FUTURE OPERATING ENVIRONMENT 2040



UNITED STATES
SPACE FORCE

"WANT OF FORESIGHT, UNWILLINGNESS TO ACT WHEN ACTION WOULD BE SIMPLE AND EFFECTIVE, LACK OF CLEAR THINKING, CONFUSION OF COUNSEL UNTIL THE EMERGENCY COMES, UNTIL SELF-PRESERVATION STRIKES ITS JARRING GONG—THESE ARE THE FEATURES WHICH CONSTITUTE THE ENDLESS REPETITION OF HISTORY."

- WINSTON CHURCHILL to the House of Commons on May 2, 1935

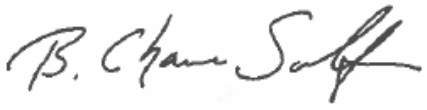
General James Mattis used the same quote above in his Forward to the 2009 NATO Multiple Futures Report. I use it specifically to call attention to two themes. First, as Giulio Douhet pointed out in his work advancing Air Power thought, those who anticipate and adapt to the changing character of war gain the military advantage. Second, consider the year of the Churchill quote and the 15-year scope of this document. From1935-1950 the globe saw over 20 million dead in a global war of unprecedented scope, a war that looms over the Korean peninsula to this day, the emerging Cold War, the industrial juggernaut of the post-war US, the jet engine, the ballistic missile, the racial integration of the US military, the development of nuclear power, and the development of the foundational technologies and studies of the space age. These gigantic historical events were unpredictable, yet the Navy commissioned the first aircraft carrier in 1922, radar demonstrations commenced in 1934, and the first B-17 flew in 1935.

The inability to predict the future does not relieve the Space Force of the requirement to plan for it.

The Future Operating Environment (FOE) for 2040 calls on Guardians to think about the evolution of space warfare. FOE 2040 is conceptual by design. It is not an intelligence assessment and deliberately refrains from prescribing courses of action or presenting solutions. Rather it is a conceptualization of a future where space superiority efforts will contend with new technologies and trends and enhanced threats while performing new and legacy missions.

This stark vision of the strategic environment is designed to spur complex thought, provoke critique, and spark meaningful dialogue about space warfare across the Space Force, the Joint Force, our allies, and partners in industry. Its statements and conclusions serve as foundations for a campaign of learning as we sharpen our minds for the fight ahead.

I challenge all Guardians and our partners to read this document critically. Question its premises and assumptions, identify what's missing, and examine where it may underestimate adversarial capability or technological opportunity. Most importantly, use the FOE 2040 to expand your understanding of what the changing character of warfare demands of the Space Force. Consider how your unit, mission, and skills will play a role in meeting those future demands, and what actions you can take now to secure an unpredictable future to our advantage.



B. Chance Saltzman
General, USSF
Chief of Space Operations

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Executive Summary

Space is the contested high ground of U.S. military power. It is the domain in which twenty-first-century security, prosperity, and stability will be won or lost. The United States Space Force (USSF) is a warfighting Service seeking superiority in a domain in which advantage is earned through decades of research, investment, and innovation, but can be lost in milliseconds.

The USSF Future Operating Environment

The 2040 USSF Future Operating Environment (FOE) is a threat-informed, warfighter-centric assessment supporting the USSF's responsibilities to secure U.S. interests in, from, and to space. It combines military theory, systems thinking, alternative futures analysis, and publicly available information to forecast long term analysis for the entire U.S. space enterprise. More than a report, the FOE is an ongoing process within the Space Force and with our partners, aiming for precision and clarity across concepts, capabilities, and organizations—so that the force we design can fight, endure, and prevail in the operating realities we may face. The FOE is also meant to inspire the next generation of Guardians and decision-makers who will come of age when space is more influential on geopolitics than ever before.

The FOE employs a rigorous approach to space as an unprecedented warfighting environment, integrating foresight and big data analytics to avoid strategic surprise. An alternative futures methodology created four future scenarios, which probed core drivers of competition and tested the outer limits of what is possible, even if not seemingly probable. Key drivers and disrupters for these scenarios were derived from large scrapes of publicly available research, news, and patent data, which were then geocoded and analyzed through network analysis to establish national patterns for disruption. Time series analysis of these and other statistical methods were used to establish trends. Leading technological disrupters were then assessed by subject matter experts to establish capability baselines and to project technological readiness levels for 2040. Public and state discourse on national strategy and other key drivers were similarly analyzed through large scrapes and statistical and network analysis to develop trends for scenario development. Each scenario explored distinct combinations of these adversary doctrines and technological breakthroughs, as well as economic, demographic, and legal drivers whose current trajectories will shape the fight to come. These scenarios were then workshopped with key stakeholders and experts across the USSF and related military, civilian and commercial space enterprise. While only two of the four futures are presented in this iteration of the FOE, the larger FOE project and all of the contributing scenarios will serve as a rigorous stress test of U.S. preparedness—validating force design choices, decision advantage, and coalition integration—so the United States, with its Allies and partners, can guarantee freedom of action and enduring advantage in the space domain.

Why 2040?

The FOE projections focus on 2040 because it informs long lead investments and planning decisions being made today, that will shape the USSF in 2040 and beyond. By that timeframe, new technologies and strategic trajectories will very likely converge into a space operating environment fundamentally different than today. Artificial Intelligence (AI) and autonomy will transform constellations, orbital proximity operations, and ground segments into adaptive combat systems that sense, decide, and act at machine speed. The future operating envelope will expand beyond familiar orbits to the Earth-Moon system, where logistics, refueling, and resources are likely to become instruments of statecraft and coercion. The electromagnetic spectrum (EMS)—long treated as a mere instrument of other domains— will almost certainly emerge as critical terrain that can be manipulated, contested, and potentially decisive. In this envisioned future, time compresses, trust is tested, and the side that masters speed, maneuver, and resilience across physical and spectral domains will define the rules of the contest.

China: The Pacing Threat

The pacing threat is clear. The People's Republic of China (PRC), and to a lesser extent the Russian Federation, are pursuing strategies to transform outer space from a civil commercial frontier into a fully contested battlespace. Both are developing offensive and dual-use capabilities designed to hold at risk the space-enabled lifelines that Americans and their allies rely on every day—positioning, navigation, and timing (PNT), financial clearing and trading, global communications, and weather and disaster response.

The methods of warfare that adversaries are preparing prize speed, autonomy, and ambiguity. They lower thresholds for kinetic and non-kinetic attack, saturate the physical and electromagnetic environment, and convert dual-use platforms into weapons of opportunistic denial. These methods will resemble dense, self-healing webs of satellites, drifting high-altitude stratospheric relays, drones, and cyber agents that operate through, re-route in milliseconds, and overwhelm single points of failure. The larger strategic environment is characterized by ***Unrestricted Spectrum Warfare (USW),*** a novel integrated approach that combines kinetic, electronic, and cyber military actions against space infrastructure with use of diplomatic, economic, and information instruments of national power. To compete in this environment, the Space Force must be combat credible in a domain where freedom of action is contested daily, and must be prepared to fight in space, from space, and to space.

The Space Force's mandate is to ensure freedom of action and navigation across the Earth-Moon system, to protect Lines of Communication, and to deter aggression with credible combat power. To achieve this by 2040, we must establish proliferated, maneuverable, and tactically responsive architectures as the baseline. We must field space battle management systems that keep

commanders in the loop while operating decisively inside adversary decision cycles. We must expand space domain awareness (SDA) beyond geosynchronous orbit (GEO) into cislunar space, deliver resilient alternatives for timing and navigation, and be prepared to contest pretextual safety zones that cynically leverage civil science and exploration missions to establish de facto sovereign control. We must integrate commercial strength and capacity by design and deepen allied interoperability in data, defense, and decision-making. We must invest in electromagnetic hardening, counter-directed energy, deception, and decoy suites as first-order requirements. And we must align acquisition and testing with the speed of the fight we will face.

1. Introduction

U.S. and allied leaders and warfighters must be able to rely on space-derived capabilities: warning, PNT, communications, intelligence, and targeting support. As competitors seek to erode that confidence, the most successful architectures will be designed for persistence and recovery—proliferated constellations, maneuverable and serviceable platforms, and Command and Control (C2) that integrates human judgment with machine-speed decision support. The methods will change; the obligation to deliver assured effects and to anchor our preferred future in trust will not.

By 2040, deterrence will rest on visible resilience, rapid reconstitution, credible attribution, and integrated campaigning with allies across all domains, all backed by will to impose costs. The USSF aims to convince potential aggressors that attempts to fracture stability—on Earth or in orbit—will fail and carry unacceptable costs, while assuring that nuclear thresholds remain protected by secure warning and command, control, and communications. Deterrence defends our image of the future without firing a shot and sets the conditions should shots be fired.

Competing futures are also defined by what is denied. Adversaries will try to make space services the backbone of their coercion and long-range kill chains. The Joint Force will expect USSF to make adversary reliance on space uncertain and costly—disrupting long range kill chains, complicating timing and routing, and imposing operational ambiguity that blunts aggression. Denial is not an end in itself; it is a means to shape behavior and reinforce a future in which space does not enable intimidation or fait accompli strategies.

The Theory of Success in space means sustaining effects despite attack, restoring capability faster than it can be suppressed, and imposing dilemmas that shift adversary calculus.[a] The character of operations will continue to evolve through more automation, more distributed systems, more dynamic maneuver, and deeper integration with the Joint Force. The USSF's purpose endures: to preserve freedom of action in space, so that the United States and its allies retain freedom of action on Earth.

These values serve as a compass for navigating a contested future. USSF values do not lock us into a single path; they align decisions, capabilities, partnerships, and posture. The contest is practical, not abstract, and it creates tensions we must manage by balancing the mission to protect and

[a] The three core tenets of the Space Force "Competitive Endurance: A Proposed Theory of Success" are to avoid operational surprise, deny first-mover advantage, and conduct responsible counterspace campaigning.

defend U.S. and allied space capabilities, with the equally imperative mission to deny the adversaries' space capabilities.

Importance of Space in 2040

The year 2040 represents the beginning of a new decade in which Beijing desires to reach space power parity with the United States.[1] Chinese military writings suggest the PRC believes that space is not just symbolic of great power status, but that space assets are critical enablers for future People's Liberation Army (PLA) joint strike operations, blockade operations, border wars, and air defense.[2] ***2040 will likely be a convergence between the Belt and Road Initiative (BRI) and the readiness of technologies like directed-energy weapons (DEW), metamaterials, brain-computer interface (BCI), and AI***.

What Happens to Civilian Life if We Lose Space Services?

A single day: No severe weather alerts, slowed emergency response, grounded aircraft, rerouted ships, and halted financial markets. Loss of navigation systems.

Within weeks: Global Positioning System (GPS)-synchronized logistics failure, fuel and hospital supplies shortages, and loss of assured comms and navigation for first responders.

After a month: Ports back up, rail schedules drift, precision agriculture misses windows, power grids lose synchronization, and cross-border finance slows.

After a year: Food insecurity in import-dependent regions, rising preventable deaths, slowed maritime trade, and governments shift focus from abroad to domestic stability.

What Happens to the Joint Force if We Lose Space Services?

A single day: GPS-guided weapons lose accuracy, Satellite Communication (SATCOM)-dependent C2 falters, Intelligence, Surveillance, and Reconnaissance (ISR) coverage shrinks, and strike coordination slows. Long range fires are disabled.

Within weeks: Air and naval tasking cycles lengthen, tanking and routing suffer from degraded navigation, and ground forces rely on less precise methods that slow maneuver and raise fratricide risk.

After a month: Campaign tempo fractures—air defense cueing lags, precision resupply falters, strike packages lose timing, and coalition operations strain without assured data links.

After a year: Precision stockpiles dwindle, forward basing weakens from sustainment risk, alliance interoperability collapses, and adversaries gain initiative across theaters.

By 2040, conditions will likely exist where the PLA has both the means and desire to use integrated, AI-enabled space-ground operations on a global scale.[3]

Russia, by 2040, will likely have decided that pursuit of asymmetric counterspace capabilities is critical to overcome structural limitations and technological isolation to operationalize asymmetric counterspace capabilities rather than pursue space power parity with the North Atlantic Treaty Organization (NATO) and the U.S. Russia has been pursuing "force-multiplier" technologies for several years to counter and disrupt adversary satellite

constellations.[4] AI technologies that enable interference with NATO and U.S. C2 systems are also expected to mature by this time. [5]

In 2019, in response to the creation of the USSF, Chief of the General Staff of Russia's Armed Forces, Gen. Valery Gerasimov, warned Russia would have to respond with "mirror and asymmetric measures."[6] Following Russia's direct-ascent anti-satellite (ASAT) weapon test in 2021, Russian Defense Minister Sergei Shoigu claimed it was a deterrent against U.S. attempts to gain a "comprehensive military advantage" in space.[7] The USSF must now design a future force prepared to deter and counter Chinese and Russian asymmetric and grey zone attacks in space.[8]

Methodology

The FOE methodology recognizes that classical warfighting functions may drive different actions in orbit, given dual-use architectures, speed, orbital mechanics, persistent surveillance, and distinctive escalation dynamics. To test the ways combat could change in the next 20 years, the FOE developed four archetype future scenarios.

- **Continuation/Growth**: Existing trajectories persist. Capabilities improve incrementally, scale increases, and efficiency gains accrue. Institutions adapt at the margins, and public–private integration deepens without altering the basic competitive landscape.

- **Collapse**: Systemic shocks or cascading failures erode capacity, governance, and trust. Services are disrupted, supply chains fracture, and deterrence or credibility weakens, leading to contraction, fragmentation, and loss of coherence.

- **Discipline/Constraint**: Policy, norms, and resource ceilings channel behavior toward restraint and stewardship. Emphasis shifts to compliance, verification, hardening, and redundancy, trading speed of expansion for stability and risk reduction.

- **Transformation**: Discontinuities—technological breakthroughs, organizational redesign, or geopolitical realignments—reset assumptions and operating models. New architectures and doctrines emerge, incumbents are disrupted, and competitive positions are re-ordered.

Across all four futures, USSF values and system drivers remained constant, requiring assured support to the Joint Force and holding adversary space capabilities at risk through credible counterspace options in a contested, resource-constrained environment. Embedding these imperatives in each future analysis compelled tradeoffs rather than allowing optimism or pessimism to dictate decisions. The framework forced explicit choices among competing tensions. For example, exquisite versus proliferated constellations; on-orbit maneuver and

logistics versus terrestrial redundancy; rapid reconstitution versus hardening at the edge; reversible versus non-reversible effects; and the apportionment of resources between counterspace and protection missions. This method counters dominant assumptions about the future by stress-testing assumptions across all four futures and elevating weak signals that challenge prevailing views.

Organization of Document

The FOE includes a narrative summary of the darkest of the four scenarios that the FOE is designed to help the USSF avoid. The narrative highlights the challenges we face at maximum intensity. The narrative format is provided to help imagine how all the different drivers and insights fit together into a larger strategic picture. The FOE conclusion presents a bright future to focus the USSF's desired vision for 2040. In both narrative scenarios, technological superiority is a necessary but insufficient condition of victory. The decisive factors in the future operating environment are organization, integration, and clarity of strategic purpose.

The rest of the document is divided into four body sections. Section 2, 'Strategic Environment: 2040,' describes the geopolitical characteristics that structure competition and conflict. Section 3, 'Capabilities and Forces,' introduces the future strategic visions of China and Russia, as well as the projected force postures and capabilities each state is pursuing to achieve those visions. Section 4, 'Technological Threats and Environmental Risks,' examines the disruptive potential of emerging technologies that may enter the field of battle by 2040. The section also describes key features of the natural and regulatory space environment that pose challenges to USSF mission objectives. Section 5, 'Challenges to Achieving Space Superiority,' concentrates the insights of the FOE into ten key challenges for the USSF in 2040.

The FOE also includes an appendix containing references that provide the reader with useful tables, graphs, and supporting data, as well as the unabridged scenario narratives and explanations of the critical assumptions and methodologies used for assessments throughout the FOE. Finally, a selected bibliography lists the key documents that were consulted in the writing of the FOE.

2040: Dark Horizons

By 2040, the operating environment is marked by ongoing, hard-to-detect competition below the level of declared war. The line between peace and conflict has become unclear amid continuous electromagnetic activity, cyber operations, and covert interference in orbital regimes. The space domain has changed through consistent attrition rather than decisive campaigns. Although a major war among great powers has not occurred, a long-lasting, multi-domain conflict has emerged. The strategic situation bears resemblance to the period preceding World War I. Submarines and emerging airpower, which destabilized the early 20th-century world, are now mirrored by widespread lethal capabilities directed at digital connectivity and the reliance on extensive automation.

Initial escalatory events were primarily software- and spectrum-based rather than kinetic. Market instability was accompanied by a rise in debris-creating incidents in low Earth orbit. Private-sector actors, who own and operate much of the space infrastructure, have taken on quasi-sovereign roles, using active defenses and preemptive capabilities that often blur the line between commercial security and state-directed actions. Civil-military boundaries are porous: the roles of uniformed personnel, civilians, and autonomous systems are interconnected and often indistinguishable in practice.

U.S. space-enabled kill webs maintain significant capabilities but are brittle under the weight of continuous interference. Commanders have less confidence in target custody and node status due to the complications of spoofing, deceptive signals, and occasional outages, which complicate decision-making. Launch operations and on-orbit maneuvers are often delayed, not due to hardware issues but because of ambiguous signals and targeted coercion, including cyber-enabled intimidation of personnel and families. The overall result is operational hesitation and a tempo that lags behind the adversary.

The People's Republic of China emphasizes speed, scale, and resilience by using distributed architectures. Layered mesh concepts integrate stratospheric platforms, low-profile nanosatellite swarms, and cislunar relays. Decision cycles are sped up through tightly connected human-machine teaming and widespread AI support. Gray-zone measures—sub-threshold jamming that mimics natural interference, precise spoofing masked as routine errors, and targeted micro–supply chain disruptions framed as product recalls—gradually weaken adversary capability and will. Pressure on Taiwan appears as ongoing operational fatigue and economic friction rather than large-scale kinetic strikes. Commercial flows are sometimes interrupted through orbital meshes that segment communications and navigation services regionally and functionally.

Russia exploits gaps created by the U.S. and its allies focusing on the Indo-Pacific. Moscow uses flexible co-orbital systems, mobile jammers, and hidden "sleeper" satellites that activate when least expected. Repeated "accidents," falsified ephemerides, and escalatory nuclear signals make it hard to attribute actions and manage crises. Small territorial and political gains happen opportunistically when U.S. attention and resources are pulled away.

European actors operate in a contested environment characterized by sabotage of infrastructure, divergent alliance priorities, and uncertainty about the scope and reliability of U.S. extended deterrence in space and cyber. Several states are expanding their sovereign space surveillance, PNT augmentation, and military-commercial integration, while intra-European coordination remains inconsistent.

Artificial intelligence is now a collection of capabilities, not a single category, including autonomous systems, self-modifying code, and human–machine interfaces. These systems shorten decision timelines well beyond traditional OODA loops and complicate command authority and legal review. Operators face cognitive overload and neural fatigue while supervising swarms and adaptive control loops in degraded communications. Stress injuries and performance inconsistencies appear, affecting readiness and retention.

The overall effect is a prolonged competition marked by cumulative losses rather than decisive battles. Trust in data, networks, and command relationships becomes a problem of risk acceptance; confidence intervals replace binaries in operational decision-making. Every informational advantage introduces reciprocal vulnerabilities, and defensive adjustments create new attack surfaces.

2. Strategic Environment: 2040

The operating environment described in this report projects future wars that extend into space will be defined by USW. USW is a technologically led, strategic transformation from the domain-specific contests of the previous century to a battlespace in which the physical, digital, cognitive, and organizational categories are intentionally blurred. The future fight in the spectrum drives the pace, complexity, and potential instability of conflict in 2040, demanding deep doctrinal adaptation by the USSF and its partners.

