

America 250 Commemorative Edition



SPACE FORCE ASSOCIATION

SPACEPOWER MAGAZINE

FEATURED STORIES

What 2076 Requires of 2026

**Very Low Earth Orbit:
A New Domain of Space
Littoral Warfare?**

**Vectors of Tomorrow:
Space Technology Trends
That Will Shape the Space
Domain by 2076**

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LETTER *from the* EDITOR

A Question of Vast Importance:

What Does America's Space Future Look Like at 300?

Every edition of Spacepower Magazine begins with a question. This one started with a date.

As we crept closer to America's 250th anniversary, the editorial team began asking what a truly commemorative publication would look like. Something more than a retrospective. Something that honored this milestone by looking forward. We settled on a deceptively simple premise: if the national security space community were to assess itself at America's 300th birthday, what would it see? What would we hope to see? And what do we need to do, starting right now, to get there?

The response from the community exceeded every expectation. Writers from across the space enterprise -- Guardians and civilians, operators and strategists, technologists and educators -- answered the call with vision, rigor, and candor. What emerged is a diverse collection of perspectives that reflects the genuine complexity of charting a course fifty years into the future.

Over the past five decades, humanity has made transformative progress in science, technology, medicine, and daily life, driven by rapid innovation, global collaboration, and the integration of new tools into nearly every aspect of society. It is with certainty that America will continue to lead this trajectory while remembering and learning from the brilliant minds that have delivered us to this epic anniversary.

It is our hope that this special edition will spark more bold ideas in the spirit of forging ahead, undaunted with the vastness of the final frontier. As Aristotle said, "we are what we repeatedly do. Excellence, then, is not an act, but a habit."

With great optimism,

A handwritten signature in dark ink, appearing to read "Emily", followed by a horizontal flourish.

Emily Honhart
Editor, Spacepower Magazine
Space Force Association

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Cover Photo: A composite image of N49, the brightest supernova remnant in optical light in the Large Magellanic Cloud; the image combines data from the Chandra X-ray Telescope blue and NASA Spitzer Space Telescope red. (NASA)



MESSAGE from the CEO

Looking to the Stars at 300:

Spacepower and the Promise of America's Next Century

Two hundred and fifty years ago, a group of visionaries dared to imagine a nation built on the revolutionary idea that liberty and human potential are boundless. They could not have conceived of the world we inhabit today, one where Americans routinely operate in the vast expanse of space, where satellites underpin our economy, our security, and our daily lives, and where the cosmos itself has become a contested domain of national importance. Yet the spirit that animated those founders -- bold, forward-looking, unwilling to accept limits -- is precisely the spirit that drives the national security space community today.

This special edition of Spacepower Magazine asks us to cast our own gaze forward fifty years, to America's 300th anniversary. It is a fitting exercise. The decisions being made today about how we organize, train, equip, and partner in space will echo across decades. The United States Space Force, now a young but formidable institution, will by 2076 be a seasoned keeper of American interests in an environment that our predecessors could scarcely have imagined. What we build now matters enormously.

The Space Force Association is proud to convene this conversation. Our mission has always been to advance the dialogue around spacepower, and to ensure that the men and women who defend American interests beyond the atmosphere are supported, understood, and empowered. In that tradition, we have curated expert voices from academia, defense and industry to contribute their vision for what America's space future can — and must — look like.

The essays and analyses in these pages reflect the depth of talent and seriousness of purpose within our community. They grapple with hard questions: How do we sustain leadership in an increasingly contested domain? What role will commercial innovation and allied partnerships play in shaping tomorrow's space warfighter? How do we build and sustain a workforce equal to the challenges ahead? There are no easy answers, but there is no shortage of wisdom, and you will find much of it here.

America's 250th anniversary is a moment to celebrate how far we have come and to recommit ourselves to the journey ahead. The space domain will be central to the nation's security and prosperity at 300, just as it is today. It falls to this generation to ensure that the United States arrives at that milestone with its leadership intact, its alliances strong, and its Guardians ready.

On behalf of the Space Force Association, I am grateful to every contributor and reader who makes Spacepower Magazine possible. The conversation we are having matters. The future we are shaping together will matter even more.

Semper Supra!

A handwritten signature in black ink, appearing to read 'Damon Feltman'.

Damon Feltman
Chief Executive Officer
Space Force Association

What 2076 Requires of 2026

Artificial Intelligence, Allied Partnerships, and the Technology Bets That Will Define American Spacepower at the Nation's Tricentennial

Matt Domo

July 4, 2076. The ceremonies on the National Mall will be unlike anything the Republic has staged before. A nation 300 years old will look up at a sky it owns, seeing it differently than at its 250th birthday. The constellations of satellites overhead will not be curiosities. They will be infrastructure as essential as interstate highways were in 1976, as invisible and as taken for granted as electricity.

That future is not inevitable. It is a choice. And that choice is being made right now, in budget decisions, in acquisition reform debates, in partnership agreements signed or not, and in technology investments made or deferred. What the Space Force and the broader national security space community does between now and the end of this decade will determine whether 2076 looks like dominance or managed decline.

As Chairman of the Space Force Association, I want to be direct about what I believe this means. Three forces will define spacepower at America's tricentennial: artificial intelligence, allied integration, and the willingness to make long-term technology bets that look uncomfortable today. These three are not a wish list. They are the variables most within the Space Force's control and most consequential to whether that future is built or borrowed. Progress is evident on all three fronts, but it is not moving at the pace the competitive environment demands

AI Is Not a Tool. It Is the Operating System.

Every branch of the U.S. military is exploring artificial intelligence. The Space Force has a unique opportunity and obligation to lead that work rather than follow it. The reason is simple: the operating environment of space is a machine environment. Humans cannot be

physically present at the altitude and scale at which orbital competition occurs. Sensors, satellites, and interceptors need to make decisions faster than any human chain of command can authorize. AI is not a supplement to spacepower: It is the only way to achieve spacepower at true scale.

The Space Force's own Spacepower doctrine designates space as a warfighting domain that demands speed of action. Yet the authorization frameworks governing autonomous systems were largely inherited from a domain where humans could be in the loop. That gap between doctrine and the authority structure is where adversaries will find an advantage if we do not close it. China's deliberate investment in AI-enabled space domain awareness and maneuver has been documented in successive Department of War (formerly Department of Defense) annual reports. The question is not whether the threat is real. The question is whether our approval chains will be able to keep pace with the tempo at which those systems operate.

This is not a comfortable conversation. It should not be. But discomfort is not a reason to avoid it. The nations that first normalize AI-enabled autonomous space operations will set the terms of competition for the next 50 years. The United States should be setting those terms, not merely responding to them.

