "rules of [the] road" for activities in space."[37] The Lunar Gateway represents the natural foundation for the creation of black-space operations doctrine going forward. It will also set the tone for future US/allied acquisitions and security capabilities needed in the transit to Mars or deeper space missions. Though this has been described as an important issue for the newly formed USSF, even the newer spacefaring nations recognize that it "is conceivable that demands on logistics for this kind of [exploration] operation can only be met with multinational cooperative effort."[38]

Scenario: Space 2060. In the future, the USSF will continue to service blue-space operations and more than likely support interplanetary exploration in the same manner that the USN, USCG, and USAF currently support terrestrial exploration to remote areas such as Antarctica. Although the future remains unknown, a report such as *The Future of Space 2060 and Implications for U.S. Strategy* helps to provide at least a notional mooring point for scientific conjecture rather than embarking on pure science fiction.[39] In line with one of the "Positive Futures" contained in this report, the USSF by the year 2060 has effectively helped to establish a number of US/coalition-led outposts on both the lunar surface and Mars. Resupply spacecraft regularly travel between the successor to the Lunar Gateway and Mars, with a black-space station located at a Sun-Earth Lagrange point acting as a way-point and transportation depot during the multiweek interplanetary trek.[40] Onboard the resupply spacecraft, USSF personnel comprise critical crew functions to include command/control, navigation, engineering, and life support; at the Sun-Earth Lagrange station, the USSF maintains a rescue function to support interplanetary transit operations. Following the initial landings on Mars in the early 2030s, the USSF became responsible for the construction of the initial outpost. Such a mission was similar to the early days of lunar infrastructure development, and also relied on decades of lessons learned from similar USN and USAF forward-base construction and logistical operations in overseas austere locations. In addition to the infrastructure maintenance and planetary logistics, the current USSF blue-space footprint on Mars also includes operation of communications and imaging satellites in Martian orbit.

Although four decades in the future, this scenario illustrates—at least at a cursory level—the dual-use of blue and black-space operations within the context of human spaceflight between the Earth, Moon, and Mars. As black-space requirements expand to encompass more distant celestial bodies, the USSF may need to consider localized and more specialized blue-space zones. The creation of localized blue-space zones of operations is similar to air domain operations in which a local or regional airpower structure is created to support a wider military or humanitarian campaign in a geographically separated location. For example, a local or regional airpower capability was created to support combat operations in Serbia (1999) and Iraq (2003) with the basing of aircraft such as F-15s and F-16s within the area of operation. While the US maintains a global airpower capability, reliance on such a capability for all airpower operations is untenable and prevents the execution of short-time duration or ad hoc mission taskings within the joint or coalition environment. Within the context of the 2060 Mars scenario, black-space operations would need to morph into blue space to provide the support functions necessary to Martian operations due to a dissonance of mission expertise, the tyranny of distance, and the likelihood for emergency operations.

Conclusion

While the Korean War and wider Cold War of the 1950s served as the crucible for the newly formed USAF, the 2020s will present an entirely new set of challenges for the developing USSF. In addition to facing geopolitical threats that seek to compete with and contest the US and its access to and use of space, the USSF must navigate an increasingly congested space environment with an emergent commercial space sector. Space operations are extending and will continue to extend deeper into space. As a result, the USSF must formulate doctrine that will address the realities of conducting security, support, and crew operations both near and far from the Earth. The dichotomy of black space and blue space provides the architecture for not only classifying space operations with respect to different gravitational spheres of influence but also the formulation of doctrine and the establishment of acquisition lines of effort to support expanding missions aligned with an evolving national security posture and strategy. The development and acquisition of new technologies, the potential for constrained budgets, and the expanding roster of emerging spacefaring nations represent only a few of the challenges for the USSF as it embarks on securing US space interests in near-Earth, cislunar, and eventually interplanetary space. Implementing the black-space and blue-space space operations architecture will help the USSF organize its needs and focus areas of concern for different planning time horizons and will ultimately assist the US to delineate and execute its current and future mission responsibilities in the space domain. ✪

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