Unrestricted Spectrum Warfare

Adversary efforts to dominate the EMS, deny adversary ability to sense and communicate, and divide countries and commercial actors have historical parallels. During World War I (WWI), Germany used its submarine fleet to sink without warning, "every vessel that sought to approach either the ports of Great Britain and Ireland or the western coasts of Europe." Germany's policy of unrestricted submarine attacks constituted a "war against all nations" in which American ships were sunk and lives lost, as President Woodrow Wilson put in his address to Congress seeking a declaration of war in April 1917.

Following the attack on Pearl Harbor in World War II, the United States executed a policy of unrestricted air and submarine warfare against Japan, sinking merchant vessels without warning, mining sea lanes, and blockading Japanese ports. These naval conflicts during the 20th century foreshadow how future warfare will likely extend into the EMS and outer space.

Like previous submarine campaigns, we project USW in 2040 will mean that every frequency, signal, and orbital regime is contested terrain, and both military and civilian space infrastructure are targets. Attacks on space services are likely to occur without warning, with potentially devastating consequences for the populations they support. Adversaries may declare a specific band of the EMS or orbital segment to be a military operations zone to provide legal cover for affecting neutral and civilian space assets. And, like the United States in WWI, neutral countries and commercial actors will be drawn into conflict.

Space and the EMS are appealing targets for unrestricted warfare because there is little potential for direct casualties. USW will manifest through the coordinated employment of proliferated autonomous platforms, high-power directed energy, persistent electronic and cyber-attacks, and information operations. A hallmark of USW is the rapid, multifaceted transition between effects, including jamming, spoofing, physical disablement, cyber manipulation, and even cognitive overload—often in a single, blended operation.

Power without Symmetry: 2040 is Not Another Cold War

The world of 2040 will likely be heteropolar: a global system defined by uneven and domain-specific concentrations of capability and influence. Unlike traditional multipolarity, where multiple actors hold roughly similar types of power across most areas, heteropolarity describes a landscape where the United States and China hold dominant influence in different, though sometimes overlapping spheres, cutting across traditional sectors such as military, technology, and economy. This rivalry is trending to set the pace and conditions for conflict, with space becoming a critical theater for shaping geopolitical competition.

In this forecasted heteropolar reality, power will be exercised asymmetrically. The United States and China will hold the largest and most advanced economies, control the most sophisticated technological ecosystems, and command the most significant military power, especially in space.[9] However, their strengths and weaknesses are unlikely to align in a way that creates balance or strategic stability. India and the European Union (EU) are likely to continue asserting themselves through regional strategies, innovation, and coalition-building, wielding real but comparatively limited power. Russia maintains its great power status primarily through its ability to destroy, with little credibility to shape the global order. In 2040, the sources of Russian power are likely to continue being its nuclear deterrence, targeted technological advances, and the ability to exploit instability through flexible policy and coercive means, even as it struggles with demographic and economic stagnation.[10] ***Geopolitics in 2040 is unlikely to possess the conditions for the strategic balance that made Détente possible in the 20th century.***

Beijing welcomes the growing fragmentation of the old order. From the PRC's perspective, a heteropolar era is a long-anticipated evolution. A possible new order demands and justifies China's claim to a privileged role in shaping international norms. Driven by a historical need for "cleansing humiliation" and a conviction in major power exceptionalism, China aims to position itself at the center of the global system. Beijing views its role as not just an equal, but as a rule-maker and norm-shaper for both Earth and space. [11] In this environment, the competition for space dominance is more than just a reflection of terrestrial tensions; it is a key aspect of a world order where influence, rules, and security are contested among dominant and increasingly specialized power centers.

China's strategy has matured from slow, cautious growth to bold initiatives and a willingness to take risks. Chinese leaders view the mid-21st century as a historically unprecedented window of opportunity for national rise, symbolically linked to the centenary of the Communist Party's rise to power. In practice, this aims for China to become a tech superpower by the early 2030s and achieve full-spectrum dominance or parity by 2049, a goal Xi Jinping refers to as a, "period of rare opportunity."[12] According to key party documents and international analysis, China's approach

combines joint space-military innovation with economic coercion. China's Belt and Road in space, rapid orbital logistics, and satellite constellations are seen as national security tools and measures of civilizational strength.

Russia shares China's anti-Western stance but differs in meaningful ways. While China aims to gradually replace the United States as the leader of the world, ***Russia's goal is a more crowded playing field***, maintaining multipolarity where no one power prevents Russia from controlling its chosen sphere.[13] Russian strategy is multifaceted. It focuses on capability offsets—especially in counterspace, electromagnetic warfare (EW), and rapid-launch ASATs—while also strengthening economic and diplomatic connections with the Global South through the Brazil, Russia, India, China, and South Africa (BRICS) Group, the Shanghai Cooperation Organization (SCO), and various "civilizational" initiatives framed as alternative global orders.[14] Moscow presents these efforts using the language of universalism and multipolar equity, even as it relies on information operations to hide its authoritarian and coercive actions.

3. Capabilities and Forces

China's Space Vision

The PLA aspires to a 2040 where it can deter the United States and, if necessary, inflict critical defeats.[15] The PLA recognizes space as a crucial warfighting domain, as underscored by the establishment of the Strategic Support Force in 2015, and its subsequent evolution into the Aerospace Force in 2024.[16] This reflects a broader understanding within the PLA that control of space is integral to modern military operations and the future operating environment.[17] As referenced in Figure 1, China is expected to grow its space capability significantly over the next 15 years.

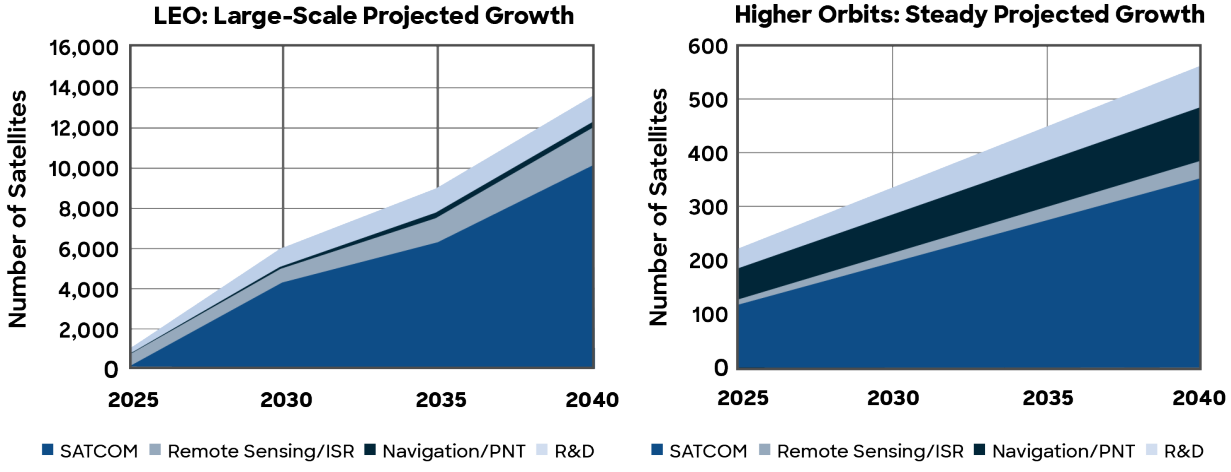


Figure 1: Illustrates the massive projected expansion of China's satellite fleet, driven by an integrated national strategy that includes both commercial and state-sponsored systems. The left chart shows exponential growth in Low Earth Orbit (LEO), where new SATCOM constellations will become the

overwhelming component of Chinese LEO satellites. The chart on the right shows SATCOM capability growth is also the primary driver of the steady growth in higher orbits, reflecting a comprehensive, long-term build-out of China's national space infrastructure.

Chinese military planners contend that future space operations will include both combat and deterrence.[18] This will manifest through threats and demonstrations, followed by a careful escalation in the precise application of force, all backed up by formidable space forces capable of "zhenshe daji," or "overawing space attack."[19]

PLA plans for space operations to have deterrence effects in all domains, with some theorists going so far as to say that space is "strategic, convenient, and controllable."[20] Writers at the Academy of Military Science have stated that operations from space will play a significant and recurring role in overall deterrence. Analysts at RAND have further elaborated that "…the PLA's approach to deterrence and escalation in space prioritizes securing political objectives over avoiding conflict."[21]

China's Key Capability Investments

Over the next 15 years, Chinese investments in space will emphasize the importance of speed, data, and information dominance. The output of these investments will be essential for achieving the PLA's concepts of "informatized" and "intelligentized" warfare.[22]

- **ISR:** The PLA will invest in more capable and sophisticated space-based ISR networks and supporting ground infrastructure because they are crucial for providing a comprehensive picture of the battlefield that enables long-range precision strikes.[23]

- **Proliferated LEO:** To rival constellations like Starlink, the PLA will develop its own proliferated LEO constellations, such as the G60 and Project SatNet. These constellations are designed to provide robust and resilient communications and data links, supporting future warfare concepts and operations.[24]

- **GEO to Cislunar:** To secure what it calls the "strategic location in space," the PLA will invest in capabilities that can project power from the GEO belt through the lunar orbit. [25] This includes on-orbit logistics concepts, as well as a space-based solar power (SBSP) system to beam electromagnetic energy back to Earth, and the development of space megastructure building expertise.[26]

- **Counterspace:** The PLA views the ability to deny an adversary's use of space as a key component of gaining space superiority. This will lead to increased investments in a wide range of capabilities to interfere with, degrade, or destroy enemy satellites.[27]

- **Space Maneuver:** Publicly available technical reports from PLA units in Beijing's "Space City" suggest that the Aerospace Forces (ASF) uses modeling and simulation for multi-orbit transfers from LEO to GEO and highly elliptical orbits (HEO), as well as LEO and GEO rendezvous and proximity operations (RPO).[28]

- **Human-Machine Teaming:** PLA investments in BCI and other human-machine teaming capabilities will enhance the speed at which China can understand and synthesize data, enabling faster decision-making than a mere human.

PLA Space Force Structure

The PLA space forces established in the 2024 Aerospace Force reorganization are likely to remain constant for the near term. The ASF consists of a series of units designated as "Bases," which can be seen as roughly analogous to the USSF Deltas. For example, Base 37 integrates long-range radar arrays, optical tracking stations, and large computing nodes, fed by a layered network of ground-based space traffic management (STM) capabilities, including radars and telescopes.[29] The missions for these ASF "bases" include ground-based space surveillance; satellite telemetry, tracking, and command (TT&C); space launch; human-crewed spaceflight; space-based ISR, mapping, and positioning, navigation, and timing (PNT); space-related RDT&E; and counterspace operations.[30] [31]

The PLA retains critical space capabilities throughout the rest of the force. The PLA Cyberspace Force, responsible for information warfare, will retain strategic EW capabilities, including non-kinetic anti-satellite measures. The Information Support Force, responsible for military networks and strategic communications, will retain management of communication satellites and EMS allocation.[32] Over the next 15 years, the PLA is likely to refine the ASF force structure and the "Base" missions. When the new ASF reforms were announced in April 2024, the PLA stated, "As circumstances and tasks evolve, we will continue to refine the modern military force structure with Chinese characteristics."[33]

PLA Space Force Posture

By 2040, the PLA is likely to evolve from a regional force to a more expeditionary force. China will likely transition from a power-seeking strategy to achieve regional objectives in the Indo-Pacific to one that utilizes regional dominance in the Indo-Pacific and the space domain to pursue a broader desire for superpower status.

A more expeditionary PLA is likely to manifest in an ASF that has significant on-orbit capabilities, paired with a rapid launch and reconstitution capability. According to the China Aerospace Studies

Institute (CASI), China's on-orbit posture combines large imaging and remote sensing constellations with space-based STM capabilities to monitor LEO and GEO. RAND further assesses that, "China is prioritizing a tactically responsive space launch capability that leverages several of its new mobile, solid-fuel launch vehicles," which would allow the PLA to posture space capabilities covering regions around the globe quickly. In addition, China expanded its supporting ground infrastructure over the past five years and is likely to enlarge this footprint over the next decade.[34] Cislunar operations, such as those already conducted by the Chang'e 5 orbiter in lunar Distant Retrograde Orbit (DRO) for precise navigation and very long baseline interferometry (VLBI), may also become a growing focus.[35]

Chinese Corporate Space Actors

Chinese commercial space companies are integral to Beijing's national strategy of military-civil fusion, which aims to advance the PLA's technological prowess through a state-driven partnership between commercial and industrial sectors. This effort is of such importance that President Xi Jinping personally chairs the Central Commission for Military-Civil Fusion Development.[36] This structurally binds "commercial" firms to PLA demand through Party committees, state ownership, guidance funds, and formal procurement. For example, the PLA places a high priority on remote sensing, with Changguang Satellite Technology Laboratory Corporation (CGSTL) ("Jilin-1"), China Siwei, and Spacety providing high-tempo Electro-Optical (EO)/Synthetic Aperture Radar (SAR) systems that open-source links to state and military end-users. Other areas where commercial capabilities augment the PLA include PNT, launch surge, data and AI exploitation, quantum technologies, and semiconductors.

Establishing Sino-centric Space Norms

In an increasingly heteropolar world order, China will be well-positioned to establish Sino-centric space norms. Beijing's instructions to Chinese firms to push PRC standards on everything from AI to SATCOM already demonstrate this trend.[37] By 2040, China will seek to shape norms in areas including:

- China-defined procedures and approvals for **STM in Earth orbit and cislunar travel**. As the CASI points out, China will likely develop its own space catalogue despite having an inherently different STM architecture that relies on fewer ground stations and fewer assets in GEO. [38]
- ***Resource extraction opportunities***, coupled with self-serving and disingenuous interpretations of international law, could be used to justify lunar exclusion zones intended to prevent corporations and governments from accessing prime water ice and Helium-3 deposits in areas like the Shackleton Crater near the South Pole.[39]
- Tacit but unwritten recognition of existing ***co-orbital safety parameters***.

- ***Targeting of commercial companies with dual-use capabilities***.
- ***Normalizing electromagnetic interference (EMI)*** such that it is no longer a significant rung on the escalation ladder.
- ***Establishing military space maneuvers and holding regular military training events on orbit***.

For China, space norms and commercial dependency on Chinese space infrastructure are a design path to global power projection. China will likely use data sharing as a form of soft power through the BRI and ILRS partners to gain momentum towards greater control of the space domain.[40]

Russia's Space Vision

By 2040, the Russian Ministry of Defense (MOD) desires to use the space domain as a "combat center of gravity." [41] More than a support function, the MOD aims to integrate the space domain into a seamless theater of war. Strategic and doctrinal writings envision the coordinated use of ground, naval, air, and space forces, along with long-range precision strikes and asymmetric activities. According to one Russian Aerospace Forces Academy analysis, offensive space operations may even "precede" operations in other domains to destroy their adversary's C2 and space infrastructure.[42] The MOD believes the United States was the first to militarize space due to an overreliance on space capabilities, making Russian space weapons defensive in nature.[43]

Russia's dwindling space capabilities will probably drive Moscow to accept greater risk in pursuit of an influential role in space. The nation that pioneered human spaceflight operated only 160 satellites as of 2023—fewer than some commercial operators and significantly below China and the United States. Russia's growing asymmetric response includes destructive and indiscriminate capabilities that may compromise the domain and further isolate Russia if they are utilized.[44]

Russia's Key Capability Investments

Into 2040, Russia's emphasis on asymmetric capabilities, artificial intelligence, commercial-grade components, and EW will shape its capability investment portfolio in space. Russia will likely need to attract foreign investment to rebuild its space industry if it hopes to support these goals.

- **Commercial supplementation of LEO:** Russia is likely to prioritize space commercialization to counterbalance Western technological leads and establish a legal framework for dual-use capabilities.[45]

- **AI augmentation and support**: Russia is investing heavily in AI to support its reconnaissance-strike complex. The Rassvet LEO satellites, developed by the Russian aerospace firm Buro-1440, are designed to provide broadband internet coverage in a constellation of 900 assets by 2035, with approximately 100 of them intended explicitly for controlling drones and unmanned aerial systems.[46] Furthermore, retired Russian

military strategists theorize on the use of AI for hybrid formations, including AI air defense and targeting.[47] In March 2024, the head of Roscosmos also claimed the Sino-Russian nuclear power plant on the Moon would incorporate AI and automation.[48]

- **Terrestrial reversible counterspace systems:** Russia is investing in fixed and mobile terrestrial EW systems to jam or spoof adversaries' SATCOM and PNT systems.[49] State sources claim the MOD's Tirada complex successfully identified and suppressed Ukraine-supporting satellites, possibly Starlink, in 2022.[50] Russia also possesses the Peresvet and Zadir laser weapons, which could be used as a LEO counterspace capability, despite their primary function being air defense.[51]

- **Nuclear ASAT weaponry:** Russia has the lowest threshold for nuclear weapons use in the world, according to its public doctrine.[52] Though the use of *space*-based nuclear weapons is not explicitly mentioned, there is increasing concern that Russia is developing a nuclear ASAT.[53] In 2024, Assistant Secretary of Defense for Space Policy Dr. John Plumb testified to Congress about the development of a "concerning ASAT capability related to a new satellite carrying a nuclear device," adding it could threaten "vital communications, scientific, meteorological, agricultural, commercial, and national security services we all depend upon."[54]

Russian Aerospace Forces (VKS) Structure and Posture

Russia is committed to space as a warfighting domain. Organizationally, the VKS, established a decade ago, supports this commitment. Its structure unifies aviation, air defense, anti-missile defense, and space forces, while also preserving space expertise.[55]

***Russian space forces recognize the importance of partnerships in an environment of scarcity to enhance global space power*.** Previous Russian ambitions beyond GEO (xGEO) may, in the future, be couched under joint Sino-Russian projects, such as the International Lunar Research Station (ILRS).[56] Russian and North Korean space ties have also increased during the Russo-Ukrainian War, and in particular, North Korean EW capabilities targeting adversary space assets may supplement Russian capabilities in the future.[57]

Roscosmos' infrastructure in BRICS nations, similar to China's BRI, will continue to provide Russia with unique vantage points for tracking space objects, including Southern Hemisphere tracking from South Africa.[58] Space will continue to enable regional drone strikes using the Orbital system, which uses satellite, fiber, and relay links. ***Russia seeks to expand the footprint of its space-connected drone facilities*,** further enhancing its strike capabilities already located at the edge of Russian territory.[59]

Above Earth, the development of the Russian Orbital Station (ROS) may supplement military sensing, radar, and early warning radar, as well as testing of other VKS space assets.[60] Moscow also aims to have 360 Starlink-style Sfera communications satellites in orbit by 2036 to support military ISR and PNT. This estimate was revised down from 600 due to component shortages.[61] Russia also claims at least one small satellite imaging constellation is in development, along with two other constellations for data relay.[62]

Russia's State-Controlled Sector

Russia's space ecosystem operates as a state-controlled, de facto monopoly, where Roscosmos functions both as a state corporation and the central coordinator of space activities. A 2015 re-nationalization consolidated over 70 enterprises under direct Roscosmos control, and firms like RSC Energia, NPO Energomash, and ISS Reshetnev appear to be independent companies but are more like divisions under unified state ownership.[63] This structure eliminates any semblance of commercial competition, as the entities receive direct assignments from Roscosmos and the Kremlin. Compared to China, this total fusion creates a weakness, where Beijing can tap vibrant, up-and-coming firms like Galactic Energy or LandSpace. In contrast, Russia's structure reduces the innovation that results from competition. Russia also does not prioritize the recruitment of Western space experts to the same degree as China, further decreasing its technology leadership over time. By 2040, Russia's inherited Soviet integration will make it firmly the junior partner to China's enterprise.