Allies Are a Force Multiplier We Are Underusing

The U.S. Space Force cannot own the space domain alone. It was never designed to. At its best, the architecture of American spacepower is a network of trusted partners that contribute sensors, ground stations, launch infrastructure, and shared intelligence across a coalition no adversary can match. At its worst, it is a set

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A depiction of fireworks over America. (Photo courtesy Matt Domo)

of bilateral agreements that activate more slowly than the threats they are meant to address.

The Combined Space Operations Center (CSpOC) at Vandenberg Space Force Base unites the United States and allied nations to coordinate space operations in real time. That is a genuine foundation. The limitation is that interoperability still fails at the data layer. Differing classification frameworks, incompatible sensor data formats, and acquisition rules that effectively penalize allied contributions slow the coalition at precisely the moments when speed matters most. The space domain needs a multilateral data standards framework built for the pace of operations, not the pace of treaty negotiation

By 2076, the nations that built genuine space coalitions in the 2020s and 2030s will be the ones with resilient architectures. Resilience in space, as in every other domain, stems from distributed systems that no single point of failure can disable. Allied integration is not a diplomatic nicety. It is a strategic requirement for survivability.

The Technology Bets We Have to Make Now

Fifty years is a long time. No one in 1976 predicted the smartphone. No one in 2026 can fully map what 2076 will require. But there are bets we can make with high confidence because the physics and the strategic logic both point in the same direction.

Nuclear power for deep space operations is one of them. Chemical propulsion has a ceiling. If the Space Force envisions operations beyond geosynchronous orbit as a serious mission set at the tricentennial, investment in nuclear thermal and nuclear electric propulsion has to begin now. Development timelines are measured in decades, not quarters. NASA and the Defense Advanced Research Projects Agency (DARPA) have begun preliminary work on nuclear thermal propulsion. The question is whether the Space Force treats that as a program to watch or a capability to co-develop and field.

Quantum communications and quantum sensing are another. The ability to communicate in ways that are physically impossible to intercept and to sense in ways that no current technology can detect will reshape both the offensive and defensive calculus of the space domain. The nations that possess those capabilities in 2076 will hold a decisive asymmetric advantage. The research investment required starts today.

Disaggregated, proliferated low-Earth orbit architecture

is a third bet. The era of exquisite, expensive, singular satellites is ending. The future is constellations of smaller, cheaper, more numerous systems that survive not through hardening alone but through mass. That architectural shift is already underway in the commercial sector. The Space Force must shape it, not simply procure from it afterward.

What This Generation Owes the Next

Every generation of American defense leadership inherits the decisions of its predecessor. The Guardians who will be responsible for American spacepower in 2076 are in high school today. They will spend their careers operating within the architecture, alliances, legal frameworks, and technology base that this generation builds or fails to build.

None of the three challenges this article describes can be solved by the Space Force alone. Autonomous AI systems require commercial technology companies willing to build to meet national security requirements and research universities willing to tackle the hardest problems in machine decision-making. Allied data standards require industry partners operating across borders and academic institutions that understand both the technical and policy dimensions of interoperability. Long-cycle technology programs require a commercial sector that can sustain investment over decades and a research community that keeps foundational science alive between budget cycles.

This is where the Space Force Association's mission is not abstract. Industry does not naturally speak the Space Force's language. Academia does not naturally operate on acquisition timelines. The Space Force does not naturally look to universities for operational doctrine. SFA exists to be the place where those gaps close, where a defense contractor, a research physicist, and a Guardian colonel are in the same room, working the same problem. That convening function is not a program. It is the ingredient that makes programs possible.

SFA has identified three specific areas where convening work is most urgent this decade. First, autonomy threshold reform: convening legal scholars, AI researchers, and Space Force operators to build the frameworks that govern when and how autonomous systems can act. Second, a multilateral space data standards initiative: aligning industry, allied governments, and the academic community on interoperability at the architectural level. Third, long-cycle technology investment protection: building legislative and budgetary mechanisms, in

partnership with commercial and academic partners, that allow 20- and 30-year research programs to withstand near-term budget pressure.

These are not aspirations. They are the decisions whose absence will be most evident to the generation that inherits what we build.

If we get this right, the Guardians of 2076 will not be celebrated the way astronauts once were. What they do will be so woven into the life of the Republic that most Americans will never know how to say thank you. That is what success looks like in a domain that works. That future is a choice. Let us choose deliberately.

Matt Domo is Chairman of the Space Force Association, CEO of FifthVantage, founder of the AWS Database Division, and author of the #1 Bestseller, Everybody Wins (Entrepreneur Books). He advises organizations at the intersection of artificial intelligence, enterprise strategy, and national security.



Guardians of the 4th Space Operations Command salute in formation during a change of command ceremony at Schriever Space Force Base, Colorado, July 11, 2025. (U.S. Space Force Photo by Tiana Williams)

Beyond Surveillance: Maintaining Space Superiority Over the Next 50 Years Demands Persistent Orbital Intelligence

Tony Frazier

On a cold March afternoon in 1926, Robert H. Goddard launched the world's first liquid-fueled rocket.

He recorded the moment with little fanfare: "The first flight with a rocket using liquid propellants was made yesterday at Aunt Effie's farm in Auburn."

A century later, as we celebrate our nation's 250th birthday, that technology has helped reshape the world.

Nearly 25,000 satellites have been launched into space using the principles Goddard proved. Over half have been launched since 2022, driven by the rapid expansion of satellite constellations. Tens of thousands more are planned in the coming years. This profound growth highlights how space has become foundational to modern life and increasingly critical to national security. A dependency likely to deepen in the decades ahead.

Recent conflicts, such as in Ukraine and Iran, demonstrate that warfare is no longer enabled by space, it extends to it.

"[Space] is critical to a military's ability to see, understand, decide, and act," Admiral Samuel Paparo, Commander, U.S. Pacific Command, explained during an April 2026 U.S. Armed Services Committee hearing. It is "the very first battle of any conflict — and it will be in the 21st century."

General Stephen Whiting, Commander of the U.S. Space Command, remarked earlier this year that "we derive enormous benefits from space for our national defense." Unfortunately, he continued, "...we face determined opponents who, if we get into a conflict, are going to try and take [the space domain] away from us."

Sustaining space superiority over the next 50 years depends on the U.S.'s ability to maintain freedom of action in space while denying adversaries the ability to exploit the domain for hostile purposes. This requires more than passive surveillance. It demands the ability to sense, understand, and act faster than adversaries in a domain defined by speed, scale, and ambiguity.