Allies and Partners in 2040

Allied visions of the future converge on a 2040 space environment that is congested, contested, and operationally consequential for joint power projection.[64] NATO is projected to continue to cultivate an effective alliance-wide capability that leverages individual strengths while anticipating more assertive Chinese, Russian, and non-state challenges to Western space advantages. [65] European partners strike a balance between a desire for strategic autonomy and alliance integration, aiming to close capability gaps through dual-use[66] "New Space" ecosystems.[67] Allies in the Indo-Pacific will seek to contribute through geography and select niche competencies[68], while advocating for mitigation measures to address debris and orbital crowding. [69]

Allied investments are likely to prioritize mission assurance and resilience across SDA[70], SATCOM, access to space, and protection of critical infrastructure. The EU plans to scale PNT[71] and Earth observation constellations and integrate AI-enabled processing to accelerate decision advantage. Meanwhile, close allies will likely recapitalize Military SATCOM (MILSATCOM)[72] and proliferate commercial and military capabilities[73] —including Arctic coverage[74]—to reduce single points of

failure. The Infrastructure for Resilience, Interconnectivity and Security by Satellite (IRIS2) seeks to expand European broadband SATCOM. [75] Across all the allies, access-to-space initiatives emphasize reusability[76], rapid launch, and diversified spaceports.[77][78][79]

***Force structure and posture trends favor interoperable, quantifiable contributions rather than Alliance-level duplication*.** NATO's planning assigns space requirements and effects across members, seeks to integrate smaller allies via commercial providers, and emphasizes common operating pictures and magazine-depth metrics. Other states (e.g., the United Kingdom, Sweden) [80] plan to build national launch options to accelerate reconstitution. [81] The EU is projected to explore a horizontal crisis organization under the Common Foreign and Security Policy (CFSP) and is considering adopting a space law to promote information exchange. [82] Japan has stated that it will pursue a general officer-led space command construct[83], hardening ground segments, and integrating with U.S. protected SATCOM frameworks, pursuing selective autonomy alongside deeper allied interoperability.

Allied trajectories reinforce a coalition approach to achieving space superiority and joint all-domain operations, characterized by distributed architectures, burden-sharing, and assured access. This approach can deter aggression, sustain critical infrastructure in a denied environment, and restore combat-credible space effects at speed.

Non-Aligned Actors

Over the next 15 years, the non-aligned states will further intensify the complexity of an evolving heteropolar order, with a growing number of capable actors that do not consistently align with any single major power. These non-aligned actors may form flexible regional blocs, establish technical standards, and contribute to shaping norms. In such an environment, gaps in engagement could leave the United States with reduced support in norm-setting venues and standards bodies, complicating efforts to sustain predictable commercial freedom of action and interoperable space services.

Non-aligned participants, like India or Brazil, are likely to field mixed civil-military portfolios that include expanded STM, proliferated communications and sensing constellations, and regulatory frameworks that accelerate commercial participation. Some could develop responsive launch ecosystems, pursue prominent broadband constellations, and explore on-orbit servicing, refueling, and space weather monitoring. Such efforts would likely be complemented with defensive counterspace measures and dual-use EW and intelligence capabilities. These developments may produce regional space markets, diversified supply chains, and new data-sharing constructs that both complement and, at times, complicate existing coalition architectures.

In 2040, non-aligned states may be willing to lean away from our adversaries' influence spheres if they see advantageous conditions. States like India or Brazil may explore greater cooperation around predictable commercial frameworks such as assured access to orbital regimes, reliable space-derived services, and explicit norms of behavior. This could be expanded to include standards for safe, secure, and sustainable space operations, as well as transparent mechanisms for crisis communication and management.

4. Technological Threats and Environmental Risks

The 2040 Technological Threat Profile: China's Innovation Race for Space Superiority

Technology as a Disruptor. By 2040, the space domain will be shaped as much by technological disruptions as by the recurring drivers of power politics. While industrial base, demographics, and geography bound an adversary's choices, technology periodically rewrites those boundaries. Technologies that exploit physical phenomena never before harnessed at scale can unlock new military effects in sensing, communication, command, maneuver, and denial. These are not linear improvements; they change the game board by opening access to asymmetric capabilities largely absent from prior eras of competition.

Technology Can Change the Foundation of Spacepower. Chinese research and investment agendas provide insight into Beijing's strategic intent, even if those technologies never fully materialize. Space technology as well as AI, BCI technology, and material sciences all top the list of priorities for which China is recruiting talent.[b] [84] China is also systematically investing in a portfolio of advanced technologies characterized by electromagnetic dominance, autonomous coordination, and **the ability to rapidly reconstitute and adapt space architectures.** Investments in AI probably will serve as the organizing principle as China seeks to link sensing, command, maneuver, and effects across orbital, link, and ground segments. AI technology will be used to build proliferated constellations that self-organize, allocate tasks, and re-plan under communications denial. This is likely to lead to new operational concepts that challenge USSF views on spacepower.[85]

China is pursuing human-machine integration for decision dominance.[86] In this possible combat environment, the Observe, Orient, Decide, Act (OODA) loop will compress at every stage—autonomous observation and fusion, model-based orientation resilient to deception, policy-constrained decision, and automated action across sensors, crosslinks, maneuver, and non-kinetic effects. Humans alone would not be able to adjudicate space control decisions in this future;

[b] China is building a vast, AI-based platform dubbed "Supermind" to track and recruit millions of scientists and researchers worldwide.

verification, escalation control, and auditable confidence measures would depend on speed as much as judgment.

The PLA is heavily invested in BCI and AI technologies to enable direct neural linkages between operators and autonomous space systems.[87] This can dramatically compress decision cycles from minutes to milliseconds while allowing single operators to manage vast constellations of satellites, weapons platforms, and sensor networks. [88] The PLA will seek to use BCI-AI fusion for orchestrating the complex, multi-domain operations inherent in USW, potentially adapting faster than current U.S. OODA loops. [89]

AI may not displace human judgment entirely, but **it will redefine where humans add value**—setting objectives, risk tolerances, and constraints, stewarding models, and adjudicating escalation—while machines execute within those bounds at operational tempo.

President Xi Jinping's 2022 report to the 20th Party Congress called network information systems the "largest variable" to improve combat effectiveness.

Weaponizing all wavelengths. By 2040, EW and DEW systems will most likely be transformed by the convergence of AI-enabled targeting, miniaturized emitters, and algorithmic modulation techniques, enabling precision and adaptability in contested EMS environments. [90, 91] Future EW and DEW platforms could employ a form of autonomous EW that identifies and exploits spectrum vulnerabilities in real-time, using machine learning algorithms to generate novel waveforms that bypass defensive filters and frequency-hopping protocols faster than operators can respond. The defeat of U.S. countermeasures would allow China to degrade large portions of our space services.

Russia has a long history recognizing the value of EW as an offensive capability integrated across the battlefield—a concept known as Radio-Electronic Warfare.[92] Russian forces in occupied Ukraine demonstrate a willingness to jam SpaceX Starlink terminals and have successfully targeted the routers of Viasat, a U.S. satellite broadband provider, to stifle Ukrainian C2.[93] Russia is likely to invest in successes from Ukraine, and build more Radio-Electronic Warfare capabilities by 2040.

Absorbing attack: China is pursuing metamaterial-enhanced deterrence by denial. When scaled, metamaterials probably will be able to create "invisibility cloaks" for satellites across specific frequency bands.[94] Programmable materials that enable satellites to dynamically adjust their electromagnetic signatures, shifting from radar-transparent to radar-opaque in microseconds[95] can cause the power requirements for successful attacks to exceed the energy budget of offensive

weaponry. The PRC has prioritized metamaterial research in its 13th 5-year plan, implying a desired vision of dominance by 2040[c] in radiation shielding, artificial EMI, sensing, thermal and acoustic cloaking.[d, 96, 97]

Quantum Sensing. China is seeking quantum radar technology to enhance performance in the EW domain. Quantum radars use single photons instead of classical electromagnetic waves for target detection and tracking. Quantum radar technology is still in the early stages of development, with much of the current work conducted in the theoretical and experimental space. By 2040, the most significant point is not whether quantum radar achieves full operational viability, but that China is actively attempting to field systems as part of its broader effort to detect all space-based platforms.

Reusable Space Platforms. To reduce launch costs and improve replenishment times, China recognizes the importance of reusable rockets. China is supporting at least 15 distinct projects at state-affiliated firms like the China Aerospace Science and Technology Corporation (CASC), China Aerospace Science and Industry Corporation (CASIC), Nayuta Space, Sepoch, and iSpace.[98] China is also interested in technologies that improve responsiveness, such as new types of fuel, materials, and design for reusable rockets, and space platforms that extend satellite lifetime through servicing.[99] Though size and shapes vary, all projects seek to operationalize partial or fully reusable rockets that launch from static or mobile platforms, some of which are recoverable by autonomous drone ships.[100] CASC already operates a Reusable Experimental Spacecraft that is capable of releasing RPO-capable micro-satellites.[101] This reusable and servicing effort will allow China to rapidly replace damaged satellites and surge new capabilities in a crisis.

Advanced propulsion systems enable Dynamic Space Operations (DSO) Both China and Russia have signaled that nuclear space propulsion will play a role in their space power expansion, supporting cislunar and deep space operations. China is researching a megawatt-scale lithium-cooled nuclear reactor, while Russian publications claim a less powerful method of propulsion is possible in its Transport and Energy Module (TEM) design, a proposed uncrewed nuclear electric tug.[102] The priority for sustained on-orbit maneuver is shaping adversary investment in other technologies, including more powerful Hall thrusters and ion thrusters.[103] In a future space environment, the side with greater maneuverability will have an advantage because it will enable high-value counterspace systems to “hide and evade” more easily than their counterparts.

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[d] Kuang-Chi Group, based in Shenzhen, is the largest Chinese filer of metamaterials patents globally, with clients that include the PLA Navy, state-owned telecoms and the Hunan Space Bureau (068 Base). Kuang-Chi has already built the world’s “first” metamaterial mass production facility.

The high-altitude threat to space control. China has demonstrated a likely commitment to dominance in high-altitude operations by 2040. High-altitude platforms (HAP), including high-altitude balloons (HABs), high-altitude long-endurance (HALE) aircraft, stratospheric airships, and hybrid HAB-drone concepts, are likely to concern the USSF because these capabilities increasingly threaten U.S. freedom of action in the space domain.[104] Operating between roughly 60,000 and 120,000 feet, HAPs exploit a portion of airspace that, from a military perspective, remains comparatively unexploited relative to LEO, medium Earth orbit (MEO), and GEO.[105] The rapid maturation and falling costs of HAP systems present a disruptive counter-space layer that adversaries can field quickly, in mass, and at a fraction of the cost of orbital platforms.[106] This cost asymmetry matters: if the outer-space regime remains capacity-constrained and capital-intensive, the ***high-altitude regime offers adversaries a cheap and fast reconstitution of space-like services***, and in some cases, strike options that present unique defensive challenges.[107] HAPs can act as a counter-space layer, enabling mobile kinetic, non-kinetic effects, and electronic support against U.S. and allied space systems.

Developing expertise: Mega-platforms on orbit. The PRC is pursuing a SBSP program, branded as the 'Three Gorges Dam in Space.'[108] The terrestrial Three Gorges Dam is a source of national pride, often likened to the Great Wall of China, and a cornerstone in the PRC's narrative of becoming a modern state.[109] The Three Gorges Dam in Space represents an organizing vision of 2040 for industrial mobilization and technology demonstration.

The project's declared ambition is straightforward: assemble large solar collector platforms in GEO (one km in size), harvest uninterrupted sunlight, and beam power to terrestrial sites via high-energy Radio Frequency (RF). ***Beijing's strategic vision for the project is quite different:*** reframe Chinese space expansion as global public works, cast electromagnetic dominance as a humanitarian good, and portray international space constraints as coercion against the world's energy poor.[e110]

By 2040, the "Three Gorges Dam in Space" could provide China with a similar benefit that the moon race did for the United States and the Soviet Union in the mid-20th century. Many of the technologies developed for the mega-project will be utilized in military applications to ensure Chinese space superiority.

[e] In effect, SBSP is lawfare by engineering—anchoring claims to spectrum, orbits, and norms in the moral language of electrification.

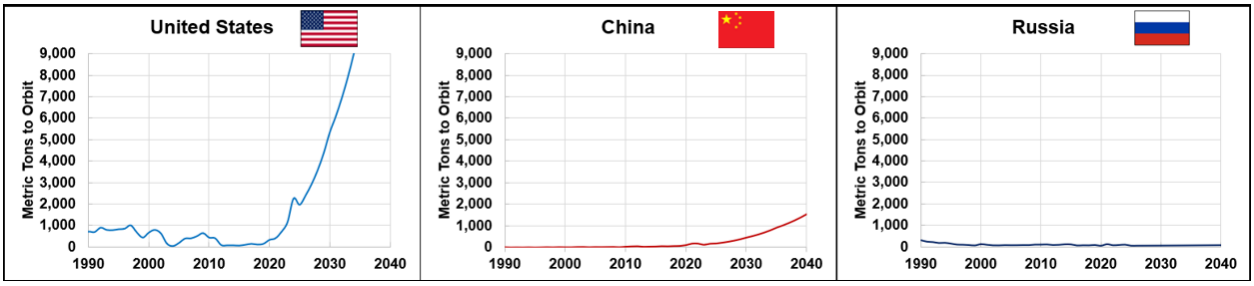


Figure 2: Historical and projected competitive space launch environment leading to 2040. The United States is projected to maintain a commanding lead in upmass, overwhelmingly driven by its commercial sector; this commercial boom will dramatically expand the domain the U.S. Space Force must monitor and defend. Concurrently, China's launch capability is projected to grow exponentially, solidifying its role as the primary pacing challenge. In contrast, Russia's capacity shows modest growth, representing a persistent, albeit not rapidly expanding, presence in orbit.

Probability of PRC Success in Achieving Space Dominance Through Technological Dominance. If the growth rate of China's lift capacity remains stable, the PRC will be unable to achieve the goals set forth for the 'Three Gorges Dam in Space.' The continued growth forecast depicted in Figure 2 is contingent upon the current rate of investment and technological improvement by China and the U.S. **Under current conditions, the U.S. will continue to outpace China in total upmass capacity, total orbital mass, orbital diversity, and therefore overall superior resilience through number and diversity in all key mission areas** publicly reported, primarily due to the U.S.'s robust commercial space sector. However, the goals set by the PRC and its comparative research investments in key space-related technologies, as depicted in *Figure 2*, strongly suggest that China is determined to change the terms of competition through disruptive industrial and technological policy changes.

Deep uncertainty exists regarding whether China can achieve a shift from linear to exponential growth in its key space capabilities, necessitating close monitoring. To put Chinese growth into perspective, China surpassed Russia's total upmass capability in 2025. In 2030, China is highly likely to exceed the USSR's peak space capability. Having previously launched on average one and a half satellites per year since the PRC's first launch in 1970, until it began a steep escalation in the early 2000s, data suggest that **the PRC is positioned to create the conditions for economic and technological surprises in 2040.** What remains to be seen is whether these surprises will be sufficient to catch up with the U.S.

Although technological innovation and state-driven economic investment will be the most significant drivers to watch, the PRC's ability to attract new consumers for Chinese space services could accelerate both drivers. Therefore, the role of norm shaping, lawfare, and economic development assistance through the BRI must also be closely monitored.

Environmental Risks

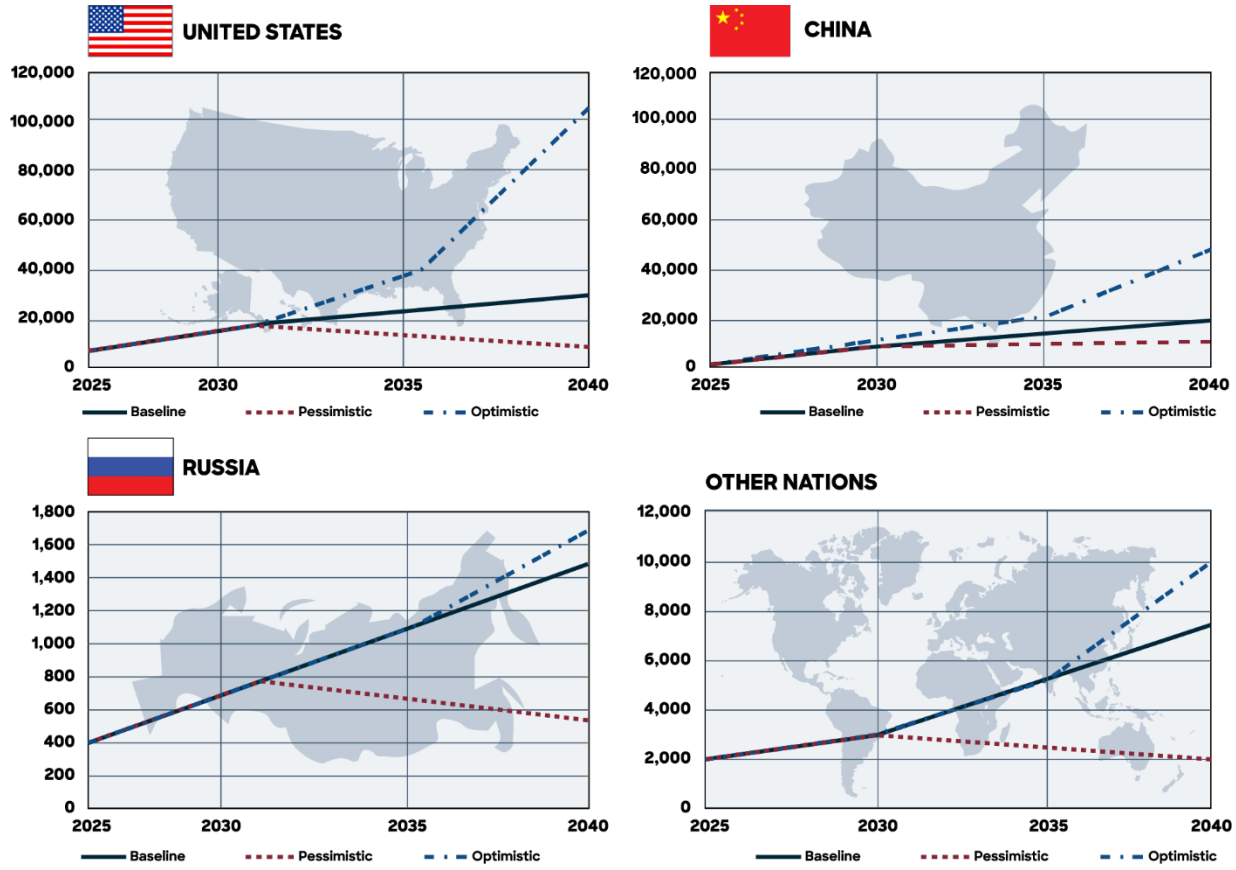


Figure 3: Projected Satellite Count by Country, 2025-2040. This figure illustrates three divergent futures for the number of active satellites in orbit (all-orbits). The baseline reflects a steady continuation of current deployment trends, while the optimistic scenario assumes revolutionary low-cost launch enables explosive growth, led by the US. Conversely, the pessimistic scenario models a post-2030 market collapse in LEO services. This crisis prompts a sharp contraction for the purely commercial US program. While China also uses commercial entities, its 'military-civil fusion' strategy provides a state-sponsored backstop, resulting in greater resilience to a market-driven downturn. The programs of Russia and Other Nations, being smaller and more reliant on long-term government budget cycles, experience a delayed impact, with their divergence from the baseline not occurring until post-2035.

As Figure 3 illustrates, the space environment of 2040 will be challenged by congestion and debris. Across all spacefaring nations, more than 50 constellations are now in development.[111] The baseline number of active satellites in orbit is estimated to increase from 5,500 to over 60,000 by 2030 alone.[112] An exponential rise in the number of objects in orbit will contribute to emissions, sunlight reflections, and radio transmissions that negatively impact Earth observation and increase the risk of collisions with other satellites.[113] In 2025, there are over 100 million pieces of debris between one millimeter and one centimeter in size that are below the detection threshold of current space surveillance systems.[114] By 2040, the space debris problem is likely to get worse, without some form of intervention.