Persistent orbital intelligence, powered by a hybrid sensor architecture that enables sustained threat custody, is critical to making that possible.

The Shift from Awareness to Understanding

For decades, U.S. space domain awareness (SDA) capabilities focused primarily on cataloging objects to ensure safety of flight. That model is no longer sufficient.

As the Space Force's "Objective Force 2040" makes clear, SDA must evolve from a "safety-of-flight" function into "warfighting battlespace awareness defined by speed, scale, and actionable information."

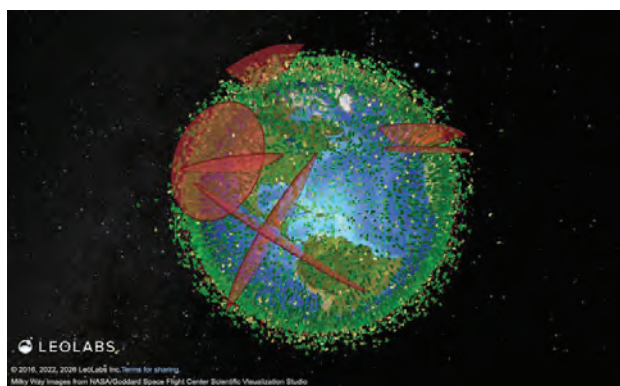
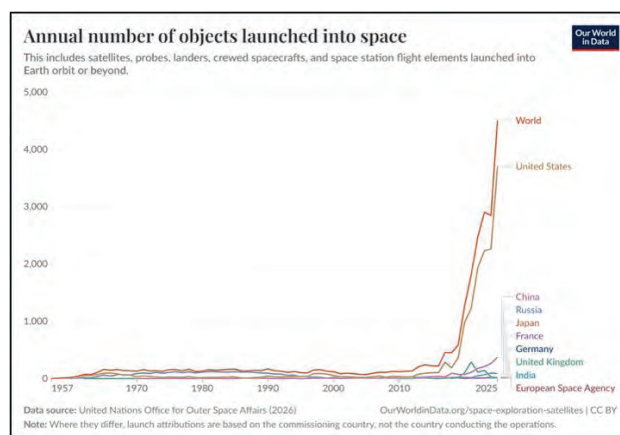


Figure 2: More than 26,000 objects are in low Earth orbit (as of May 2026), including satellites, debris, and rocket bodies, as illustrated here using LeoLabs' public LEO visualization tool. (Photo courtesy LeoLabs)

This is in direct response to the evolution of the space environment, which is now defined not only by exponential growth, but also by increasingly complex and anomalous behaviors.

“We have the world’s best space domain awareness capabilities,” explained Gen. Whiting during a spring 2026 Center for Strategic and International Studies (CSIS) event, “But is it sufficient? Because we have to be able to maintain constant custody of these threats.”

Adversaries are rapidly developing and deploying counterspace threats, such as conducting rendezvous and proximity operations, obscuring satellite deployments, and disrupting decision advantage via jamming, cyber-attacks, dazzling, and more.

The result is a domain where ambiguity is increasingly strategic, not incidental.

There have been several high-profile instances of threatening behavior by U.S. adversaries. This includes a Russian military satellite, Cosmos 2558, launching into a similar orbit as a U.S. military satellite, USA 338, in May 2022. For nearly three years, it reportedly “stalked” the U.S. asset before releasing a maneuverable sub-satellite in June 2025. “It’s evident,” Gen. Whiting said. “Russia was deploying a space weapon...putting it into an orbit where they can reach critical U.S. national security satellites.”

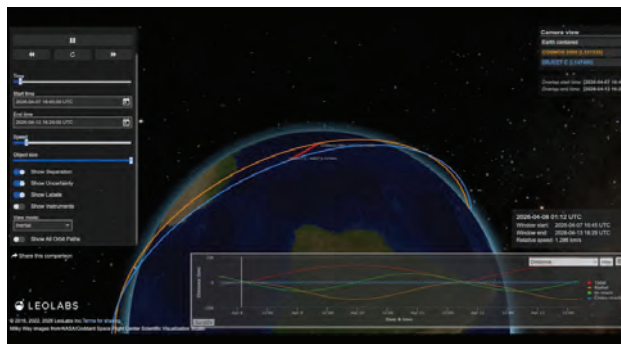


Figure 3: Russian satellite, Cosmos 2558, shown here using LeoLabs state comparison tool, reportedly “stalked” USA 338 for nearly three years before releasing a sub-satellite, Object C. (Photo courtesy LeoLabs)

China has also advanced its counterspace capabilities while rapidly growing its presence on orbit. According to the Space Force, since the end of 2015, the number of Chinese satellites in space has increased by 667%. This includes more than 510 intelligence, surveillance, and reconnaissance (ISR)-capable satellites that can observe, target, or otherwise enable harm to U.S. and allied defense forces.

In this environment, it is no longer sufficient to simply track objects. Sustained custody is required. While knowing where an object is remains important, understanding what it is, how it is behaving over time, and why it matters is even more critical.

Persistent orbital intelligence transforms raw observational data into continuous insight. By immediately detecting anomalies and characterizing behavior, it allows operators to assess intent within operational timelines.

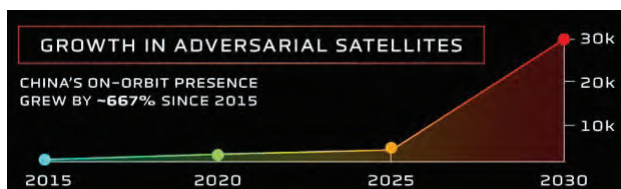


Figure 4: Upwards of 30,000 adversarial satellites are estimated by 2030. China grew its on-orbit presence by ~667% since 2015, according to the U.S. Space Force. Data from LeoLabs, ITU Filings, and Open Source Information.

It is the difference between surveillance and understanding, between reacting to events and shaping them.

Persistent Orbital Intelligence as a Warfighting Capability

Persistent orbital intelligence aligns with a central principle of the Space Forces’s modern space operations: data as a warfighting advantage.

It integrates three essential elements:

- Continuous, multi-layered sensing across space, terrestrial, and maritime domains
- Advanced analytics, leveraging artificial intelligence to identify patterns, anomalies, and indicators of adversary intent
- Operational integration, delivering intelligence in real time to enable action

Together, these elements compress the Observe–Orient–Decide–Act (OODA) loop, transforming data into decisions

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at the speed required for modern conflict. This enables operators not only to detect threats, but to understand them and take action.

In doing so, persistent orbital intelligence becomes foundational to competitive endurance. The ability to maintain advantage in a domain characterized by persistent competition, disruption, and uncertainty.

Hybrid Architectures and Commercial Advantage

Achieving competitive endurance and sustaining space superiority is not possible through existing government systems alone. The scale and dynamism of the space domain demand a more modernized, hybrid architecture that integrates U.S. government, commercial, and allied capabilities by design.

Commercial sensing networks are essential to this model. They can be rapidly deployed to fill coverage gaps, enabling more immediate threat detection, characterization, and persistent custody. They can also add resilience through distribution. Relying on a small number of exquisite systems is a risk, as illustrated during recent conflicts where radar systems were targeted. By leveraging commercial sensors, the future architecture can be proliferated, layered, and diverse. This complicates adversary targeting and enables graceful degradation.

Commercial capabilities are not simply additive; they are transformative. When integrated effectively, they expand capacity, accelerate innovation, and provide critical redundancy.

Allied Advantage Through Burden-Sharing

Persistent orbital intelligence also strengthens the role of allies and partners. Space is a global domain, and no single nation can achieve comprehensive SDA alone.

Future operations will depend on seamless data sharing and interoperability across coalition partners. Shared intelligence enables coordinated responses, enhances resilience, and reinforces deterrence.

A burden-sharing approach to investment in global SDA radars and related capabilities fosters interoperable data and systems through enhanced information sharing and integrates partners across force design, development, and operations.

This cooperative framework not only strengthens the overall security architecture, but also accelerates capability development, improves cost-effectiveness through pooled resources, and ensures that operations are seamless before a crisis or conflict arises. Through initiatives like “Allied by Design,” allies and partners are increasingly being integrated into the Space Force’s exercises, strategies, and systems for this purpose.

From Architecture to Action

Realizing persistent orbital intelligence requires shifts in policy and strategy.

First, hybrid architectures must become the default, with commercial and allied capabilities integrated from the outset. Second, investments must prioritize real-time, decision-ready intelligence, including data fusion, AI-enabled analytics, and low-latency data transport. Third, scalable data-sharing frameworks must be enabled to support coalition operations while maintaining security and mission assurance.

These shifts are essential to building a resilient, interoperable, and intelligence-driven space defense architecture.

Looking Ahead to 2076

By America’s 300th anniversary, the space domain will be further defined by competition. Proliferated constellations by adversarial nations, autonomous systems, and integrated multi-domain operations will compress timelines and increase complexity.

In that environment, speed of understanding will determine success.

By operationalizing commercial innovation today and building architectures that are distributed, resilient, and intelligence-driven, the U.S. can ensure deterrence through attribution, protect high-value assets, and sustain freedom of action in space.

Maintaining U.S. space superiority in the future is dependent on how much we see, how well we understand, and how quickly we act.

Toward that aim, persistent orbital intelligence will be critical.

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Robert H. Goddard, Ph.D., with Nell, the first liquid-fueled rocket, mounted on the launch stand at Auburn, Massachusetts, 16 March 1926. (Percy M. Roope, Ph.D.)

Very Low Earth Orbit: A New Domain of Space Littoral Warfare?

Jahara “Franky” Matisek & Mark T. Mueller

Armies have always sought high ground. This principle of elevation became key to modern warfare with the French Aerostatic Corps in 1794, a path that led eventually to the “first space war” during Desert Storm in 1991. Since then, the air and space domains have only grown more complex, giving rise to a new decisive arena: the seam between atmosphere and orbit.

This is the “space littoral”: a vast, transitional zone stretching from the upper stratosphere to the edge of space, which we define as 20 km to 450 km above Earth. The lower boundary begins around 60,000 feet (20 km), the altitude of the 2023 Chinese surveillance balloon, while the upper boundary extends into very low Earth orbit (VLEO) of 450 km. This single, cohesive domain encompasses a diverse range of platforms, from high-altitude “stratollites” operating around 50 km to satellites orbiting above the 100 km Kármán Line. While companies are pioneering VLEO constellations for high-resolution imagery and low-latency communications, China and Russia are fielding capabilities like hypersonic vehicles and high-altitude platforms to turn this seam into a new warfighting front.

Drawing a parallel to U.S. Navy and Marine Corps doctrine of Littoral Operations in Contested Environments (LOCE), this space littoral is a complex seam where aerodynamics meet orbital mechanics. Unfortunately, the U.S. military treats this seam in a doctrinally ambiguous way: too high for most Air Force assets and too low for traditional Space Force operations, leaving no single service with clear ownership. Its strategic value comes from a fundamental trade-off: proximity to Earth offers immense performance gains, but at the cost of significant atmospheric drag and atomic oxygen corrosion.

Mastering this domain is therefore essential. Should traditional orbits become unusable due to debris or attack, the space littoral may become the only viable alternative. Dominating operations in this environment will grant a decisive warfighting edge to the nation that effectively integrates it into joint all-domain operations and will undermine any adversary who fails to do so.

The Strategic Value of the Space Littoral

While U.S. space strategy has focused on ambitious goals in cislunar space, the decisive terrain for the next conflict is lower, cheaper, and more accessible. For instance, “micro-lift” systems can place small payloads into VLEO for as little as \$70,000 and sounding rockets can deliver larger payloads into VLEO for less than \$1.5 million. Deep-space dominance is difficult and expensive; reaching Lagrange points, for example, requires precise maneuver, high-energy propulsion, and hardened spacecraft. In contrast, a country does not need expensive cislunar propulsion to challenge the U.S. in the space littoral. It needs only altitude, persistence, and ingenuity.

The physics of this region create its strategic value. Proximity to Earth offers revolutionary performance gains, governed by the inverse-square law; halving a satellite’s altitude quadruples the strength of a received radio frequency signal. This allows for smaller, more powerful sensors and turns the space littoral into a critical grid for terrestrial conflict. This domain is now a hotbed of innovation, hosting a diverse ecosystem of platforms. High-altitude balloons and solar-powered pseudo-satellites (HAPS) can loiter for weeks or months, providing persistent regional surveillance. Hypersonic glide vehicles (HGVs) can skip across the atmosphere in ways that confound sensors designed for either the air domain or higher orbital tracks. Most significantly, commercial VLEO satellite constellations are becoming a reality.

The primary obstacle to sustained VLEO operations has always been the trade-off between performance and persistence. The same atmospheric drag that provides a “self-cleaning” effect also causes rapid orbital decay. However, a technological inflection point is transforming the littoral from a transitional corridor into a sustainable, operational domain. Novel, high-efficiency propulsion systems and advanced, corrosion-resistant materials are enabling satellites to maintain their orbits for years, not months. This is no longer theoretical; Japan’s SLATS “Tsubame” test satellite successfully maintained an orbit as low as 167.4km in 2017, and the U.S. Space Force started experimenting with a STP-S30 “DiskSat” in 2025 to demonstrate the ability to operate below 300km. This

combination of high strategic value and increasing accessibility is precisely why the space littoral has become a focal point of great-power competition, a domain where adversaries are already moving to exploit perceived U.S. vulnerabilities.