Cislunar operations will also threaten the lunar environment. The first piece of material to unintentionally reach the lunar surface recently came from a discarded Chinese Long March 3C rocket booster, indicating that the vast amount of orbital debris has already reached further than most have considered.[115] In addition, China and Russia have announced a joint nuclear-powered lunar research station that they plan to have operational by 2035. Yet, neither nation has published any documentation that considers the risks of nuclear accidents or lunar resource extraction to the Moon.[116]

Lawfare in Space

Lawfare in space is quickly becoming a sophisticated tool designed to "subdue the enemy without fighting."[117] China and Russia have long used international and domestic legal frameworks and regulatory mechanisms to degrade their opponents' capabilities, weaken opposing coalitions, and obtain international sympathy and support from third parties. With international space law having remained essentially unchanged since the 1960s and 1970s, when the four foundational United Nations treaties were established, lawfare presents an asymmetric approach to restricting U.S. freedom of action in the space domain.[118]

> **China**: China codified the practice of lawfare through its *Three Warfares Doctrine*, which includes media warfare, psychological warfare, and legal warfare.[119] In simplistic terms, Chinese lawfare aims to present arguments that China is complying with the law, its adversaries are violating the law, and even if China breaks the law, there are legitimate mitigating circumstances for its actions.[120]
>
> **Russia**: Although Russia does not have an official doctrine directing the use of lawfare to advance its interests, it is consistent with the 2013 *Gerasimov Doctrine*, which emphasizes the role of hybrid warfare, which can include lawfare.[121] Regardless, Russia has employed lawfare numerous times on the international stage.

Implications for Commercial Integration and Space Traffic Management

The risks associated with USW will drive commercial protection to a level approaching that of military systems.[122] Space insurers, a critical component of the commercial space industry, will be increasingly concerned about collision risks and the vulnerability of commercial assets as legitimate military targets, suggesting alternative forms of risk-sharing may be necessary.[123] As a result, *commercial operators in 2040 will probably desire more information sharing with the USSF.*

5. Challenges to Achieving Space Superiority

Section Four of the FOE identified critical threats posed by our adversaries. Section Five explores the ways in which the USSF must adapt to meet those threats. The unique demands of future competition and combat in space are not abstract challenges. They are real problems which must be solved to win in an age of space power. Addressing them is not a matter of choice, but a prerequisite for future success.

The Top 10 Challenges

1. **Battlespace Awareness in a Degraded Environment.** Decisive and effective action is only possible with an accurate understanding of the operational environment. Yet unchecked denial and deception efforts will obscure our commanders' understanding of that environment. To combat this, battlespace awareness must track objects from LEO through cislunar space, fusing data at machine speeds, and compressing decision timelines. To accomplish this task, the USSF will require sensors in diverse orbits and on diverse platforms with assured communication links. In a dynamic and degraded electromagnetic environment, this capability must anticipate deception so that spoofed signatures are neutralized before they result in catastrophic errors. A clear and timely understanding of adversary intent and action will enable more precise and effective targeting.

2. **Highly Resilient Adversary Kill Mesh.** Adversary kill mesh rely on space capabilities such as proliferated ISR constellations, redundant communication technologies, and in-flight targeting updates.[124] In 2040, the space components of adversary kill webs will be complex, multi-nodal networks designed to survive our attacks. To help defend the Joint Force, the USSF must identify the weak points in those adversary networks and exploit them. Successful execution will require fielding combat units capable of fires that range from reversible to destructive effects. These combat units must deny and deceive sensing capabilities, collect and jam intersatellite links, and when necessary, responsibly destroy satellites without littering the domain with debris. As operations expand beyond GEO, reversible to lethal capability must extend into cislunar space.

3. **Timely Strike Without Warning.** The space environment is harsh and increasingly transparent. As advanced sensing capabilities proliferate to both adversaries and the hobbyist astronomer, the vast distances of space will no longer provide the same ability to conceal. A world where everything on-orbit is trackable complicates our ability to attack an enemy at a time, place, or manner for which they are unprepared. This same dilemma will present itself in other domains, as ISR tracks a Carrier Strike Group moving across the

Pacific or an armored Task Force staging for an assault. The USSF must plan for new ways to create confusion and surprise the enemy. The most promising way to create this denial and deception lies in novel EMS operations. We must find ways to mask signatures and spoof the adversary into taking actions that benefit the Joint Force.

4. **Protecting Friendly Attack Surfaces.** Our adversaries will target the breadth of our military capabilities to defeat us in battle. In space, this means they will seek to deny or disrupt the ground, link and orbital segments. To prevent this, the USSF must harden its systems against enemy attack while dispersing capabilities across resilient, proliferated satellite constellations. Proliferation and diversity deny adversaries a first-mover advantage and changes their targeting calculus and magazine depth requirements. Resilience must also extend to our Guardians, their families, our researchers, and our space industrial base. They must be protected against cyber intrusion, coercion, and micro deterrence campaigns. A flexible, dispersed, and hardened attack surface creates deterrence by denying adversary objectives.

5. **A Protracted Fight in the Largest Domain.** In 2040, we must anticipate drawn-out conflicts, where shock and awe campaigns are followed by a long, slow grind. The space domain will be complicated by the need to sustain the fight across vast and costly distances, from LEO to cislunar and beyond. If the USSF cannot demonstrate readiness for such a conflict, our adversaries will know they can simply outlast us. Preparing for the long fight begins with the capacity and logistics to rapidly launch, deploy and reconstitute forces. Rapid launch capability and expanded launch capacity enables the replacement of damaged satellites and the surge of critical payloads. Preparation also includes the ability to place or even manufacture assets in key strategic locations to control chokepoints and critical capabilities. Once in conflict, domain dominance requires sustained maneuver to achieve objectives before the enemy can force a culmination point[f]. On-orbit refueling and repair will be needed to extend satellite life and restore that maneuver. Without on-orbit refueling options, a satellite that expends all its fuel to survive an attack is still functionally dead.

6. **Decision Authority Pushed to the Edge.** Human-machine teaming will push the speed of fight to the point that sensing, attribution, and target custody in space occurs in fractions of a second. At the same time, traditional communications will face time lags. Ground stations to GEO have a .24 second roundtrip. Communication to cislunar space grows to 2.56 seconds. Our adversaries will solve this by placing automated decision making at the

[f] The culmination point is the point in an operation where a force's combat power reaches its peak and begins to decline, after which objectives can no longer be accomplished.

edge, either on a satellite or in the vicinity. To mitigate automated and autonomous threats, the USSF must consider the risks we are willing to take by delegating decisions to automated processes. Adapting to a machine-speed environment could include sufficient compute capacity onboard satellites, new constellations of space battle management satellites, or novel forms of communication that close the time-lagged gap.

7. **Escalation Control While Making Decisions at Machine Speed.** Command judgments and machine-speed effects must be fused**.** Automated defenses and degraded pictures can turn errors into inadvertent escalation before humans can intervene. The USSF must build guardrails or human-in-the-loop (HITL) linkages into autonomy, pre-delegated authorities to commanders, and adjustable control measures into kill webs to prevent runaway feedback loops. System control necessitates treating attribution as a weapons system requirement, not a niche analytic. We must also plan for contested commercial self-defense, as industry now owns critical segments of the orbital backbone that the nation relies upon. This means codifying authorities, indemnification frameworks, and response options for commercial operators under attack, so that an algorithmic "misunderstanding" does not become a geopolitical catastrophe.

8. **Unrestricted Warfare in Space.** Both World Wars of the 20th century saw campaigns of unrestricted submarine warfare on merchant shipping. In 2040, the space domain will face its own unrestricted warfare campaign. The attacks will span from reversible to destructive, from the EMS to kinetic attacks on commercial satellites. The USSF must be prepared on two levels. First, we must be prepared to defend commercial partners against attack because our use of commercial space systems makes them legal military targets during armed conflict. Second, we must be prepared to carry out attacks or other actions to negate commercial space assets when they support adversary military operations.

9. **Agile Innovation and Acquisition Culture.** Future processes must operate at the speed of commercial technology. Militaries bound by twentieth-century industrial models will lose the next fight before it begins. Victory requires a pivot to new ways of doing business across the lifecycle—from recruiting and retaining Guardians with rare technical skills, to acquiring software-defined payloads and updatable algorithms, to testing in live virtual environments that approximate the speed and ambiguity of real operations. The USSF must find ways to "move fast and break things," while still being good stewards of the taxpayer's dollars.

10. **Synchronizing with Partners.** Space is a team sport and must be partnered by design. Allies, partners, and the commercial industry are more than simple force multipliers, they

are the force. But we continue to face a complex web of layered policies, classification gates, and disclosure barriers that slow decisions and sap our advantage. Integration cannot be an afterthought. Interoperability and confidence must be built into architectures, authorities, and playbooks from the outset. This will reinforce norms of responsible behavior, share burdens, and move faster and from more locations than any competitor can on its own. This is not a transactional proposition. It is a commitment to mutual benefit and shared security—the essence of coalition power. As the Chief of Space Operations emphasized, “none of us is going to be successful going in alone.”[125]

2040: A Vision for Victory

By 2040, the Joint Force and its coalition partners achieve a decisive advantage through the integration of electromagnetic spectrum and orbital maneuver capabilities as core elements of combat power. What previously manifested as orbital ambiguity—spoofing, jamming, deceptive signatures—has been converted into a managed battlespace. The persistent, undeclared contest across frequencies and ephemerides endures, but the horizon is monitored, shaped, and, when required, controlled.

This transition accelerated when command and control shifted from reactive timelines to anticipatory decision cycles. Guardians and coalition operators employ machine partners that generate courses of action explicitly bounded by authorities, constraints, and risk tolerances. Representative actions include routing a cislunar tanker via low-scatter corridors; repositioning LEO relays into dynamic nulls; and Commercial orbits are crowded yet governed. Coalition patrols blend safety, stewardship, and security tasks. Allies and partners operate as integral nodes within the decision lattice. In 2040, USSF underwrites freedom of navigation as a practiced condition, not a future objective.

Space custody has evolved from an aspiration to a routine practice. The common operating picture is intent-centric rather than track-centric, drawing inferences from historical behaviors of both human organizations and autonomous systems. A distributed sensing lattice—ground telescopes through HEO pickets to cislunar sentries—fuses multi-phenomenology inputs across optical, RF, and quantum-secure links. The United States Space Force posture is dispersed, diversified, and reconstituted. Advantage is sustained by learning cycles that outpace adversary adaptation.

Electromagnetic spectrum operations are treated as maneuver, not merely support. The force achieves its effects by disentangling contested signatures, denying the adversary's sensemaking, and preserving the continuity of Joint All-Domain Command and Control. Mission assurance is embedded in all aspects of the system. Carrier strike operations no longer cede initiative to over-the-horizon threats; Joint fires transition from cold to hot with validated targeting, synchronized timing, and survivable battle networks. When links are disrupted, software-defined roles are reassigned in milliseconds, executing locally until spectrum corridors are resecured for the next offensive pulse.

The People’s Republic of China remains the pacing challenge; however, the U.S. and its allies have retained credible, lethal forces in the space domain. The coalition can degrade or blind critical sensors at decisive moments. Chinese decision-makers confront a credible risk that U.S. and allied forces can impose internal disruption to their kill webs. Deterrence is demonstrable through repeatable performance, not asserted through rhetoric.

6. Conclusion: A Conceptual Path Forward

A clear directive has been issued by senior USSF leaders: space is contested, our adversaries are closing the gap, and immediate action is required. Though our rivals may seek opportunity through Unrestricted Spectrum Warfare (USW), our decisive advantage lies with the USSF Guardians—Guardians who grasp the challenges ahead, who apply relentless ingenuity to overcome them, and who stand ready.

The Future Operating Environment (FOE) is the foundational text for this effort, providing a framework for the critical debate, discussion, and discovery our Guardians must undertake. Section One establishes the 2040 epoch and details the rigorous methodology behind the analysis. Section Two introduces Unrestricted Spectrum Warfare (USW), linking it to past conflicts and a future heteropolar world. Section Three provides a deep-dive into Chinese and Russian space forces and their evolving capabilities. Section Four explores how an adversary can turn our own technological advantages into direct threats. Finally, Section Five distills the entire analysis into the Top Challenges for achieving and maintaining space superiority.

The next step is a dynamic campaign of learning that will drive further discovery and assess the future environment presented here. We must take the Top Challenges as design drivers that inform the practical aspects of force design and acquisition. Using the 2040 environment as a starting point for the service to pursue lines of query and investigation is foundational to the design process. It will feed critical insights into the objective force that fights, adapts, and recovers faster than any opponent.

The work of the FOE is not a conclusion, but the beginning of a crucial conversation. We must build a process that continually monitors investments in research and technology, and that stays up to date on adversary forces and doctrine. The FOE must drive a campaign of learning to bring more insights from experts: space operators, scientists and engineers, the Intelligence Community, and warfighters in other domains. Failure means our adversaries will not just close the gap—they will leave us behind. Success will ensure the United States stays ahead and that our spacepower will always provide an offset. Success means that the Space Force dominates the domain in the long tradition of overwhelming American firepower.

The mandate remains unchanged: to ensure freedom of action and navigation across the Earth-Moon system, protect shared lifelines, and deter aggression with overwhelming, lethal combat power.

Appendices

Appendix A. Key Capabilities and Supporting Technologies in the 2040 Operating Environment

ENABLING AND DISRUPTIVE TECHNOLOGIES IN THE 2040 OPERATING ENVIRONMENT		
CORE CAPABILITIES	**EXPLANATION OF CHALLENGE**	**2040 POSSIBLE ENABLING AND DISRUPTIVE TECHNOLOGIES**
Command and Control	The exercise of authority over forces must leverage human–machine teaming to achieve rapid decision-making and execution while seamlessly integrating across joint, allied, and commercial networks.	• AI-enabled command autonomy and human–machine teaming (including BCI) • Interoperable mission data fabrics across joint, allied, and commercial networks • Assured crosslinks (quantum, optical, RF) with policy-constrained autonomy • Auditable control, verification, and escalation safeguards
Information	Information must be elevated from an operation enabler to a decisive advantage. The USSF will require battlespace awareness that tracks objects from LEO through cislunar space, fusing data at machine speeds, and compressing decision timelines.	• Quantum Sensors • Multi-spectral and hyperspectral sensors from LEO through cislunar • Space-based radar and quantum sensing/quantum radar • AI/ML data fusion, anomaly detection, and deception filtering at machine speed • Resilient RF, optical, and quantum communications links
Intelligence	Space intelligence operations must leverage advanced sensing, automate comprehensive fusion, and enable rapid, actionable attribution to prevent surprise and enable joint force kill chains.	• Proliferated autonomous ISR constellations with on-orbit processing • Autonomous crosslinking and edge analytics for rapid tasking • High-altitude platform (HAP) sensing layers augmenting space ISR • AI-driven attribution and deception-resilient models for STM
Fires	To be the dominant power, we must field combat units capable of executing effects that range from reversible to destructive, defending constellations and ensuring freedom of action from LEO through cislunar space.	• Non-kinetic counterspace EW (autonomous EW, ML-generated waveforms) • Directed energy weapons (lasers, high-power microwaves) • Co-orbital RPO systems for reversible to destructive effects • Debris-avoiding kill mechanisms and precision spectrum deception/spoofing • Novel Hypersonic Weapons • Lunar-Based Weapons • Predictive warfare algorithms (targeting support)

Movement and Maneuver	The USSF must design its forces to achieve a lethal positional advantage, enabling a seamless transition from crisis to conflict.	• Refueling and Servicing • Advanced electric propulsion (high-power Hall and ion thrusters) • Nuclear-electric propulsion and space tugs for cislunar operations • Autonomy for Dynamic Space Operations and evasive maneuver • Stealth/metamaterial signature control and resilient cislunar navigation
Protection	Architecturally, the USSF must transition from reliance on a few exquisite systems to resilient networks of many interoperable and potentially expendable satellites and nodes.	• Metamaterials and programmable EM skins (radar/thermal cloaking, radiation shielding) • Cyber-resilient, disaggregated, and proliferated architectures • Autonomous reconstitution and adaptive routing across constellations • Anti-jam, anti-spoof, and zero-trust communications
Sustainment	Space sustainment must provide the capacity and logistics to deploy, reconstitute, refuel, and repair at a pace that supports joint force victory in a protracted conflict. Responsive launch is crucial for maintaining resilience and lethality.	• Reusable and responsive launch systems • On-orbit servicing, repair, and refueling with RPO-capable servicers • Modular satellites with in-space reconfiguration and autonomous depots • Power and materials advances informed by SBSP mega-platform technologies
Escalation Control in a world of machine speed	Command judgments and machine-speed effects must be fused**.** Automated defenses and degraded pictures can turn errors into crises before humans can intervene.	• Autonomous kill webs (with controls) • Predictive warfare algorithms • Policy-constrained AI with verification, audit trails, and human veto paths • BCI-enabled human-in/on-the-loop interfaces for time-critical control • Automated deception detection and AI red-teaming • Secure quantum communications and digital twins for risk-aware decision support

Appendix B. Critical Assumptions: The Value of a Discipline Future

Projecting the 2040 FOE for the USSF requires an analytical approach that constrains the broad spectrum of hypothetical futures by grounding its narrative in key assumptions. The FOE is drawn from the alternative futures methodology and is neither a "business as usual" projection nor an exercise in unconstrained collapse or transformation. Instead, it recognizes profound stress and mutation within the international order, while positing that the foundational rules of global interaction, although stretched, have not collapsed.

The future vision provided reflects multiple possible futures integrated to stress-test doctrine, force design, and policy, giving coherent boundaries for scenario development, ensuring analytic rigor, and enabling actionable planning. Without these constraints, futures analysis risks either vagueness or an implausible proliferation of contingencies that obscure more than they illuminate. The following ten assumptions structure the FOE, providing a robust yet bounded vision of the world in which the USSF will operate in 2040.

1. Economy: The report assumes that the global market-based economic order and rules-based trading system will persist—albeit under strain and frequent manipulation. No catastrophic global depression or revolutionary new financial system is projected, such as a post-scarcity order. Instead, economic cycles will fluctuate within historically established patterns, thereby maintaining the foundational mechanisms that underpin interdependence and competition among states and commercial actors.

2. Wars: No major wars fundamentally altering the state system—such as a U.S.-China clash over Taiwan or a NATO-Russia escalation in Ukraine—will occur before this 2040 projection. Conflicts and crises may arise and intensify, but the existing major frontiers and the global balance of power will be preserved. The world remains fraught with rivalry and limited conflict, but it avoids systemic breakdown or large-scale territorial revisionism.

3. Artificial general intelligence (AGI): While artificial intelligence and autonomous technologies will achieve unprecedented proficiency and independence in warfare, logistics, and space operations, there will be no emergence of AGI capable of independent judgment or initiating wars. AI will transform the character of competition, but always as an extension of human policy and command—not as a self-directed actor.

4. Environmental and Resource Security: Environmental stress will continue to mount, increasing incentives for space-based solutions such as extra-terrestrial mining, orbital energy collection, and atmospheric modification.

5. Geopolitical Ambitions: Great power strategic objectives will remain consistent through 2040. Russia's goals focus on regional dominance, energy corridors, and strategic depth; China will persist in pursuing Taiwan's integration and extending global influence—favoring blockade, subversion, and gray zone sabotage over open war. India will pursue strategic autonomy and regional preeminence, but avoid binding alignment with any one bloc, reflecting both the opportunities and constraints in its foreign policy.

6. Outer Space Environment: There will be no Kessler cascade that renders key orbital regimes unusable; however, crowding, debris growth, and the uneven maturity of STM will pose persistent, significant challenges. Conjunction hazards and fragmented data-sharing will increasingly constrain launch windows, maneuver planning, and insurance risk. Absent universally adopted norms and interoperable STM, attribution disputes and misinterpretations of proximity operations will elevate the risk of escalation, even as debris mitigation, remediation pilots, and improved STM keep orbits complex but usable.

7. Alliance Structure Commitments among established allies and partners will endure. NATO, Australia, the United Kingdom, and the United States (AUKUS), as well as the U.S.–Japan alliance and the U.S.–South Korea alliance, along with enduring U.S. partnerships, will remain the backbone of Western deterrence. Adversarial alignment among Russia, China, Iran, and North Korea will continue informally, but without the creation of a formal "anti-U.S." bloc or new league of treaty-based alliances.

8. Nuclear Deterrence Nuclear deterrence remains intact. China, Russia and other states will possess the capability to place weapons of mass destruction (WMDs) in space or detonate operational nuclear devices in orbit, though they have not yet done so. Strategic deterrence will remain robust and continue to shape the choices of all major powers, with weapons of mass destruction serving as a constraint on escalation, not yet a tool for space warfare.