China and Russia Already Compete in the Space Littoral

While U.S. space doctrine remains focused on high orbits, China and Russia are actively exploiting the space littoral to gain an asymmetric advantage at low cost.

China, in particular, has a formal doctrine for this domain, which it calls “near space” a distinct battlefield connecting air and space. The 2023 surveillance balloon that traversed the North America was a clear manifestation of this strategy. This maneuverable platform was part of a global ISR fleet, demonstrating how Beijing uses the littoral for persistent intelligence gathering. This capability is fused with its development of weapons like the GDF-600 hypersonic glide vehicle that operates at an altitude of 40km, pairing near-space ISR assets, with a weapon that can evade traditional defenses. China intends on integrating platforms like HAPS with hypersonics and counter-space operations to stretch U.S. air and space defenses thin. These developments are a cornerstone of its anti-access/area-denial (A2/AD) strategy.

Russia, while often playing the role of a technological spoiler, has also weaponized the space littoral. Its actions in Ukraine provide a stark preview of this new form of warfare. By systematically targeting Starlink’s ground infrastructure and user terminals with electronic warfare, Russia has demonstrated how to wage a littoral campaign against a VLEO constellation by attacking its vulnerable terrestrial nodes, thereby degrading an entire kill chain. This is complemented by a suite of counter-space capabilities, from ground-based jammers to the Nudol anti-satellite missile. Most alarmingly, U.S. officials have revealed a Russian program to develop a nuclear-armed anti-satellite weapon, designed to detonate in orbit and create a debilitating radiation environment that would indiscriminately disable unhardened commercial and military satellites in low Earth orbit (LEO).

Ultimately, deep space is costly; the space littoral is not. If the U.S. leaves this seam unguarded, Beijing and Moscow will turn it into an aerospace equivalent of a contested maritime chokepoint.

The United States is not Organized for Space Littoral Competition

The United States is hamstrung by a doctrinal and organizational architecture ill-suited for competition in the space littoral. Drawing parallels to naval littoral doctrine, the challenge is one of integration in a complex seam. Just as LOCE demands seamless Navy-Marine operations where sea and land meet, the space littoral requires a deeply integrated Air Force-Space Force approach where air and space converge.

Currently, no such integration exists. The U.S. military dominates below 60,000 feet and has world-class space infrastructure in higher orbits, but the seam between them is under-defended. Air Force doctrine and force design are not oriented toward persistent operations in the thin atmosphere above the Armstrong limit (around 60,000 feet), where aircraft struggle with control authority, lift, heating, and endurance (besides a U-2 operating at 80,000 feet).

This operational seam exists because Space Force doctrine emphasizes orbital maneuver, cislunar planning and dominance, LEO to geosynchronous orbit (GEO) constellations, and deep-space situational awareness. While U.S. Space Command’s area of responsibility formally extends down to 100 km, this has not translated into doctrinal focus, dedicated operational concepts, or resource allocation. This is why it is missing from the command’s Integrated Priority Lists. The 2023 Chinese balloon incident laid this gap bare, highlighting confusion between NORAD’s homeland defense mission and responsibilities of various commands.

The result is a joint force blind spot where the lack of a defined mission owner inhibits force design, acquisition, and the development of clear rules of engagement, allowing adversaries to impose cost and confusion in an undefended domain.

A Strategy for Winning the Space Littoral

Winning in the space littoral requires acknowledging it as a distinct battlespace – just like China’s military has – and adopting a strategy built on clarity, speed, and joint integration. Five essential steps will ensure America regains a competitive advantage.

First, assign a mission owner to drive joint force integration. the core problem is a lack of focused priority, not a lack of formal responsibility. The

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Pentagon must designate a single entity accountable for developing integrated Air Force-Space Force operational concepts, unifying sensor integration, establishing clear rules of engagement, and driving acquisition pathways for the littoral. Without a single point of accountability, this domain will remain a doctrinal blind spot.

Second, build a persistent, layered ISR architecture with allies. A sensor mesh of high-altitude balloons, HAPS, VLEO satellites, and ground-based sensors is needed for continuous coverage of the entire littoral. This architecture, should be developed jointly with allies to create resilient “stand-in constellations” that ‘live’ in constant contact with adversaries. This leverages the geographic placement and technical capabilities of key partners, creating a truly global surveillance network that is more robust and less costly than a unilateral approach. This layered sensor network is critical for enabling efforts like the Proliferated Warfighter Space Architecture and for providing the foundational domain awareness needed to track advanced threats like hypersonic glide vehicles. By fusing space littoral ISR with allies, this complicates adversary calculations of trying to move military forces and engage in other hostile actions when satellites are not overhead to collect intelligence.

Third, integrate commercial space into space littoral deterrence. Mega-constellations such as Starlink, Kuiper, and OneWeb are now critical infrastructure for the U.S. military and its allies. Most intend to operate within and across this region. America needs resilience standards, rapid-replacement agreements, and joint planning frameworks with commercial providers. Space littoral competition will be lost if commercial operators remain unprotected and unintegrated.

Fourth, field defenses and offensive options tailored for the littoral. The United States needs counter-balloon and counter-HAPS systems, jammers, directed-energy weapon systems, and interceptors, such as using fighter jets for air-launched anti-satellite (ASAT) missiles, optimized for thin-atmosphere engagement. Offensive capabilities such as reversible electronic warfare, sensor blinding, and persistent high-altitude platforms are essential for imposing dilemmas on adversaries who are already building a network of infrastructure in the region. Since VLEO is considered “self-cleaning”, unpowered objects below 200km will reenter within days or weeks; policy concerning kinetic offensive and defensive measures in space needs to be reconsidered. Since drag is dominant

in this region, a debris-generating event is relatively short-lived.

Finally, institutionalize space littoral doctrine and training. The joint force must wargame and exercise in this domain. Operators, from the tactical to the strategic levels, must understand the physics of the seam: drag, atomic oxygen, ionization, heating, skip-glide instability, and VLEO decay. Winning in the space littoral first begins with education and becomes a comparable warfighting advantage when working with allies to ensure it is integrated into joint all domain operations.

Conclusion: Commanding the Contested Space Littoral Seam

Great powers win by mastering the spaces between domains. The space littoral is the most critical and overlooked battlespace of our time, essential for future intelligence, command and control, and warfighting. It is where satellites transit, where hypersonics maneuver, and where commercial constellations are building the future of global communications. It is also where China and Russia are actively exploiting a U.S. doctrinal blind spot to forge an asymmetric advantage.

If the United States wants to maintain freedom of action in orbit, it must dominate this littoral. The 2023 Chinese balloon incident was not an anomaly; it was a clear signal that adversaries will weaponize this seam to impose cost, confusion, and coercion. Losing the space littoral will jeopardize American power in every other domain. Near-space security is the foundation of deep-space strategy, joint force lethality, and coalition warfighting.

The United States and its allies still have time to secure this vital ground, but the window is closing. The choice is clear: either organize to compete by assigning a mission owner and fielding capabilities tailored for this unique environment or cede the advantage and allow adversaries to turn this seam into a chokepoint that holds American power at risk.

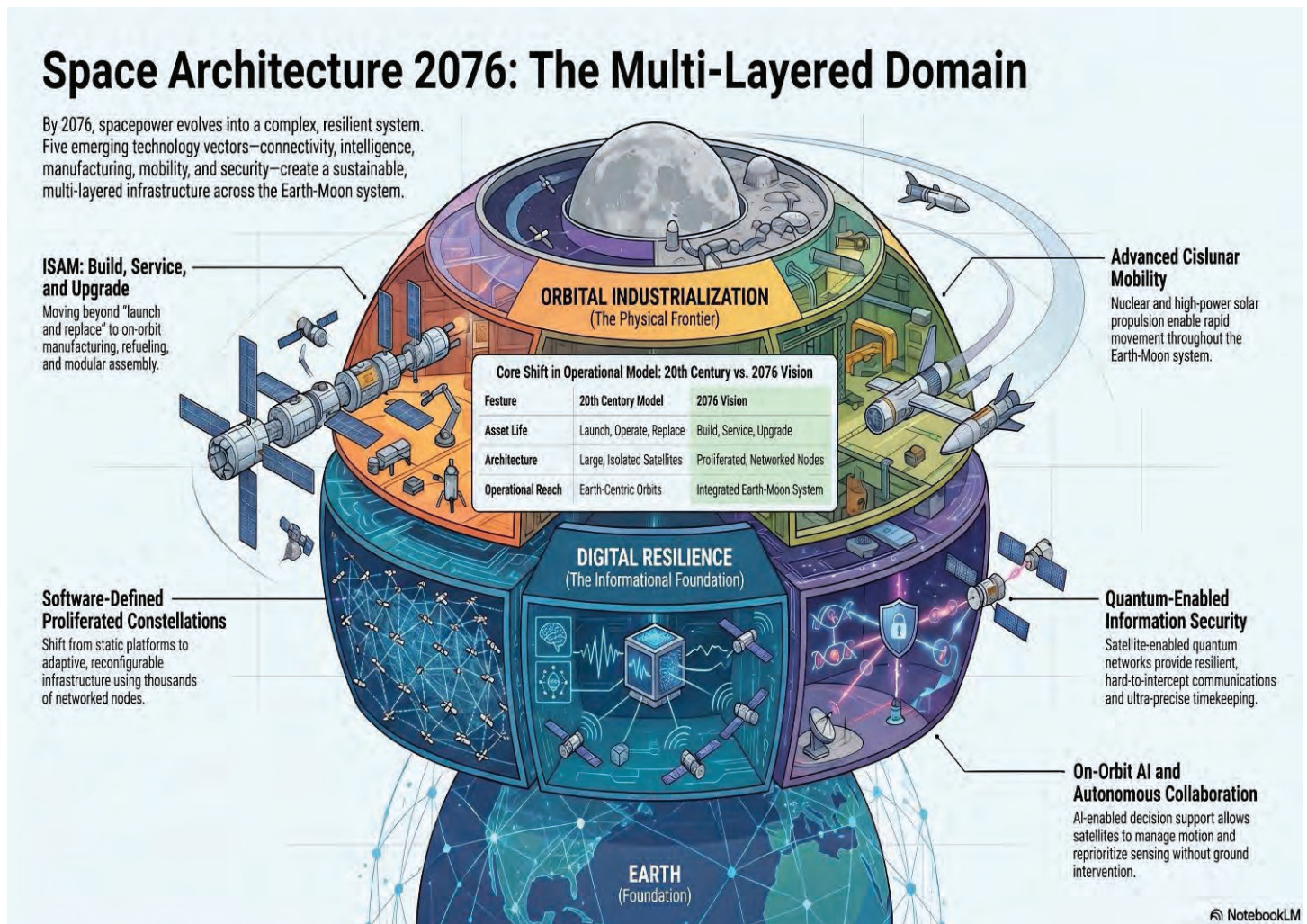
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DOD Disclaimer: Views are their own.

Vectors of Tomorrow: Space Technology Trends That Will Shape the Space Domain by 2076

Cecilio Ponce



A conceptual view of the 2076 space domain, highlighting proliferated constellations, autonomous systems, ISAM infrastructure, cislunar mobility, and quantum-enabled links across the Earth-Moon system—showing how long-term choices in technology, standards, and partnerships reshape spacepower. Image created by Cecilio Ponce using NotebookLM.

By the time the United States marks its 300th anniversary in 2076, the space domain will be shaped less by a few exquisite satellites and more by decades of compounded technological change. The capabilities fielded in orbit, the services people on Earth rely on, and the stability of the domain itself will all reflect a small number of powerful technological trends that are already emerging today. Grounded in current U.S. Space Force doctrine, the "Future Operating Environment 2040" (FOE), national security space strategy, and open-source technical analyses from NASA, industry, and independent research organizations, this article focuses on how long-term choices about standards, norms, partnerships, and investment priorities will shape the character of the space domain—rather than on any single program or system.

As the Space Force's "Space Capstone Publication: Spacepower – Doctrine for Space Forces" (Headquarters USSF, 2020) notes, national spacepower is the totality of a nation's ability to exploit the space domain in pursuit of prosperity and security, with core responsibilities to preserve freedom of action in space, enable joint lethality and effectiveness, and provide independent options to national leadership. Foundational work on spacepower doctrine further emphasizes that enduring advantage in space depends not only on orbital presence, but on industrial capacity, technological innovation, and the speed with which new ideas become operational capabilities (Gray, 2010; Rumbaugh & Gleason, 2020). The FOE extends this logic to 2040, describing space as "the contested high ground of U.S. military power"

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and highlighting that advantage is earned through decades of research, investment, and innovation but can be lost in milliseconds. Looking from 2040 toward 2076, five technology vectors stand out as especially consequential for how spacepower is generated and how the space domain evolves.