9. International Order/Space Regime While the legitimacy and authority of the Outer Space Treaty and other international legal regimes will be persistently undermined by "lawfare" and alternative rulemaking efforts, they will not be abandoned or formally superseded. The order will bend but not break; legal ambiguity and competitive norm-building will produce a contentious status quo rather than outright legal collapse.

10. Physics: Advances in launch technology, propulsion, and space maneuver will be significant, but remain within the bounds of our current understandings of physics and orbital mechanics. Getting mass to orbit and maneuvering in space will become more efficient and flexible, but no

breakthroughs will render existing limitations irrelevant or enable “miracle” space power capabilities.

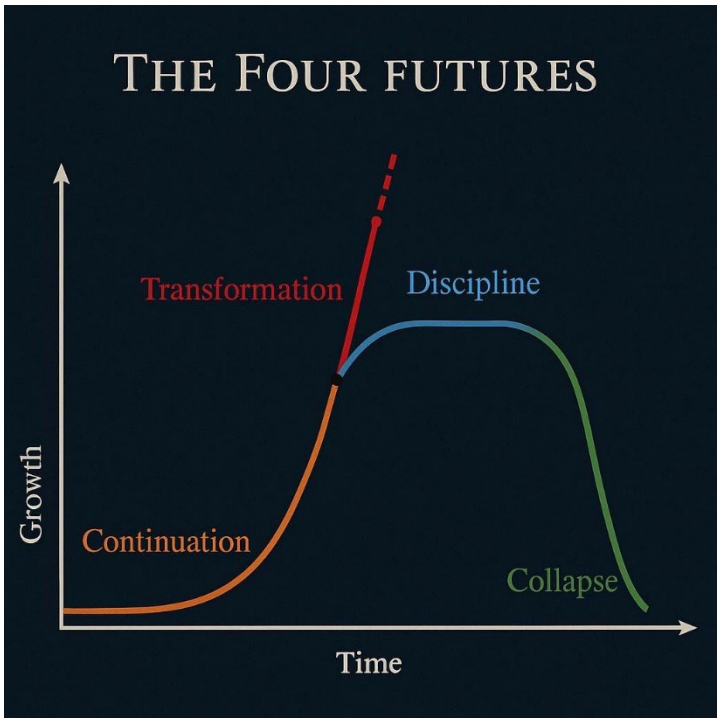
Appendix C. Methodology

FOE Narrative

The FOE Narrative methodology was briefly outlined in Section One, including the four archetype futures scenarios illustrated below. These scenarios are derived from the Manoa Futures Methodology developed at the University of Hawai'i Research Center for Futures Studies. This methodology is ideally suited for the FOE because it employs long-term analysis, avoids trend bias by emphasizing the unexpected, and allows for the study of not just what could happen but also what should happen.

- **Continuation/Growth**: Existing trajectories persist. Capabilities improve incrementally, scale increases, and efficiency gains accrue. Institutions adapt at the margins, and public–private integration deepens without altering the basic competitive landscape.

- **Collapse**: Systemic shocks or cascading failures erode capacity, governance, and trust. Services are disrupted, supply chains fracture, and deterrence or credibility weakens, leading to contraction, fragmentation, and loss of coherence.



- **Discipline/Constraint**: Policy, norms, and resource ceilings channel behavior toward restraint and stewardship. Emphasis shifts to compliance, verification, hardening, and redundancy, trading speed of expansion for stability and risk reduction.

- **Transformation**: Discontinuities—technological breakthroughs, organizational redesign, or geopolitical realignments—reset assumptions and operating models. New architectures and doctrines emerge, incumbents are disrupted, and competitive positions are re-ordered.

The Futures Team initially developed the four scenarios for SSDP and tested them at the June 2025 Futures Workshop in Colorado Springs.[g] The purpose was to validate the scenarios and gather subject matter expertise. The workshop participants were separated into four groups, with each group exploring a different issue across three time epochs: 2030, 2035 and 2040. The issues were Command & Control, Counterspace, Space Mission Areas, and Integration. The workshop forced explicit choices among, for example, exquisite versus proliferated constellations; on-orbit maneuver and logistics versus terrestrial redundancy; rapid reconstitution versus hardening at the edge; reversible versus non-reversible effects; and the apportionment of resources between counterspace and protection missions. This method counters dominant assumptions about the future by stress-testing assumptions across all four futures and elevating weak signals that challenge prevailing views.

The Futures Team compiled the data gathered from this workshop into a post-workshop report, which was then used to develop the framework and outline for the FOE Narrative.

The first step in building the Framework was to define the axiomatics of space competition and warfare. The team clarified assumptions about integrated deterrence, the commercial–military blending, the primacy of reversible versus non-reversible effects as a decision variable, and how resilience requirements can create incentives that reshape adversary behavior and crisis thresholds. The team identified Space Force–specific paradoxes, including balancing counterspace missions with protect and defend missions; navigating “space essentialism” in authorities and norms; and recognizing that resilience for the USSF extends beyond the space domain to cybersecurity, terrestrial infrastructure, and the industrial base.

The FOE framework organized critical questions into analytical segments, each of which was assigned to an experienced researcher. The researchers gathered information from a wide range of resources, including academic research, journals, and think-tank studies. The team prepared Technology Readiness Level reports for each of the technologies explored in the narrative. In every analytic segment, the Futures Team considered English translations of relevant publications from China and Russia. Where the existing research was scarce, the Futures Team used two methods to gather additional primary source data. First, they used THALES, a real-time automated monitoring platform, to gather data on research, patents and other publicly available information. Second, they commissioned a consulting team to conduct field research and prepare white papers on technical issues, that then informed the overall analysis.

[g] The workshop participants included subject matter experts from SSDP, SWAC, Task Force Futures, SpOC, SSC, USSPACECOM, USSTRATCOM, S4S, SMDC, USARPAC, USASOC, USSF HQ, NSIC, Sandia National Labs, MIT/LL, Rand, Peak Solution, SAIC, and the Aerospace Corporation.

FOE Enterprise

The foundational basis for the FOE Methodology is the FOE Enterprise.

The Enterprise methodology was adapted from an Alternative Futures approach grounded in systems theory and then aligned with Joint Force doctrine to illuminate plausible, probable, and preferred operating environments. Since space lacks a combat history, the team began with first principles. They established axioms of competition and conflict tailored to the orbital environment and tested them against technical realities, geopolitical drivers, and operational risk.

The 15-year time horizon of the FOE necessitates the use of futures scenarios to stress test the force design and expose faulty assumptions in the present. Stress testing is a systems engineering concept applied to warfighting. It asks whether the architecture can sustain the functions outlined in the design drivers under simultaneous spectrum denial, cyber compromise, cognitive attack, and kinetic losses. It quantifies how long and at what level of effects the force can sustain operations. It exposes single-point failures across technology, human processes, legal frameworks, commercial dependencies, and time.

Futures scenarios must possess conditions representative of existing trends and an adversary's strategic and tactical dispositions. Unlike physics-based simulation environments, futures scenarios work through the logic-based expanse of possible combinations of adversaries and tactics that often exceed formal modeling capabilities. Futures scenarios are a vital supplement to our Model-Based Systems Engineering (MBSE) practices because our adversaries will not engage one at a time or one capability at a time. In conflict, we will face multiple actors and a blended spectrum of attacks—kinetic, jamming, spoofing, and cyber disruption combined with directed energy and HPM strikes from geosynchronous platforms—all layered with lawfare and cognitive campaigns to exploit vulnerabilities.

The methodology culminates in "victory futures"—practical pathways to preferred outcomes across multiple plausible operating environments. The FOE identified critical thresholds that were found to be robust under uncertainty across all four futures, and should be used as design drivers for the future force. This fusion of axiomatic theory, systems analysis, expert engagement, and iterative testing is designed to equip the Space Force to anticipate, compete, and prevail in a contested and rapidly evolving space domain.

Two of the narrative scenarios are provided in Annex D. The first is the darkest of the four scenarios to highlight the challenges we face at maximum intensity. The narrative format is provided to help imagine how all the different drivers and insights fit together into a larger strategic picture. The second narrative scenario presents a bright future to focus the USSF's

desired vision for 2040. In both scenarios, technological superiority is a necessary but insufficient condition of victory. The decisive factors in the future operating environment are organization, integration, and clarity of strategic purpose.

Appendix D. Scenario Narratives

Dark Horizons 2040

In a possible 2040, every horizon is broken. Invisible rays, neural networks, and digital ghosts blur the lines of reality. This timeline to 2040 isn't born of a sudden apocalypse, but of a secret war that pulsed through quiet boardrooms, orbital relays, and bloodied hedgerows for nearly two decades before the world finally awoke. There is no "World War III," only something stranger. The Cold War never ended; it simply mutated. In the heat of the Pacific sun, the darkness of the Baltic forests, and the silent electron storms of cyberspace, America, China, Russia, their allies, and spoilers bled one another in the orbital shadows of innovation and betrayal.

China's rise revolves around its "Supermind Project," an unprecedented fusion of state-driven research management, machine learning, and targeted talent acquisition. As the U.S. research funding waned in the late 2020s, Chinese planners seized the opportunity, mapping shifting clusters of frontier science and systematically recruiting top researchers into state initiatives. China cultivated a gravitational center in innovation that redirected the flow of students, talent, and high-impact laboratories into state-sponsored initiatives. The global science landscape shifted: conferences thinned, patents shifted abroad, and prize-winning teams clustered in Beijing, Shenzhen, and Shanghai, underwriting China's emergence as a dominant space power.

Supermind's dividends proved extraordinary. China fused breakthroughs in mesh autonomy, brain-computer interfaces, directed energy platforms, and quantum communications. When the "Three Gorges Dam in Space"—a vast, dual-use geosynchronous complex—went live, it served as a literal and figurative engine of power. The Dam became the operational hub for the People's Liberation Army Aerospace Force (PLAASF), whose mesh of swarms, high-altitude relays, autonomous satellites, and Brain-Computer Interface (BCI)-enabled command nodes executed EW, spectrum denial, and kinetic strikes with unmatched speed and lethality, even as Beijing cloaked each step in the language of peaceful energy diplomacy. Chinese mesh operations thrive on ambiguity—persistent jamming, spoofing, micro-targeted supply chain attacks, and harassment that stops short of open war. Taiwan blockade campaigns showcased this method: orbital mesh activity isolated the island, crippled communications and ISR, undermined U.S. commercial confidence, and eroded the will to resist through attrition and economic exhaustion. These operations carry vulnerabilities: the complexity of mesh orchestration, the risk of cascading mesh failures when disrupted synchronization falters, and the delicate political balance leaders in both the Global South and Beijing must preserve as the PRC pushes the limits of 'gray zone' escalation.

In this crucible, the United States and its allies pursued a "Golden Dome"—a multi-layered, proliferated constellation of satellites, air and ground platforms, space-based interceptors, and commercial

partnerships to keep information, targeting, and missile defense alive. More interceptors, more sensors, more places. But redundancy brought complexity, and complexity bred vulnerability. The very networks built to resist attack now offer countless attack surfaces for cyber sabotage, kinetic strikes, hijacked signals, and microwave lances from space. The U.S. kill web is powerful—but fragile--stretched thin by uncertainty about which node can be trusted and which might go dark at any moment.

Russia exploits every seam. Though lacking China's scale or the analytic unity of Supermind, Moscow sows chaos with maneuverable ASATs, mobile jammers, and aggressive "gremlin" satellites ready to disrupt, confuse, and misdirect U.S. and coalition decision-making. The steady sequence of simulated accidents, spoofed signals, and nuclear posturing provides Moscow with a flexible means to escalate and test U.S. resolve, particularly when U.S. attention is divided by Chinese campaigns in the Pacific. Russian and Chinese mesh architectures are compatible at the machine level, facilitating pragmatic coordination without treaty entanglements and further confounding U.S. defenses.

Throughout the preceding years, civilian, commercial, and military actors became fully entangled. Private companies, commercial satellite constellations, and international insurance syndicates are targets, serving as proxies or unwitting participants in operations undertaken under the cover of deniability or "routine" commercial intervention. Pirates and privateers armed with algorithms rival states in destructive power and vanish without a trace. Persistent lawfare, forum shopping, and the sheer speed and frequency of mesh-enabled events render international law impotent. Space is not merely crowded but turbulent; debris clouds and staged "accidents" create the constant threat of escalation by miscalculation or plausible deniability.

Europe finds itself unmoored, its space ambitions battered by commercial sabotage, conflicting alliances, and a terrifying realization: with the U.S. kill web stretched to breaking, it may stand alone against Moscow's ambition. Commercial space miners, telecoms, and satellite relay firms no longer trust their home countries to protect them, launching their own uncoordinated EW countermeasures—often mistaken for acts of war.

Technology in 2040 is not just advanced; it is posthuman. Brain-computer interface teams control waves of variably autonomous satellites and drones, fighting at the speed of networked thought and burning themselves out faster than the circuits that link them. New forms of operationally induced stress disorders plague operators. Directed energy—lasers, HPMs, and plasmonic-skinned satellites blinking in and out of measurable existence—carves out holes in space and disables radars worldwide. Metamaterials bend light and radio, cloaking assets and fooling even quantum radar, while advanced quantum encryption and the rumored deployment of neutrino communication promise C2

beyond even the reach of SATCOM-denial operations—signals passing straight through the planet, undetectable and unjammable.

Yet the fog of war has never been thicker. Space, once a promise of commercial bounty and planetary unity, is now a junkyard filling faster than any nation can clean. Autonomous "gremlins" attack not just military satellites but also insurance underwriters' relays, navigation systems for container ships, and even the support networks for emergency care drones, timing systems for financial markets, and commercial services Americans depend on, from GPS to supply chains that ensure food and essentials. Hundreds of satellites shift orbits daily, sometimes to avoid genuine attacks, sometimes routine debris, and sometimes—no one knows why? The frequency and scale of maneuver strain even advanced space-domain awareness systems.

Worse than the machines are the new methods of population-centric warfare. Adversaries—state or proxy—threaten and injure the families of America's critical warfighters through "micro-deterrence" campaigns. U.S. space launches are delayed not only by drone attacks but also because operators refuse to leave home, held hostage by encrypted ransom notes threatening their loved ones. The frontline of the space war is at home.

Bright Horizons 2040

In 2040, the United States learned to bend the spectrum. What once scattered into fog—spoofs, jammers, phantom signatures—now passes through a prism the U.S. coalition holds steady. The war that never declared itself is still there, coiled in frequencies and ephemerides, but the horizon is no longer broken. It is shaped.

The change began when U.S. C2 stopped fighting time. The operator rooms don't look like war; they look like studios—quiet, with a heatless glow on faces and fingertips. Guardians and allies sit before surfaces that think aloud, their assistants trained not to hiss warnings but to propose actions bound to authorities and risk. A faint tone signals a choice: pivot a cislunar tanker through a low-scatter corridor; swing a LEO relay into a null; publish a disclosure packet that nullifies a spoofed signal before it metastasizes. The machine offers a pathway; a human approves or slows it down. When the tempo spikes, control measures add decision space. Every order comes with an attribution confidence and an escalation ceiling that the operator can see and trust.

It matters because custody is no longer an unachievable concept. The map that hangs in the air does not show dots; it shows intentions inferred from behavior. A solar reflector breathes at a rhythm that suggests power beaming; a co-orbital inspector prowls in a pattern that says reconnaissance, not rescue. The lattice that feeds this picture spans from ground telescopes to HEO pickets and cislunar

sentries, fused over optical, RF, and quantum links. The U.S. coalition's data maintenance service marks the synthetics in amber and prevents anything from hardening into targeting data without corroboration. You can still be fooled on the first blink; you are rarely fooled twice.

The U.S. leads not because it owns the sky, but because it can disentangle it. Prism operations expose the weak points in hostile kill chains and distribute friendly dependencies, ensuring that failure remains localized. Spectrum operations stopped being a supporting act; they became a maneuver in their own right. An adversary slides a wideband knife across a theater, and the U.S. coalition steps sideways in the noise, shifting waveforms, polarizations, and timing so fast that it looks like a premonition. A hostile inspector inclines toward a commercial hub, and a choreography unfolds: a decoy emission nudges its attitude solution off by a degree, a micro-burn breaks geometry, a narrowcast warning goes public with cryptographic receipts. If a node must be removed, the strike is low-debris and accountable, and the evidence of why is prepared before the first fragment cools.

Assurance has congealed into the critical machinery of power projection. The joint kill mesh—the web of ISR, PNT, comms, and fire-control—breathes like a lung under compression and never collapses. When a link is disrupted, software-defined roles migrate in milliseconds. The problem is not eliminated; it is never allowed to cascade in the first place. This is the essence of U.S. strategic position: coherence at machine speed, paired with restraint that allies believe and adversaries must watch.

China remains the formidable peer it has built itself to be. The Supermind generation matured into an aerospace force whose autonomy is elegant, whose directed energy is quiet and precise, whose orchestration can flood a theater with ambiguity on demand. But the calculus shifted. The U.S.-led coalition can disable Chinese sensors along their most critical pathways at the moments that matter, forcing receivers into less effective modes and turning saturation into dilution. Chinese decision-making is shaped by the fear that if forced, the U.S. could take control from within.

Attribution arrives quickly enough to make deniability expensive. Beijing still probes and postures; it rarely pushes to the point where the U.S. coalition would start cutting umbilicals. Everyone in the room understands the risk: in a head-to-head fight, the U.S. and its partners could compartmentalize Chinese space support—peel away PNT integrity, fracture comms meshes, isolate fire-control links—without smashing the commons. Strategic amputation haunts every escalatory gameboard. The deterrent is not thunder; it is the knowledge that the scalpel is sharp, and the hand is steady.

Russia plays familiar cards with familiar cunning. Its gremlin satellites still sidle up to things that do not belong to them; mobile jammers still bloom along frontiers where satellites skim low. Yet the value of mischief falls when the coalition can show the tape. The joint attribution cell is part lab and

part courtroom; it binds evidentiary chains across sovereigns and releases them fast. Staged accidents now arrive in the world's feeds with signatures and timelines attached. The gaps Russia exploits have narrowed. Moscow stays crafty, but it has grown cautious, aware that escalation would invite precise counters that it cannot afford.

The commercial sky is crowded and, for the first time in years, governed by more than hope. Telecom constellations weave around manufacturing stacks. Lagrange depots barter propellant, the way island ports once traded water and fuel. Cislunar transports run lanes posted days in advance, dodging nothing more sinister than dust and declared surveys. This steadiness is not a gift; it is the result of visible custodianship. Coalition patrols are part traffic cop, part rescue tender, part sentry. They watch emissions and proximity with the patience of a port authority; they intervene with reversible force when a hand reaches toward a purse. Freedom of navigation is a practice—behavior-based, multinational, predictable—and because it is practiced, capital and insurance return. Operators plan for growth, not evacuation.

"Space pirates" didn't vanish; they withered. The story usually goes the same way. A hijack attempt rides a mask on a commerce relay; within an hour, the uplinks are null-steered, automated sanctions frameworks freeze the accounts behind the effort, and a seizure team arrives with a legal order and a willingness to cut the payload free. The Proximity and Emissions Conduct Accords ensure that distances and dwell times are accurate; the Spectrum Stewardship Convention assigns misuse a shared name and a shared penalty. A Commercial Self-Defense Framework clarifies what a private operator can do and when coalition help arrives. The result is ordinary: disputes resolved in days, deterrence set by precedent, not spectacle.

Allies and partners are not strapped to the hull; they are part of the ship. Europe, Japan, India, Australia, Canada, and others are situated within the decision lattice, each with its own sensors, relays, and maneuver assets. Classification barriers are handled in blockchain rather than conference rooms; releasability is a tag, not a week of paperwork. A Norwegian radar flags an anomalous dwell; an Indian inspector requests a lane; a Japanese relay takes a reroute to hold a weapons timeline; everyone sees just enough to act together. The coalition Space Guard—constabulary, rescue, traffic management—flies a handful of flags on every patrol and enforces rules with the politeness of a practiced cop and the speed of a practiced pilot.