Proliferated, Software-Defined Constellations

The first vector is the move from a small number of large, single-purpose systems to proliferated constellations composed of dozens, hundreds, or even thousands of relatively small satellites. Commercial mega-constellations providing broadband, Internet of Things connectivity, and persistent sensing have demonstrated the economic viability of this approach, and national security space architectures are following suit for reasons of resilience and agility. The “National Security Space Strategy” (Department of Defense & Office of the Director of National Intelligence, 2011) explicitly emphasizes adapting to a “congested, contested, and competitive” space environment and calls for more resilient, distributed architectures to reduce vulnerabilities and improve operational flexibility.

The FOE’s 2040 assessment assumes that successful U.S. architectures will be “proliferated, maneuverable, and tactically responsive,” designed for persistence and recovery with distributed nodes rather than single points of failure. Proliferation changes the geometry of vulnerability: instead of a small number of high-value targets, an adversary faces a distributed network that can lose individual nodes without losing the mission. At the same time, satellites are becoming increasingly software-defined: payload functions, waveforms, and even mission roles can be updated after launch, allowing capabilities to evolve at software speed rather than hardware replacement cycles. By 2076, constellations are likely to function more like adaptive, reconfigurable infrastructure than static platforms, with implications for deterrence, crisis stability, and the tempo of innovation.

Autonomy, AI, and Cyber-Resilient Space Systems

The second vector is the deep integration of autonomy and artificial intelligence into space systems and operations. Today, AI assists with mission planning, anomaly detection, and data analysis on the ground; the trajectory points toward AI-enabled decision support and autonomy on orbit, where time and bandwidth are scarce. U.S. and allied research already explore machine-learning-enabled space domain awareness, autonomous proximity operations, and intelligent payload tasking across proliferated constellations (CSET, 2023; ABI Research, 2026).

The FOE projects that by 2040, “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,” compressing decision timelines and stressing human command authority. Autonomous satellites can collaborate in formations, manage relative motion, and dynamically reprioritize sensing or communications tasks based on commander’s intent and real-time conditions. In space domain awareness, machine learning can fuse observations from proliferated sensors, detect anomalous behavior, and provide predictive insight at scales far beyond unaided human cognition. These advances will be essential in a 2076 environment that is more crowded, more contested, and more dependent on space services. They also expand the cyber-attack surface, as space systems become more software-intensive and more networked, reinforcing the need for built-in cyber resilience and secure autonomy from the outset (Defense Space Strategy, 2020).

In-Space Servicing, Assembly, and Manufacturing

A third trend—In-Space Servicing, Assembly, and Manufacturing (ISAM)—promises to change the economics and physics of what can be built and sustained in orbit. NASA’s In-Space Servicing, Assembly, and Manufacturing (ISAM) State of Play reports (NASA, 2024, 2025) describe a rapidly maturing ecosystem spanning life-extension servicing, refueling, repair, on-orbit assembly of large structures, and manufacturing of components in microgravity. The National ISAM Implementation Plan (COSMIC ISAM, 2025) outlines how civil, commercial, and national security stakeholders could leverage these capabilities as “foundational infrastructure” for future space activity.

Over the next fifty years, ISAM could shift the model from “launch, operate, and replace” to “build, service, and upgrade,” with significant consequences for spacepower. Large apertures for sensing and communications, power and logistics hubs, and elements of cislunar infrastructure may be assembled in orbit from modular components rather

than launched fully integrated from Earth. ISAM also underpins a future in-space economy that includes tugs, depots, recycling facilities, and factories that convert debris or extraterrestrial resources into usable material (Kulu, 2025; CisLunar Industries, 2025). By 2076, the nations and coalitions that lead in ISAM will help define the economic geography of Earth orbit and the Earth–Moon system, giving them leverage over reconstitution, logistics, and large-scale infrastructure that FOE identifies as critical for a “protracted fight in the largest domain.”

Advanced Propulsion, Cislunar Mobility, and the EMS

The fourth vector is advanced propulsion and power systems that make cislunar space and the lunar surface more accessible and more operationally relevant. Concepts under development include nuclear thermal and nuclear electric propulsion, high-power solar electric propulsion, and other technologies that offer higher thrust and efficiency than traditional chemical propulsion for certain mission profiles. Analyses of U.S. and Chinese activities in cislunar space highlight the strategic importance of mobility, logistics, and space domain awareness beyond geosynchronous orbit in the coming decades (National Institute for Defense Studies, 2024).

Programs such as DARPA’s Demonstration Rocket for Agile Cislunar Operations (DRACO) illustrate the national security interest in maneuvering rapidly and responsively throughout cislunar space. In parallel, fission surface power and related systems are being studied to support sustained presence on the Moon for scientific, commercial, and strategic purposes. The FOE frames the Earth–Moon system as the future operating envelope, with the Space Force’s mandate extending to ensure freedom of action and navigation “across the Earth–Moon system” and to protect space lines of communication in that regime. By 2076, the decisive movement of spacepower may be measured not only by who holds key orbits around Earth, but by who can move, sense, and operate effectively across this extended operating complex while fighting through “unrestricted spectrum warfare” in the electromagnetic domain.

Quantum-Enabled Communications and Sensing

The fifth vector is quantum technology as an emerging layer of space-based information infrastructure. Quantum communication satellites are being explored to distribute cryptographic keys and realize elements of a global quantum network, providing new options for secure communications. Demonstrations of space-to-ground entanglement distribution and recent results showing that ground-to-space “uplink” quantum links are feasible (Quantinuum, 2024; ScienceDaily, 2026) strengthen the case for satellite-enabled quantum networks.

Quantum-enabled systems could also support ultra-precise timekeeping and gravity measurements, enhancing navigation and sensing. For national security space, these capabilities offer both opportunities and challenges: they can provide resilient, hard-to-intercept communications and exquisite sensing, but they also drive competition among states seeking to secure or disrupt quantum-enabled infrastructure. The FOE highlights quantum sensing and advanced spectrum operations as part of the 2040 “technological threat profile,” noting that technologies which exploit physical phenomena not previously harnessed at scale can fundamentally change the foundations of spacepower. As quantum technologies mature and integrate with proliferated constellations, autonomy, and ISAM, they will reshape how information moves through the space domain and how spacepower is exercised by 2076.