The frontline at home is defended as deliberately as an orbital slot. The micro-deterrence campaigns that once threatened families and researchers are now mitigated within established routines: encrypted life services, counter-coercion hotlines, and financial and legal responses that drain leverage before it can be applied. BCIs are used where useful and bounded where dangerous, wrapped in health guardrails and fallbacks that keep human judgment from being a fuse.

Ambiguity hasn't died. A lunar tug can still vanish at the wrong moment; solar weather can still mimic jamming. But the system tolerates uncertainty now. Predictive SDA bridges the gaps—spectrum control maneuvers around false shadows. The attribution cell separates accident from attack in time to extinguish sparks before they find tinder.

Appendix E. Non-Aligned States

As space transitions into a heteropolar environment over the next 15 years, the number of prominent space powers is expected to rise. Due to the diversity of national interests, it is doubtful that all future space powers will be comprehensively aligned with either the United States, Russia, or China. The spectrum of alignment will fluctuate on a scale ranging from quasi-alignment to mostly divergent viewpoints within any given country. Aligned actors could advance into regional powers and, through various means, form new diplomatic blocs capable of either withstanding U.S. global power projection or even projecting global power on the same scale, or both. As these new powers rise, their alignment with the U.S. will depend on several factors, at least two of which will be ideological and economic. Two nations that fall into this category to some degree currently and are likely to continue doing so as non-aligned actors, as their space programs and capabilities continue to grow, are India and Brazil.

On the international stage, if the United States loses support for the legitimacy of its actions in space, it may find itself left behind in the creation of new international space laws and norms, and face isolation from the global space technological forum. Without strong efforts to strengthen ties with non-aligned actors, the United States could find itself lagging in global national security capabilities.

India

Indian space activities comprise both military and civilian components. On the civilian side, the Indian Space Research Organization (ISRO) is India's space agency, consisting of the SSA Control Centre. Recently, India established the Indian National Space Promotion and Authorization Center (IN-SPACe), which is charged with facilitating government-civilian space collaboration. India's Department of Space oversees both ISRO and IN-SPACe. As of 2024, India has a total of 136 operational satellites, nine of which are identified as military satellites providing MILSATCOM, PNT, remote sensing, and scientific capabilities.[126] In 2019, India established two military space agencies: the Defense Space Agency (DSA) and the Defense Space Research Organization (DSRO).[127]

The Indian Space Policy 2023 aims to develop India's commercial presence in space, drive technological development, utilize space for international relations, and implement space applications collectively for India's socio-economic development and security.[128] Regarding the commercial sector, the ISRO has stated that by 2047, India aims to send humans into space, build and operate a space station, send humans to the Moon, establish a Moon-based economy, and conduct missions to Mars and Venus. They would also like to make a global satellite internet capability.[129]

From its military arm, India's DSA aims to develop its space defense capabilities, encompassing both kinetic and non-kinetic anti-satellite capabilities, as well as signals intelligence and electronic intelligence capabilities.[130] In June 2025, India had accelerated its plans for the proposed launch of 52 defense surveillance satellites.[131]

Brazil

Brazil's space program is centered on a cross-governmental agency, the National System for the Development of Space Activities (SINDAE), which facilitates the creation and implementation of the National Program for Space Activities (PNAE). The SINDAE is responsible for the coordination between civilian and military entities to address national security concerns. The primary agency under the SINDAE is the Brazilian Space Agency.[132] Brazil has recently begun to expand on its commercial space ambitions and, in 2024, passed laws, the first creating a state-owned enterprise named 'Alada' tasked with expanding Brazil's role in the global commercial space market, and the second establishing regulations for commercial space activity.

Brazil's space launch capability is comprised of two launch locations. Alcântara Launch Center is in the town of Alcântara, within 30 kilometers of the City of São Luís, State of Maranhão. The Alcântara Base remains under the exclusive control of Brazil's government, under the jurisdiction of the Ministry of Defense, with the participation of Brazilian Space Agency (BSA). The Barreira do Inferno Launch Center, is located close to the city of Natal, capital city of the Brazilian state of Rio Grande do Norte.[133] Brazil's location and equatorial orbit access make it a valuable location for launch operations. Brazil may leverage access to its launch facilities for collaboration on space technologies and systems to advance its space capabilities.

The Brazilian Air Force's Aerospace Operations Command (COMAE) directs military space operations and has the primary mission of overseeing all air and space operations in the country.[134] Brazil currently operates eight satellite platforms: four Earth observation satellites and four military communication and multi-mission. Brazil has eight more satellites in the planning stage (1x Earth observation, 5x military communication and multi-mission, 1x remote sensing, and 1x space weather).[135] The Brazilian Air Force also coordinates the Space Systems Strategic Program (PESE) that will oversee the development and launch of six LEO satellites and three GEO satellites, plus the development of a control ground station and a reception and data processing system, providing ground observation, telecommunications, geo-positioning, and monitoring capabilities to the Armed Forces.[136]

Appendix F. Data and Methodology for Satellite Count and Upmass Baselines

Methodology

Satellite and upmass data are not intended as precise counts or probabilistic forecasts but rather as strategically plausible baselines constructed within a "Continued Growth" futures framework. Baselines were made using publicly available information from the European Space Agency, United Nations, Union of Concerned Scientists, BryceTech, Euroconsult, the International Telecommunication Union, and announcements from corporations and Chinese state-owned enterprises. Total satellite growth rate follows a tapered compound annual growth rate (CAGR) pattern of 21% from 2026 to 2030, 8% from 2031 to 2035 and 6% from 2036 to 2040. Upmass figures use a combination of actual historical data (1980-2025) from Jonathan McDowell and projections (2026-2040) using CAGRs in three five-year epochs between 2025 and 2040 that follow a similar taper: US 22→14→10%, China 20→15→11% and Russia 2→3→3%. Country-level satellite figures reflect an increase in Chinese share over time as LEO mega-constellations mature. Mission mix figures reflect an increased portion of total satellites devoted to communications, and assume Earth observation, technology demonstration, scientific and PNT mission growth as well.[h]

Satellites by Orbit

Year	LEO	MEO	GEO	Other	Total
2025	10,296	234	1,053	117	11,700
2030	27,000	600	2,100	300	30,000
2035	41,400	1,125	2,250	225	45,000
2040	55,800	1,800	2,100	300	60,000

Satellites by Country

Year	US	China	Russia	Other	Total
2025	7,291	1,871	407	2,131	11,700
2030	17,163	9,123	750	2,964	30,000
2035	23,861	14,717	1,109	5,313	45,000
2040	30,246	20,913	1,488	7,353	60,000

[h] In 2019, a representative of China's National Timing Service Center speaking at the Stanford PNT Symposium stated the country had plans for at least 120 LEO PNT satellites; China LEO mission mix figures reflect this claim.

China LEO Mission Mix

Year	Communications	Earth Observation	Tech Demo	Science/Other	PNT
2025	250	650	130	130	0
2030	4000	1000	400	400	0
2035	6000	1500	600	600	120
2040	10000	2000	800	800	120

China MEO, GEO and Other Mission Mix

Year	Communications	Earth Observation	Tech Demo	Science/Other	PNT
2025	120	5	15	25	60
2030	200	15	25	35	70
2035	280	25	25	45	80
2040	360	35	25	55	90

Absolute Satellite Upmass (Projections in Blue)

	U.S.	China	Russia/USSR
1980	38	0	358.6
1981	224.2	0.8	377.6
1982	351	1.8	391.7
1983	458.8	1.8	383
1984	610.2	3.6	378
1985	1008.9	1.8	391
1986	118.9	2.7	348.5
1987	19.7	3.9	440.1
1988	257	4.2	468.6
1989	596.1	0	334.9
1990	725.6	10.8	296.5
1991	703.8	1	231.2
1992	911	4.4	212
1993	806.3	1.3	170
1994	795.6	6.7	178.7
1995	836.4	0	142.2
1996	863.2	4.4	98.8
1997	1017.5	11.5	91.4
1998	691.2	5.7	76.4
1999	448.9	13.9	59.1
2000	680.6	9.1	117.5

2001	806.2	7.7	88.9
2002	642	18.3	63.4
2003	168.2	20.9	61.2
2004	55.4	9.8	71.7
2005	199.8	17.6	68
2006	403.3	15.2	69.2
2007	414.3	19.1	74.3
2008	516.8	22.2	73.8
2009	657.5	11	96.4
2010	447.4	32.6	97.4
2011	418.5	46.9	104.1
2012	100.9	53.8	78.9
2013	86.7	29.6	87.7
2014	87.5	37.5	110.5
2015	77.1	41.6	106.2
2016	115	56.8	57.6
2017	158.7	50.8	65.9
2018	126.1	62.7	63
2019	158.5	69.4	78.1
2020	341.3	106.3	46
2021	416.5	177.1	115.6
2022	717.7	178.5	67.3
2023	1168.8	124.8	79.7
2024	2267.7	172.6	94.6
2025	1974.6	183	47.3
2026	2409.012	219.6	48.246
2027	2938.995	263.52	49.21092
2028	3585.573	316.224	50.19514
2029	4374.4	379.4688	51.19904
2030	5336.768	455.36256	52.22302
2031	6083.915	523.666944	53.78971
2032	6935.663	602.2169856	55.4034
2033	7906.656	692.5495334	57.06551
2034	9013.588	796.4319635	58.77747
2035	10275.49	915.896758	60.5408
2036	11303.04	1016.645401	62.35702
2037	12433.34	1128.476396	64.22773
2038	13676.68	1252.608799	66.15456
2039	15044.34	1390.395767	68.1392
2040	16548.78	1543.339301	70.18337

Endnotes

[1] Goswami, N. (2023, April). *China's space ambitions: Drivers, goals and capabilities*. American Foreign Policy Council. https://www.afpc.org/uploads/documents/China_Space_Ambitions_FINAL_FINAL_-_April_2023_.pdf

[2] Stokes, M., et al. (2020, March 30). *China's space and counterspace capabilities and activities*. Project 2049 Institute. https://www.uscc.gov/sites/default/files/2020-05/China_Space_and_Counterspace_Activities.pdf

[3] The State Council of the People's Republic of China. (2024, October 15). *China releases space science development program for 2024–2050*. https://web.archive.org/web/20241021061621/https://english.www.gov.cn/news/202410/15/content_WS670e03b9c6d0868f4e8ebe40.html

[4] Bendett, S. (2021, September 23). *Advanced military technology in Russia: Capabilities, limitations and challenges*. Chatham House. https://www.chathamhouse.org/2021/09/advanced-military-technology-russia

[5] Bendett, S. (2021, September 23). *Advanced military technology in Russia: Capabilities, limitations and challenges*. Chatham House. https://www.chathamhouse.org/2021/09/advanced-military-technology-russia

[6] Sankaran, J. (2022, June 22). Russia's anti-satellite weapons: A hedging and offsetting strategy to deter Western aerospace forces. *Contemporary Security Policy*. https://www.tandfonline.com/doi/full/10.1080/13523260.2022.2090070

[7] Sankaran, J. (2022, March). Russia's anti-satellite weapons: An asymmetric response to U.S. aerospace security. *Arms Control Today*. https://www.armscontrol.org/act/2022-03/features/russias-anti-satellite-weapons-asymmetric-response-us-aerospace-superiority

[8] Gallagher, N., et al. (2023, September). *Minimizing the negative effects of advances in military-relevant space capabilities on strategic stability*. American Academy of Arts & Sciences. https://www.amacad.org/publication/military-capabilities-space-diplomacy-strategic-stability

[9] World Bank. (2025, June). *Global economic prospects*. World Bank. https://thedocs.worldbank.org/en/doc/8bf0b62ec6bcb886d97295ad930059e9-0050012025/original/GEP-June-2025.pdf

[10] Reach, C., Demus, A., Han, E., Lilly, B., Marcinek, K., & Shokh, Y. (2022, June 23). *Russian military forecasting and analysis: The military-political situation and military potential in strategic planning*. RAND Corporation. https://www.rand.org/pubs/research_reports/RRA198-4.html

[11] MITRE Corporation. (2022, June 27). *China's strategic vision: Part one—The Communist Party's strategic framing* (PR-21-02877-5). https://www.mitre.org/sites/default/files/2022-09/pr-21-02877-5-chinas-strategic-vision-part-one-the-communist-partys-strategic-framing.pdf; MITRE Corporation. (2022, June 27). *China's strategic vision: Part three—Envisioning a Sinocentric world* (PR-21-02877-7). https://www.mitre.org/sites/default/files/2022-09/pr-21-02877-7-chinas-strategic-vision-part-three-envisioning-a-sinocentric-world.pdf

[12] MITRE Corporation. (2022, June 27). *China's strategic vision: Part one—The Communist Party's strategic framing* (PR-21-02877-5). https://www.mitre.org/sites/default/files/2022-09/pr-21-02877-5-chinas-strategic-vision-part-one-the-communist-partys-strategic-framing.pdf

[13] Ashby, H., & Glantz, M. (2023, May 10). What you need to know about Russia's new foreign policy concept. United States Institute of Peace. https://www.usip.org/publications/2023/05/what-you-need-know-about-russias-new-foreign-policy-concept; Reach, C. (2022, September 16). The rise of the rest: How Russia views the future world order. *The National Interest*. https://nationalinterest.org/feature/rise-rest-how-russia-views-future-world-order-204796

[14] Marcinek, K., & Han, E. (2023, March 13). *Russia's asymmetric response to 21st century strategic competition: Robotization of the armed forces*. RAND Corporation. https://www.rand.org/pubs/research_reports/RRA1233-5.html; Reach, C., Demus, A., Han, E., Lilly, B., Marcinek, K., & Shokh, Y. (2022, June 23). *Russian military forecasting and analysis: The military-political situation and military potential in strategic planning* (pp. 66–67). RAND Corporation.

https://www.rand.org/pubs/research_reports/RRA198-4.html; Reach, C. (2022, September 16). The rise of the rest: How Russia views the future world order (p. 5). *The National Interest*. https://nationalinterest.org/feature/rise-rest-how-russia-views-future-world-order-204796

[15] Cohen, R., Kepe, M., Beauchamp-Mustafaga, N., Clark, A., Conn, K., Grisé, M., & Zhou, H. (2023, February 20). *Assessing the prospects for great power cooperation in the global commons*. RAND Corporation. https://doi.org/10.7249/RR-A597-4

[16] Pollpeter, K., Chase, M., & Heginbotham, E. (2017, November 10). *The creation of the PLA Strategic Support Force and its implications for Chinese military space operations*. RAND Corporation. https://doi.org/10.7249/RR2058; Jamestown Foundation. (2024, April 26). A disturbance in the force: The reorganization of People's Liberation Army command and elimination of China's Strategic Support Force. *China Brief, 24*(8). https://jamestown.org/program/a-disturbance-in-the-force-the-reorganization-of-peoples-liberation-army-command-and-elimination-of-chinas-strategic-support-force/

[17] Pankova, L., & Gusarova, O. V. (2020). Space dimension of the innovation-technological breakthrough. *World Economy and International Relations, 64*(11), 62–73. https://doi.org/10.20542/0131-2227-2020-64-11-62-73

[18] Flanagan, S. J., et al. (2023, August 31). *A framework of deterrence in space operations* (RRA820-1). RAND Corporation. https://www.rand.org/t/RRA820-1

[19] Flanagan, S. J., et al. (2023, August 31). A framework of deterrence in space operations (RRA820-1). RAND Corporation. https://www.rand.org/t/RRA820-1

[20] Flanagan, S. J., et al. (2023, August 31). A framework of deterrence in space operations (RRA820-1). RAND Corporation. https://www.rand.org/t/RRA820-1

[21] Alkire, B. (2025, April 3). *The expansion of China's military space and counterspace capabilities and implications for space as a contested domain* (CT-A3951-1). RAND Corporation. https://www.rand.org/pubs/testimonies/CTA3951-1.html

[22] Kang, M., Park, S., & Lee, Y. (2024, 1 May). A survey on satellite communication system security. *Sensors, 24*(9), 2897. https://doi.org/10.3390/s24092897

[23] China's military goes all out in space. (2025, July 15). *The Economic Times*. https://economictimes.indiatimes.com/news/defence/chinas-military-goes-all-out-in-space/articleshow/122496208.cms

[24] Alkire, B. (2025 April 3). *The expansion of China's military space and counterspace capabilities and implications for space as a contested domain* (CT-A3951-1). RAND Corporation. https://www.rand.org/pubs/testimonies/CTA3951-1.html

[25] Burke, K. (2024, March). *PLA on-orbit satellite logistics*. China Aerospace Studies Institute. https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2024-03-18%20PLA%20On-Orbit%20Satellite%20Logistics.pdf

Burke, K. (2024, September). *China can track GSSAP*. China Aerospace Studies Institute. https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2024-09-09-2%20China%20Can%20Track%20GSSAP.pdf

[26] Tong, Z. (2025, January 9). China plans to build 'Three Gorges Dam in space' to harness solar power. *South China Morning Post*. https://www.scmp.com/news/china/science/article/3294091/china-plans-build-three-gorges-dam-space-harness-solar-power

[27] Decker, A. (2025, April 3). How China is expanding its anti-satellite arsenal. *Defense One*. https://www.defenseone.com/threats/2025/04/how-china-expanding-its-anti-satellite-arsenal/404283/

[28] Burke, K. (2023, December). *PLA counterspace command and control*. China Aerospace Studies Institute. https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/PLASSF/2023-12-11%20Counterspace-%20web%20version.pdf

[29] Burke, K. (2023, September). *The PLA's new base for space situational awareness – Opportunities and challenges for the U.S.* China Aerospace Studies Institute. https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/PLASSF/2023-09-11%20The%20PLA's%20New%20Base%20for%20SSA.pdf

[30] Allen, K. W. (2024, May 1). Planned obsolescence: The Strategic Support Force in memoriam (2015–2024). *China Brief, 24*(8), 11. https://jamestown.org/program/planned-obsolescence-the-strategic-support-force-in-memoriam-2015-2024/

[31] Costello, J. (2025, July 11). PLA military aerospace force: On the frontier of innovation and competition. *China Brief, 25*. https://jamestown.org/program/pla-military-aerospace-force-on-the-frontier-of-innovation-and-competition/

[32] Allen, K. W. (2024, May 1). Planned obsolescence: The Strategic Support Force in memoriam (2015–2024). *China Brief, 24*(8), 11. https://jamestown.org/program/planned-obsolescence-the-strategic-support-force-in-memoriam-2015-2024/

[33] McReynolds, J., & Wuthnow, J. (2024, April 26). A disturbance in the force: The reorganization of People's Liberation Army command and elimination of China's Strategic Support Force. *China Brief, 24*(8), 19. https://jamestown.org/program/a-disturbance-in-the-force-the-reorganization-of-peoples-liberation-army-command-and-elimination-of-chinas-strategic-support-force/

[34] Alkire, B. (2025, April 3). *The expansion of China's military space and counterspace capabilities and implications for space as a contested domain* (CT-A3951-1, p. 3). RAND Corporation. https://www.rand.org/pubs/testimonies/CTA3951-1.html

[35] Burke, K. (2020, March). *What is China doing at the lunar distant retrograde orbit?* China Aerospace Studies Institute. https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/CASI%20Articles/2022-04-11%20What%20is%20China%20Doing%20at%20the%20Lunar%20Distant%20Retrograde%20Orbit.pdf

[36] U.S. Department of State. (n.d.). What is MCF? [Fact sheet]. https://www.state.gov/wp-content/uploads/2020/05/What-is-MCF-One-Pager.pdf

[37] Schaefer, B., & Pletka, D. (2022, March 7). Countering China's growing influence at the International Telecommunication Union. The Heritage Foundation, American Enterprise Institute. https://www.heritage.org/sites/default/files/2022-03/BG3689.pdf; Pop, S. (2021, February 8). From lightbulbs to 5G, China battles West for control of vital technology standards. *The Wall Street Journal*. https://www.wsj.com/world/china/from-lightbulbs-to-5g-china-battles-west-for-control-of-vital-technology-standards-11612722698

[38] Burke, K. (2024, December). *China's different approach to space situational awareness*. China Aerospace Studies Institute. https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2024-12-02%20China's%20Different%20Approach%20to%20Space%20Situational%20Awareness.pdf?ver=C9GMGVpQFfXWJWBtKeaIEA%3d%3d

[39] United Nations Office for Outer Space Affairs. (n.d.). 47/68. Principles relevant to the use of nuclear power sources in outer space. https://www.unoosa.org/oosa/en/ourwork/spacelaw/principles/nps-principles.html; Reuters. (2024, March 5). Russia says it is considering putting a nuclear power plant on the Moon with China. https://www.reuters.com/technology/space/russia-china-are-considering-putting-nuclear-power-unit-moon-ria-2024-03-05/; Baptista, E. (2025, April 23). China, Russia may build nuclear plant on Moon to power lunar station, official says. *Reuters*. https://www.reuters.com/business/energy/china-led-lunar-base-include-nuclear-power-plant-moons-surface-space-official-2025-04-23/; Duffy, S. (2025, August 4). Directive on Fission Surface Power (FSP) development. NASA. https://www.nasa.gov/wp-content/uploads/2025/08/nasa-fsp-directive-aug42.pdf?emrc=4b2928; Fa, W., & Jin, Y.-Q. (2007, September). Quantitative estimation of helium-3 spatial distribution in the lunar regolith layer. *Icarus*. https://www.sciencedirect.com/science/article/abs/pii/S0019103507001285; Slyuta, E. N., & Turchinskaya, O. I. (2023, March 1). Helium-3 in the lunar soil. In *Advances in Geochemistry, Analytical Chemistry, and Planetary Sciences*. https://link.springer.com/chapter/10.1007/978-3-031-09883-3_21; Li, et al. (2018, August 20). Direct evidence of surface exposed water ice in the lunar polar regions. *Earth, Atmospheric and Planetary Sciences*. https://www.pnas.org/doi/abs/10.1073/pnas.1802345115; Wang, et al. (2023, December 29). Scientific objectives and

payload configuration of the Chang'E-7 mission. *National Science Review, 11*(2). https://academic.oup.com/nsr/article/11/2/nwad329/7503932?login=false; Wilcox, K. (2023, August 25). The Moon's rugged intriguing south pole. NASA. https://appel.nasa.gov/2023/08/25/the-moons-rugged-intriguing-south-pole/; Fristad, et al. (2004, March). Ideal landing sites near the lunar poles. 35th Lunar and Planetary Science Conference. https://ui.adsabs.harvard.edu/abs/2004LPI....35.1582F/abstract; Wilmer, 2nd Lt. A. (2021, December 23). Space domain awareness assessment of cislunar periodic orbits for Lagrange point surveillance. Thesis, Air Force Institute of Technology. https://apps.dtic.mil/sti/trecms/pdf/AD1166533.pdf; Defense Innovation Unit. (2024, March 20). DIU's Sinequone project prototypes the ability to access beyond GEO leveraging commercial technology. https://www.diu.mil/latest/dius-sinequone-project-prototypes-the-ability-to-access-beyond-geo

[40] Secure World Foundation. (2017). Summary of the 2017 AMOS Dialogue. https://web.archive.org/web/20210513223708/https://swfound.org/media/206083/2017-amos-dialogue-report.pdf

[41] Suess, J. (2021, November 26). Space and the future of war according to Russia. Royal United Services Institute (RUSI). https://www.rusi.org/explore-our-research/publications/commentary/space-and-future-war-according-russia

[42] Connell, M. (2023, November). The role of space in Russia's operations in Ukraine. CNA Corporation. https://www.cna.org/reports/2023/11/Role-of-Space-in-Russias-Operations-in-Ukraine.pdf

[43] NATO. (2019, March 30). General Gerasimov on the vectors of the development of military strategy. https://www.ndc.nato.int/fr/general-gerasimov-on-the-vectors-of-the-development-of-military-strategy/; Tretter, C. (2025, January 21). Exploring factors for U.S.-Russia crisis stability in space. RAND Corporation. https://www.rand.org/pubs/research_reports/RRA2313-3.html

[44] Defense Intelligence Agency. (2022, March). Challenges to security in space: Space reliance in an era of competition and expansion. https://www.dia.mil/Portals/110/Documents/News/Military_Power_Publications/Challenges_Security_Space_2022.pdf ; National Space Intelligence Center & National Air and Space Intelligence Center. (2023, December). Competing in space, 2nd edition. https://www.spaceforce.mil/portals/2/documents/2024/Competing_in_Space_-_2nd_Edition.pdf; Starling-Daniels, C., & Massa, M. (2024, February 15). Russian nuclear anti-satellite weapons would require a firm US response, not hysteria. *Atlantic Council*. https://www.atlanticcouncil.org/blogs/new-atlanticist/russian-nuclear-anti-satellite-weapons-would-require-a-firm-us-response-not-hysteria/

[45] Connell, M. (2023, November). The role of space in Russia's operations in Ukraine. CNA Corporation. https://www.cna.org/reports/2023/11/Role-of-Space-in-Russias-Operations-in-Ukraine.pdf; Hendrickx, B. (2022, December 19). The secret payloads of Russia's Glonass navigation satellites. *The Space Review*. https://www.thespacereview.com/article/4502/1

[46] TASS. (2024, May 21). Three satellites of Rassvet-2 mission successfully orbited – Bureau 1440. https://tass.com/science/1791293; Stepaneko, et al. (2025, June 22). Russian force generation and technological adaptations. ISW. https://understandingwar.org/wp-content/uploads/2025/06/Russian20Force20Generation20and20Adaptations20Update20June20112C20202520PDF.pdf

[47] Petersen, et al. (2025, July). Russian concepts of future warfare based on lessons from the Ukraine war. CNA. https://www.cna.org/reports/2025/08/Russian-Concepts-of-Future-Warfare-Based-on-Lessons-from-the-Ukraine-War.pdf

[48] Suess, J., & Crawford, J. (2024, April 12). Russia and China reaffirm their space partnership. RUSI. https://www.rusi.org/explore-our-research/publications/commentary/russia-and-china-reaffirm-their-space-partnership

[49] Connell, M. (2023, November). The role of space in Russia's operations in Ukraine. CNA Corporation. https://www.cna.org/reports/2023/11/Role-of-Space-in-Russias-Operations-in-Ukraine.pdf

[50] Koryakin, O. (2022, October 15). Killers of satellite communications: What is known about the Tirada and Rudolf complexes. RG. https://web.archive.org/web/20250619135017/https://rg.ru/2022/10/15/ubijcy-sputnikovoj-sviazi-chto-izvestno-o-kompleksah-tirada-i-rudolf.html

[51] Connell, M. (2023, November). *The role of space in Russia's operations in Ukraine*. CNA Corporation. https://www.cna.org/reports/2023/11/Role-of-Space-in-Russias-Operations-in-Ukraine.pdf; Samson, V. (2025, June). *Russian co-orbital anti-satellite testing*. Secure World Foundation. https://cdn.prod.website-files.com/66dcc6872f6ed23bce1db235/684ada4e76e85940ac2d3513_Fact%20Sheet%202025_Russian%20Co-orbital%20Anti-satellite%20Testing.pdf

[52] Schneider, M. B. (2025, February 5). *The implications of Russia's new nuclear doctrine*. National Institute for Public Policy. https://nipp.org/information_series/mark-b-schneider-the-implications-of-russias-new-nuclear-doctrine-no-615-february-5-2025/

[53] Berkowitz, M., & Williams, C. (2024, May 16). *Russia's space-based, nuclear-armed anti-satellite weapon: Implications and response options*. National Security Space Association. https://nssaspace.org/wp-content/uploads/2024/05/Russian-Nuclear-ASAT.pdf

[54] U.S. House Permanent Select Committee on Intelligence. (2024, May 1). *Biden administration official publicly acknowledges to Chairman Turner that Russia is developing an anti-satellite nuclear weapon*. https://intelligence.house.gov/news/documentsingle.aspx?DocumentID=1400; Hendrickx, B. (2024, May 13). *Russian research on space nukes and alternative counterspace weapons (Part 1)*. *The Space Review*. https://www.thespacereview.com/article/4793/1

[55] TASS. (2015, August 3). *Russia establishes aerospace forces as new armed service – Defense Minister*. https://web.archive.org/web/20160513232430/http://tass.ru/en/russia/812184; De Larrinaga, N. (2015, August 4). *Russia creates new aerospace force service branch*. IHS Jane's Defense Weekly. https://web.archive.org/web/20151227073639/http://www.janes.com/article/53416/russia-creates-new-aerospace-force-service-branch#; Myers, N. (2018). The Russian Aerospace Force. Armed Forces, Military Technology. https://wsb.edu.pl/files/pages/634/8-3.pdf

[56] Bela, V. (2025, May 14). *China and Russia sign nuclear reactor deal to fuel lunar research station*. *South China Morning Post*. https://www.scmp.com/news/china/science/article/3310315/china-and-russia-sign-nuclear-reactor-deal-fuel-lunar-research-station; TASS. (2021, May 22). *First mission of Russia's nuclear-powered space tug to take 50 months*. https://tass.com/science/1292721; Interfax. (2023, April 14). *Russia's new nuclear space tug to remove old geostationary satellites from orbit – Roscosmos Chief*. https://interfax.com/newsroom/top-stories/89647/#:~:text=April%2014%20%28Interfax%29%20-%20Russia%20is%20creating%20a,near-Earth%20space%20%22clean%22%2C%20Roscosmos%20chief%20Yury%20Borisov%20said

[57] Yamamoto, T. (2025, August). *The history and evolution of North Korea's space capabilities*. CSIS. https://csis-website-prod.s3.amazonaws.com/s3fs-public/2025-08/250819_Yamamoto_DPRK_Space.pdf?VersionId=hyjBSfWeplIGKDehnblBwNtuaUcVmXut

[58] Zak, A. (2024, February). *A limping giant: Russian military space in the first half of the 2020s*. CNA. https://www.cna.org/reports/2024/02/A-Limp-Giant-Russian-Military-Space-in-the-First-Half-of-the-2020s.pdf

[59] Raynus, et al. (2025, August 23). *Russian force generation and technological adaptations*. ISW. https://understandingwar.org/wp-content/uploads/2025/08/0825202520Tech20Adaptations20Update2028PDF29.pdf

[60] Zak, A. (2024, February). *A limping giant: Russian military space in the first half of the 2020s*. CNA. https://www.cna.org/reports/2024/02/A-Limp-Giant-Russian-Military-Space-in-the-First-Half-of-the-2020s.pdf

[61] Starchak, M. (2024, July 8). *Russia wants 2,600 satellites in orbit by 2036. Is this realistic?* DefenseNews. https://www.defensenews.com/space/2024/07/08/russia-wants-2600-satellites-in-orbit-by-2036-is-this-realistic/

[62] Hendrickx, B. (2020, August 10). *Upgrading Russia's fleet of optical reconnaissance satellites*. *The Space Review*. https://www.thespacereview.com/article/4006/1; TASS. (2022, November 10). *Over 130 Marafon Internet-of-Things satellites to be launched in 2025 – Manufacturer*. https://tass.com/science/1535103; TASS. (2023, November 9). *Russia to deploy Grifon CubeSat orbital monitoring system in 2024-2026 – Roscosmos*. https://tass.com/science/1704099

[63] Vidal, F., & Privalov, R. (2024, August). *Russia in outer space; A shrinking space power in the era of global change*. *Space Policy*. https://www.sciencedirect.com/science/article/pii/S0265964623000462#:~:text=When%20the%20Russian%20Federal

%20Space,of%20the%20national%20space%20sector; The Planetary Society. (n.d.). *The Roscosmos State Corporation for Space Activities*. https://www.planetary.org/the-roscosmos-state-corporation-for-space-activities

[64] Her Majesty's Government. (2021, September). *National space strategy* (p. 12). https://assets.publishing.service.gov.uk/media/6196205ce90e07043d677cca/national-space-strategy.pdf; European Commission & High Representative of the Union for Foreign Affairs and Security Policy. (2023, March 10). *European Union space strategy for security and defence: Joint communication JOIN (2023) 9 final* (p. 17). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=JOIN%3A2023%3A9%3AFIN; Pekkanen, S. M. (2024, August). *Japan in the new lunar space race*. *Journal of Space Policy Studies*. https://www.sciencedirect.com/science/article/pii/S0265964623000449

[65] Tuomala, E., O'Keefe, K., & Baker, J. (2021, December 16). *North Atlantic Treaty Organization and space: Recommendations for a new space policy* (p. 7). Lawrence Livermore National Laboratory. https://cgsr.llnl.gov/sites/cgsr/files/2024-08/NATO_Space_Capstone_Final_161221.pdf; NATO. (2019, June 27). *NATO's overarching space policy*. https://www.nato.int/cps/en/natohq/official_texts_190862.htm

[66] European Commission. (2025, June). *Vision for the European space economy*. Directorate-General for Defence Industry and Space. https://defence-industry-space.ec.europa.eu/document/download/f9f09eb2-6f58-412f-ae1d-64cd06160e2d_en?filename=Vision-European-Space-Economy-factsheet.pdf; Sacchi, M. (2024, May 2). *Space domain awareness and the EU's securitization of space* (p. 2). Info Flash, Finabel — The European Army Interoperability Centre. https://finabel.org/wp-content/uploads/2024/03/IF-PDFs-Matilde.pdf; Europe as a Space Power. (2023, October 1). ESPI Brief. European Space Policy Institute. https://www.espi.or.at/briefs/europe-as-a-space-power/

[67] European Commission. (2025, June). *Vision for the European space economy*. Directorate-General for Defence Industry and Space. https://defence-industry-space.ec.europa.eu/document/download/f9f09eb2-6f58-412f-ae1d-64cd06160e2d_en?filename=Vision-European-Space-Economy-factsheet.pdf

[68] Pekkanen, S. M. (2024, August). *Japan in the new lunar space race*. *Journal of Space Policy Studies, 69*, 1–??. https://www.sciencedirect.com/science/article/pii/S0265964623000449; Kutty, N. (2023, June 5). *See how Japan's space industry is gaining momentum*. World Economic Forum. https://www.weforum.org/stories/2023/06/see-how-japan-s-space-industry-is-gaining-momentum/

[69] Polyakov, M. (2025, April 23). *Japan's space program, part 3: Famous missions and a vision for the future*. MaxPolyakov.space. https://maxpolyakov.com/japan-s-space-program-part-3-famous-missions-and-a-vision-for-the-future/; CNBC. (n.d.). The moon-shot: Japan's era of new space [Advertorial]. CNBC. https://www.cnbc.com/advertorial/the-moon-shot-japans-era-of-new-space

[70] Hadley, G. (2024, August 19). *NATO signs first contract for its largest space program ever*. *Air & Space Forces Magazine*. https://www.airandspaceforces.com/nato-contract-satellite-imagery-space/

[71] European Defence Agency. (2023, November 14). *The 2023 EU capability development priorities* (p. 17). https://eda.europa.eu/docs/default-source/brochures/qu-03-23-421-en-n-web.pdf; European Commission. (2016, October 26). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Space Strategy for Europe, COM (2016) 705 final* (p. 8). https://cms.spacesecurityportal.org/uploads/CELEX_52016_DC_0705_EN_TXT_07bd287ba1.pdf

[72] Her Majesty's Government. (2021, September). *National space strategy* (p. 38). https://assets.publishing.service.gov.uk/media/6196205ce90e07043d677cca/national-space-strategy.pdf

[73] NATO. (2021, April 23). *Satellite communications*. https://www.nato.int/cps/en/natohq/topics_183281.htm

[74] NATO. (2025, July 30). *Space*. https://www.nato.int/cps/en/natohq/topics_175419.htm

[75] European Defence Agency. (2023, November 14). *The 2023 EU capability development priorities* (p. 17). https://eda.europa.eu/docs/default-source/brochures/qu-03-23-421-en-n-web.pdf

[76] European Commission. (2016, October 26). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Space Strategy for Europe, COM(2016) 705 final* (p. 8). https://cms.spacesecurityportal.org/uploads/CELEX_52016_DC_0705_EN_TXT_07bd287ba1.pdf

[77] European Commission. (2016, October 26). *Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Space Strategy for Europe, COM(2016) 705 final* (p. 8). https://cms.spacesecurityportal.org/uploads/CELEX_52016_DC_0705_EN_TXT_07bd287ba1.pdf

[78] Ikeda, T. (2021, May 17). *Japan to develop passenger spaceships in 2040s linking world's major cities in 2 hours*. Mainichi. https://mainichi.jp/english/articles/20210515/p2a/00m/0sc/013000c?mc_cid=67a7de0a4f&mc_eid=17e73a80fc; European Spaceflight. (2024, October 30). *JAXA confirms inaugural Callisto flight test has slipped to 2026*. Space Launch Schedule. https://www.spacelaunchschedule.com/space-news/jaxa-confirms-inaugural-callisto-flight-test-has-slipped-to-2026/

[79] Space Centre Australia. (2025). Atakani Space Centre. Space Centre Australia. https://spacecentreaustralia.com/atakani-space-centre/

[80] Associated Press. (2023, January 13). *EU inaugurates first mainland satellite launch port*. Courthouse News Service. https://www.courthousenews.com/eu-inaugurates-first-mainland-satellite-launch-port/; HM Government. (2021, September). *National Space Strategy*. London: Her Majesty's Government. https://assets.publishing.service.gov.uk/media/6196205ce90e07043d677cca/national-space-strategy.pdf

[81] NATO. (2025, February 13). *NATO Commercial Space Strategy* (last updated June 24, 2025). https://www.nato.int/cps/en/natohq/official_texts_236520.htm

[82] European Parliament and the Council. (2023, March 10). *European Union Space Strategy for Security and Defence, Joint Communication JOIN (2023) 9 final*. Brussels: European Union. https://cms.spacesecurityportal.org/uploads/EU_Space_Strategy_for_Security_and_Defence_fb31753be0.pdf

[83] Ministry of Defense, Japan. (2023, July). *Defense of Japan 2023, White Paper*. Tokyo: Ministry of Defense, Japan. https://cms.spacesecurityportal.org/uploads/JPN_DOJ_2023_EN_Full_65a60a269b.pdf

[84] Hannas, W. (2024, February 29). China's new AI "supermind" deepens challenge to U.S. Center for Security and Emerging Technology. https://cset.georgetown.edu/article/chinas-new-ai-supermind-deepens-challenge-to-u-s/

[85] European Space Agency. (2023, April). *Artificial Intelligence for Space: Use Cases and Commercial Applications*. https://commercialisation.esa.int/wp-content/uploads/2023/04/Artificial_Intelligence_for_Space_MiniReport_230420.pdf

[86] Stokes, J. (2024, February 1). Military artificial intelligence, the People's Liberation Army, and U.S.–China strategic competition (Testimony before the U.S.–China Economic and Security Review Commission). Center for a New American Security. https://s3.us-east-1.amazonaws.com/files.cnas.org/documents/Jacob_Stokes_Testimony.pdf

[87] Goodwill, J., et al. (2023, July). *Current AI Technology in Space*. NASA Goddard Space Flight Center. https://ntrs.nasa.gov/api/citations/20240001139/downloads/Current%20Technology%20in%20Space%20v4%20Briefing.pdf; Al Hommsi, A., et al. (2024, April). Artificial intelligence techniques for next-generation massive satellite networks. *IEEE Communications*. https://ieeexplore.ieee.org/abstract/document/10286330

[88] Kania, E. (2020, January). Minds at war: China's pursuit of military advantage through cognitive science and biotechnology. National Defense University Press. https://ndupress.ndu.edu/Portals/68/Documents/prism/prism_8-3/prism_8-3_Kania_82-101.pdf; Brazil, C., & Gabriel, M. (2025, March 28). Brain-computer interface systems, Qiyuan Lab, and the PRC's AI push. The Jamestown Foundation. https://jamestown.org/program/brain-computer-interface-systems-qiyuan-lab-and-the-prcs-ai-push/; Mullin, E. (2024, April 30). China has a controversial plan for brain-computer interfaces. *Wired*. https://www.wired.com/story/china-brain-computer-interfaces-neuralink-neucyber-neurotech/; Tong, Z. (2025, August 7). China plots pathway to tech supremacy through brain-computer interfaces. *South China Morning Post*. https://www.scmp.com/news/china/science/article/3321136/china-plots-pathway-tech-supremacy-through-brain-computer-interfaces

[89] People's Liberation Army Daily. (2024, April 20). Commentator of the People's Liberation Army Daily: Strive to build a strong modern information support force. https://web.archive.org/web/20250630084144/http://www.mod.gov.cn/gfbw/jmsd/16302172.html

[90] Congressional Research Service. (2021, November 23). *Defense primer: Directed-energy weapons*. https://apps.dtic.mil/sti/trecms/pdf/AD1153696.pdf

[91] Sodders, L., & Smith, B. (2024, September 23). Focused on the threat: Kinetic energy weapons (Part 4 of 6). *Space Systems Command*. https://www.ssc.spaceforce.mil/Newsroom/Article-Display/Article/3915076/focused-on-the-threat-kinetic-energy-weapons-part-4-of-6

[92] Chirac, O., & Withington, T. (2024, March 21). Russian electronic warfare: From history to modern battlefield. *Irregular Warfare Initiative*. https://irregularwarfare.org/articles/russian-electronic-warfare-from-history-to-modern-battlefield/; U.S. Army Europe and Africa. (2025, March). *How Russia fights: A compendium of Troika observations on Russia's special military operation*. https://api.army.mil/e2/c/downloads/2025/07/11/f2b1e75e/how-russia-fights-a-compendium-of-troika-observations-on-russia-s-special-military-operations.pdf; U.S. Department of the Army. (2024, February). *ATP 7-100.1 Russian Tactics 2024*. https://archive.org/details/atp-7-100.1-russian-tactics-2024/page/5-6/mode/2up?q=electromagnetic

[93] Cyber Peace Institute. (2022, June). Case study: Viasat. https://cyberconflicts.cyberpeaceinstitute.org/law-and-policy/cases/viasat; Hird, et al. (2022, October 15). Russian offensive campaign assessment. *Institute for the Study of War*. https://understandingwar.org/backgrounder/russian-offensive-campaign-assessment-october-15

[94] Khan, et al. (2024, February). A focused review on techniques for achieving cloaking effects with metamaterials. *Optik*. https://www.sciencedirect.com/science/article/abs/pii/S0030402623010732

[95] Shittu, et al. (2025). Radar cross section reduction metamaterials: A review of principles, design methods, and applications beyond. *IEEE*. https://ieeexplore.ieee.org/abstract/document/10829729

[96] Silberglitt, R. (2019, June 7). New and critical materials: Identifying potential dual-use areas. RAND Corporation. https://www.rand.org/content/dam/rand/pubs/testimonies/CT500/CT513/RAND_CT513.pdf#:~:text=Functional%20nanomaterials%20and%20metamaterials%20were%20identified%20as%20priority,into%20China%E2%80%99s%20metamaterials%20efforts%20and%20its%20application%20focus; Gaida, et al. (2023). ASPI's critical technology tracker. Australian Strategic Policy Institute. https://metamaterials.network/wp-content/uploads/2023/03/ASPIs-Critical-Technology-Tracker_0.pdf; Levesque, G. (2019, October 8). Military-civil fusion: Beijing's "guns and butter" strategy to become a technological superpower. *The Jamestown Foundation*. https://jamestown.org/program/military-civil-fusion-beijings-guns-and-butter-strategy-to-become-a-technological-superpower/; Chen, et al. (2022, April 30). Metamaterials: From fundamental physics to intelligent design. National Laboratory of Solid State Microstructures. https://web.archive.org/web/20240418165319/https://dsl.nju.edu.cn/litao/papers/Chen_J-InterMaterials(2022)-Review.pdf; Zhang, T., et al. (2021, January). The technology of lunar regolith environment construction on Earth. *Acta Astronautica*. https://www.sciencedirect.com/science/article/abs/pii/S0094576520305361; Schwandt, et al. (2012, December). The production of oxygen and metal from lunar regolith. *Planetary and Space Science*. https://www.sciencedirect.com/science/article/abs/pii/S0032063312001821; Shi, et al. (2022, October 6). Extracting oxygen from Chang'e-5 lunar regolith simulants. *ACS Sustainable Chemistry & Engineering*. https://pubs.acs.org/doi/abs/10.1021/acssuschemeng.2c03545; Jia, et al. (2023, March 29). Research of lunar water-ice and exploration for China's future lunar water-ice exploration. *Space: Science & Technology*. https://spj.science.org/doi/full/10.34133/space.0026; Chen, et al. (2020, March 3). Graphene and carbon nanotubes in space. *Cambridge University Press*. https://www.cambridge.org/core/journals/proceedings-of-the-international-astronomical-union/article/graphene-and-carbon-nanotubes-in-space/997E1F1A8BF8A52DA58E406EA9604502; Jia, et al. (2021, January). Dual-functional graphene/carbon nanotubes thick film: Bidirectional thermal dissipation and electromagnetic shielding. *Carbon*. https://www.sciencedirect.com/science/article/abs/pii/S0008622320308654; Li, et al. (2021, June 11). Research on experimental method of carbon nanotubes space environment effect. *6th International Symposium on Vehicle Emission Supervision and Environment Protection*. https://www.e3s-conferences.org/articles/e3sconf/abs/2021/44/e3sconf_vesep2020_01065/e3sconf_vesep2020_01065.html; Deng, et al. (2022, August 1). Morphology engineering processed nanofibrous membranes with secondary structure for high-performance air filtration. *Separation and Purification Technology*. https://www.sciencedirect.com/science/article/abs/pii/S1383586622006505; Pernigoni, et al. (2021, April 21). Self-healing materials for space applications: Overview of present development and major limitations. *CEAS Space Journal*. https://link.springer.com/article/10.1007/s12567-021-00365-5; Zhu, et al. (2019, August 14). Synthesis of UV-responsive self-healing microcapsules and their application in aerospace coatings. *ACS Applied Materials & Interfaces*.

https://pubs.acs.org/doi/abs/10.1021/acsami.9b10737; Xu, et al. (2019, October 23). Highly homogenous polysiloxane flexible coating for low Earth orbital spacecraft with ultraefficient atomic oxygen resistance and self-healing behavior. *ACS Applied Polymer Materials*. https://pubs.acs.org/doi/abs/10.1021/acsapm.9b00671; Lan, et al. (2021, April 23). Smart solar array consisting of shape-memory releasing mechanisms and deployable hinges. *AIAA Aerospace Research Central*. https://arc.aiaa.org/doi/abs/10.2514/1.J059281; Lan, et al. (2023, January 25). Smart space deployable truss based on space-memory releasing mechanisms and actuation laminates. *AIAA Aerospace Research Central*. https://arc.aiaa.org/doi/abs/10.2514/1.A35649; Li, et al. (2016, July 11). Preliminary design and analysis of a cubic deployable support structure based on shape memory polymer composite. *International Journal of Smart and Nano Materials*. https://www.tandfonline.com/doi/full/10.1080/19475411.2016.1212948; Ferrone, et al. (2022, October 28). A review of magnetic shielding technology for space radiation. *MDPI*. https://www.mdpi.com/2673-592X/3/1/5

[97] Point Bello. (2021, February). Kuang-Chi Group: A PRC technology acquisition platform. https://www.pointebello.com/insights/case-studies-in-prc-foreign-tech-transfers-3

[98] Mad Scientist Blog, U.S. Army TRADOC. (2024, November 21). 515. Implications of China's LOX reusable rockets. https://madsciblog.tradoc.army.mil/515-implications-of-chinas-lox-reusable-rockets/; Xinhua. (2024, May 29). China's commercial rocket launches satellites from sea. https://web.archive.org/web/20250214125917/https://english.news.cn/20240529/f00d7d839986460f93bc589098a71928/c.html; Jones, A. (2024, November 1). Chinese launch startup Cosmoleap secures funding for rocket featuring chopstick recovery system. *Space News*. https://spacenews.com/chinese-launch-startup-cosmoleap-secures-funding-for-rocket-featuring-chopstick-recovery-system/; Jones, A. (2025, January 27). Chinese launch startup secures early funding for fully reusable rocket plan. *Space News*. https://spacenews.com/chinese-launch-startup-secures-early-funding-for-fully-reusable-rocket-plan/; Global Times (China). (2025, May 29). China's private space company Sepoch recovers nation's first liquid methane-fueled stainless steel reusable rocket. https://web.archive.org/web/20250803022052/https://www.globaltimes.cn/page/202505/1335084.shtml

[99] Weichert, B. J. (2025, July 14). Russia is building a reusable methane-powered rocket for space missions. *The National Interest*. https://nationalinterest.org/blog/buzz/russia-building-reusable-methane-powered-rocket-space-bw; Xin, L. (2024). Orienspace launches world's most powerful all-solid rocket. *The Innovation Energy*. https://www.the-innovation.org/article/doi/10.59717/j.xinn-energy.2024.100012

[100] Li, A. (2025, August 8). China launches first SpaceX-style drone ship to recover reusable rockets. *South China Morning Post*. https://www.scmp.com/economy/china-economy/article/3321210/china-launches-new-spacex-style-drone-ship-recover-reusable-rockets

[101] Chen, D. (2024, June). China's space capability and what this means for the West. *China Aerospace Studies Institute*. https://www.airuniversity.af.edu/Portals/10/CASI/documents/Research/Space/2024-06-03-2%20Chinas%20Space%20Capability%20and%20what%20it%20means%20for%20the%20West.pdf

[102] Wu, et al. (2024, February 23). Design and R&D of megawatt lithium-cooled space nuclear reactor. *Scientia Sinica Technologica*. https://www.sciengine.com/SST/doi/10.1360/SST-2023-0202; TASS. (2021, May 22). First mission of Russia's nuclear-powered space tug to take 50 months. https://tass.com/science/1292721; Luzin, P. (2021, June 9). Russia's approach to nuclear power in outer space. *The Jamestown Foundation*. https://jamestown.org/program/russias-approach-to-nuclear-power-in-outer-space/

[103] Williams, C. (2024, April 2). Dynamic space operations: An overview and assessment. *National Security Space Association, Moorman Center for Space Studies*. https://nssaspace.org/wp-content/uploads/2024/04/Dynamic-Space-Operations-Paper.pdf; USSPACECOM. (2023, April 21). USSPACECOM outlines requirements for sustained maneuver, "Dynamic Space Operations." https://www.spacecom.mil/Newsroom/News/Article-Display/Article/3370546/usspacecom-outlines-requirements-for-sustained-maneuver-dynamic-space-operations/; Semenkin, A. V. (2004, June 25). High-power Hall devices: Status and current challenges. *Defense Technical Information Center*. https://apps.dtic.mil/sti/pdfs/ADA446484.pdf; Global Times (China). (2020, January 19). China makes major breakthrough in space propulsion technology. https://web.archive.org/web/20250614093403/https://www.globaltimes.cn/content/1177263.shtml

[104] International Telecommunication Union. (2025, January). *HAPS – High-altitude platform systems*. ITU. https://www.itu.int/en/mediacentre/backgrounders/Pages/High-altitude-platform-systems.aspx; The "near space" designation for HAPs is slightly deceiving. HAPs operate from 60,000 feet (18.288 km / 11.36 mi) to 120,000 feet (36.576 km / 22.72 mi) while the Karman Line, which is generally recognized as the boundary between the terrestrial domain and space is 100 km (62 miles) above Earth's surface. Therefore, the Earth's surface is closer to "near space" than space is; ITU Radio Regulations define the HAP operating area as between 20 and 50 km; Grest, H. (2022, July). Platform systems: Alternative, supplement, or competition to satellites? *Joint Airpower Competence Centre Journal, Ed. 34*. https://www.japcc.org/articles/high-altitude-platform-systems/

[105] International Telecommunication Union. (2025, January). HAPS – High altitude platform systems. ITU. https://www.itu.int/en/mediacentre/backgrounders/Pages/High-altitude-platform-systems.aspx; Grest, H. (2022, July). Platform systems: Alternative, supplement, or competition to satellites? *Joint Airpower Competence Centre Journal, Ed. 34*. https://www.japcc.org/articles/high-altitude-platform-systems/; Slebir, M. (2025). Weaponizing the edge of space? Progress and prospects of military high-altitude platforms. *Revista Científica General José María Córdova, 23*(51), 565–588. https://doi.org/10.21830/19006586.1483

[106] Slebir, M. (2025). Weaponizing the edge of space? Progress and prospects of military high-altitude platforms. *Revista Científica General José María Córdova, 23*(51), 565–588. https://doi.org/10.21830/19006586.1483

[107] Singer, P. W., & Ryan, M. (2023, March 7). Weaponized balloons challenge US air superiority, quite littorally. Defense News. https://www.defensenews.com/opinion/commentary/2023/03/07/weaponized-balloons-challenge-us-air-superiority-quite-littorally/

[108] Rogers, D. (2025, January 10). China plans to build 'Three Gorges in space.' *Global Construction Review.* https://www.globalconstructionreview.com/china-plans-to-build-three-gorges-in-space/

[109] Bellette Lee, Y.-C. (2025, June 12). *China's state ideology and the Three Gorges Dam: The political theodicy of development* (1st ed.). Routledge. https://doi.org/10.4324/9781003531494

[110] Jessen, J. (2025, January 15). China's plans to produce renewable energy in space. *Sustainability Magazine.* https://sustainabilitymag.com/articles/chinas-1km-solar-array-the-manhattan-project-of-energy

[111] NewSpace. (n.d.). NewSpace: Israel's space community. https://www.newspace.im/; Kulu, E. (2024, October 14–18). Satellite constellations – 2024 survey, trends and economic sustainability. 7th International Astronautical Congress. https://www.newspace.im/assets/Constellations-2024_ErikKulu_IAC2024.pdf

[112] Howard, K., & Von Ah, A. (2022, September). Technology assessment: Large constellations of satellites, mitigating environmental and other effects. U.S. Government Accountability Office. https://www.gao.gov/assets/730/723162.pdf

[113] Dallas, et al. (2020, May 10). The environmental impact of emissions from space launches: A comprehensive review. *Journal of Cleaner Production.* https://www.sciencedirect.com/science/article/abs/pii/S0959652620302560

[114] National Aeronautics and Space Administration. (n.d.). *Orbital debris program office: Frequently asked questions.* NASA. https://orbitaldebris.jsc.nasa.gov/faq/

[115] Mann, A. (2022, February 22). The moon could soon have a space junk problem. *Science.* https://www.science.org/content/article/moon-could-soon-have-space-junk-problem

[116] Bela, V. (2025, May 14). China and Russia sign nuclear reactor deal to fuel lunar research station. *South China Morning Post.* https://www.scmp.com/news/china/science/article/3310315/china-and-russia-sign-nuclear-reactor-deal-fuel-lunar-research-station; Kuiken, M. (2025, April 3). Hearing on "The Rocket's Red Glare: China's ambitions to dominate space." U.S.-China Economic and Security Review Commission. https://www.uscc.gov/sites/default/files/2025-04/April_3_2025_Hearing_Transcript_0.pdf

[117] Cook, P. J. (1999, April 7). Applying Sun Tzu's ancient 'Art of War' to the future. Department of the Army, USAWC Strategy Research Paper. https://apps.dtic.mil/sti/tr/pdf/ADA363888.pdf

[118] United Nations. (2002). *United Nations treaties and principles on outer space.* https://www.unoosa.org/pdf/publications/STSPACE11E.pdf

[119] Cheng, D. (2021, March). China's three "information warfares." *Proceedings, U.S. Naval Institute.* https://www.usni.org/magazines/proceedings/2021/march/chinas-three-information-warfares

[120] Cheng, D. (2023, August 2). China and space: The next frontier of lawfare. United States Institute of Peace. https://www.usip.org/publications/2023/08/china-and-space-next-frontier-lawfare; Dunlap, C. (2023, July 30). Dean Cheng on "China and space: The next frontier of lawfare." *Lawfire.* https://www.lawfireblog.com

[121] Valery Gerasimov's new generation warfare model was introduced in 2013 and highlighted a non-military over military hybrid warfare, a part of which was lawfare; It can be argued that Russian hybrid warfare follows the Gerasimov Doctrine; however, this is disputed; Giles, A. (2020, September). Valery Gerasimov's doctrine. *ResearchGate.* https://www.researchgate.net/publication/346195526_'Valery_Gerasimov's_Doctrine; Voyger, M. (2018, December 5). Russian lawfare – Russia's weaponization of international and domestic law. Baltic Defence College. https://www.marshallcenter.org/sites/default/files/files/2020-09/pC_V10N1_en_Voyger.pdf

[122] Kim, et al. (2025, April 15). Integrating commercial space services into DoD architecture. *Rand Corporation.* https://www.rand.org/pubs/research_briefs/RBA2562-1.html

[123] Kunstadter, C. T. W. (2021, March 4). Space insurance and collision risk. AXA XL, European Space Agency presentation. https://conference.sdo.esoc.esa.int/proceedings/mmw01/paper/17/mmw01-paper17.pdf

[124] Tingley, B. (2023, December 4). Space Force general warns of adversaries surpassing US abilities in orbit: 'We are at an inflection point.' *Space.com.* https://www.space.com/space-exploration/space-force-general-warns-of-adversaries-surpassing-us-abilities-in-orbit-we-are-at-an-inflection-point

[125] Brennan, M. (2023, April 10). Manifest Podcast: First broadcast interview as CSO. https://www.cnbc.com/2023/04/20/space-force-chief-on-new-era-of-threats-beyond-earth.html

[126] Space Security Portal. (2024, March). India. United Nations Institute for Disarmament Research (UNIDIR). https://spacesecurityportal.org/states/india

[127] Goswami, N. (2024, August 23). Measuring the depth of India's space program. *The Diplomat.* https://thediplomat.com/2024/08/measuring-the-depth-of-indias-space-program/

[128] Space Security Portal. (2024, March). India. United Nations Institute for Disarmament Research (UNIDIR). https://spacesecurityportal.org/states/india

[129] Goswami, N. (2024, August 23). Measuring the depth of India's space program. *The Diplomat.* https://thediplomat.com/2024/08/measuring-the-depth-of-indias-space-program/; Indian Space Research Organisation. (2022, November 23). *Gaganyaan.* Department of Space. https://www.isro.gov.in/Gaganyaan.html; Go Digit General Insurance Limited. (2024). ISRO upcoming missions list. https://www.godigit.com/guides/space-exploration/isro-upcoming-missions

[130] Goswami, N. (2024, August 23). Measuring the depth of India's space program. *The Diplomat.* https://thediplomat.com/2024/08/measuring-the-depth-of-indias-space-program/

[131] Negi, M., & Sharma, S. (2025, June 30). India fast-tracks launch of 52 military satellites after Operation Sindoor. *India Today.* https://www.indiatoday.in/india/story/india-fast-tracks-launch-of-52-military-satellites-after-operation-sindoor-2748170-2025-06-30

[132] Space Security Portal. (2023, September). Brazil. United Nations Institute for Disarmament Research (UNIDIR). https://spacesecurityportal.org/states/brazil

[133] Labolita, T. T., & Simoes, A. (2020, September 28). Aerospace exploration in Brazil: The Alcântara Space Center. *International Bar Association.* https://www.ibanet.org/article/6c35f58b-8f94-488a-a5ce-464e5dfff954; Universidad de Navarra. (n.d.). Brazil relaunches its space industry by opening the Alcântara base to the US. https://www.unav.edu/web/global-affairs/detalle/-/blogs/brazil-relaunches-its-space-industry-by-opening-the-alcantara-base-to-the-us

[134] FANDOM. (n.d.). Aerospace operations command. https://military-history.fandom.com/wiki/Aerospace_Operations_Command

[135] GMSpazio. (2024, February 7). GMSPAZIO enhances the defense of space assets in Brazil. https://findyourobject.gmspazio.com/en/en/art/11/5278/gmspazio-enhances-the-defense-of-space-assets-in-brazil.aspx

[136] International Trade Administration. (2025, August 21). Brazil country commercial guide: Space technologies and systems. https://www.trade.gov/country-commercial-guides/brazil-space-technologies-and-systems