Preparing the Workforce for a 2076 Space Domain: People, Technology, and Economics

As these technology vectors converge, universities are retooling to support the space enterprise. Institutes, grand-challenge initiatives, and innovation centers are treating space and national security as applied problem domains, pairing students with practitioners to work on issues such as resilient architectures, ISAM concepts, and spectrum resilience. Drawing on Dr. David Pistruì’s people–technology–economics framework, leading programs approach workforce development as a dynamic system in which human capabilities, technological trajectories, and economic incentives must be aligned to avoid an “exponential gap” between rapid innovation and slower social and institutional adaptation.

Pistruì and colleagues’ research on the Industry 4.0 talent pipeline highlights that future technical professionals must combine discerning skills (systems thinking and foresight), people skills (collaboration and empathy), and purposeful skills (ethical judgment and value creation) to thrive in technology-intensive ecosystems. Programs such as Vanderbilt

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University's Wond'ry IMPACT initiative, which organizes interdisciplinary student teams around deep-tech challenge areas including "Innovation Beyond Earth" and national security, exemplify how academia is building this kind of talent pipeline—linking people, technology, and economics to the contested, AI-enabled, cislunar environment described in USSF's Future Operating Environment 2040. By 2076, the quality of this integrated workforce—technically fluent, system-literate, and economically aware—will be as central to spacepower as the hardware on orbit.

Steering the Domain to 2076

These technological trends interact. Proliferated, software-defined constellations provide the fabric on which autonomy, ISAM, advanced propulsion, and quantum services can operate. ISAM and cislunar mobility reshape what that fabric can look like and where it can be deployed, while quantum technologies alter the security and performance of the data that flows across it. The FOE's 2040 scenarios—ranging from "dark horizons" marked by persistent gray-zone competition and unrestricted spectrum warfare to a more favorable "vision for victory"—underscore that technological superiority is necessary but insufficient; organization, integration, and clarity of strategic purpose are decisive.

For the United States and its allies, the central question is not whether these trends will unfold, but how they will be shaped. Strategic choices about standards, norms of behavior, public-private partnerships, and investment priorities will determine whether the 2076 space environment is resilient and interoperable, or congested and brittle. Guiding these vectors toward architectures and practices that preserve freedom of action, enable joint operations, integrate commercial and allied strength by design, and support responsible stewardship of the domain is at the heart of sustaining spacepower into the nation's fourth century (Headquarters USSF, 2020; Space Force Doctrine Document 1, 2025; USSF FOE 2040).

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Cislunar Strategy at 300 Years: Preventing Fragmentation in the Lunar Infrastructure Race

Shreya Chandra

By 2076, the United States will not measure its position in cislunar space by how many flags were planted on the Moon, but by whether American-built systems became the default interfaces that everything else had to plug into. The current discussion around the lunar economy focuses on access, launch cadence, and surface missions. The harder and more consequential problem is more specific. Right now, different groups are quietly choosing voltages, frequencies, timing references, data formats, and docking geometries that will determine whether future systems can connect at all.

Those choices are being made independently. The Artemis Accords call for interoperability, but they stop at principle. There is no agreed standard for a surface power bus, no defined interface for cross-provider communications relay, and no shared timing reference for navigation beyond Earth orbit.

That means a lander built by one provider may not be able to draw power from a nearby installation, even if it is physically within reach. It means a rover may not be able to hand off its data to the nearest relay satellite if that relay belongs to a distinct network. These are not edge cases. They are the difference between a system that scales and one that stalls.

Take surface power. Early lunar systems are converging on solar generation with battery storage, but the details matter. If one provider distributes power at 120 volts DC and another at 300 volts DC, but with heterogeneous connector designs and safety protocols, then power sharing becomes nontrivial. Every interface requires custom hardware, validation, and risk acceptance. Over time, operators will default to using only their own systems because it is predictable. That is how fragmentation hardens.

Communications is heading in the same direction. Cislunar relay architectures are being designed with assorted frequency bands, routing assumptions, and network management approaches. A relay optimized for a single provider's missions does not need to support external traffic. Without agreed crosslinks or protocol translation layers, each network becomes its own island. The immediate result is duplication. The

longer-term result is that switching between providers carries operational risk, which discourages it.

Navigation may be the most consequential case. There is no lunar equivalent of the Global Positioning System yet, but multiple efforts are moving in that direction. If these develop as separate positioning frameworks with disparate reference frames and timing standards, then location data becomes system-dependent. A rover navigating with one service cannot seamlessly integrate data from another. For precision operations like landing near preexisting assets or coordinating multiple vehicles, that mismatch matters. It also creates dependence. If your system relies on a specific navigation service, you inherit its availability, accuracy, and governance.

None of this requires bad intent. It is the natural outcome of parallel development under schedule pressure. The NASA Artemis program is optimizing for near-term mission success. Commercial firms are optimizing for cost and speed. Other actors, including China, are building architectures aligned with their own priorities. Without a forcing function, convergence does not happen on its own.

The argument that "the market will sort it out" is weak in this context. The cost of incompatibility on the Moon is operational. You cannot easily swap hardware, patch systems, or send a technician to rewire an interface. If two systems do not connect, the fallback is mission redesign or failure (not simply inconvenience). That changes how operators behave. They minimize dependencies, avoid cross-system integration, and build close loops. Those decisions make sense locally and produce fragmentation globally.

Avoiding that outcome requires deciding, very specifically, what must be common and what can remain competitive. Not everything needs a standard. Trying to standardize entire systems would slow development and likely fail. The focus should be on the narrow set of interfaces where incompatibility creates cascading constraints.

For surface power, that means defining a common external interface (e.g. voltage range, connector geometry, and handshake protocol that allows

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one system to supply another). This is analogous to standardizing an electrical outlet (yet not dictating how appliances are built). Once that interface exists, providers can design around it, and users can rely on it.

For communications, the equivalent is an inter-network relay protocol. Systems should be able to pass data across network boundaries using a shared format and routing convention, even if their internal architectures differ. That could be implemented as a translation layer at the relay level rather than forcing identical designs. The key is that a user does not need to know which network they are on to transmit data off the surface.

For navigation, the priority is a shared reference frame and timing standard. Multiple providers can offer positioning services, but they should anchor to a common coordinate system and time base. That verifies that data from varying sources is directly comparable. It also allows redundancy without inconsistency, which is vital for safety.

Timing is the constraint that is urgent (although not because coordination efforts are absent).

Organizations such as the Open Lunar Foundation are actively working on problems such as a shared lunar time reference, and agencies are discussing interoperability in forums tied to the Artemis Accords. The gap is that these efforts are not yet driving the hardware that is being built. A lander program selecting its power architecture today is making its decisions about voltage, connectors, and fault protection based on internal requirements and schedule, not on a binding external standard. The same is true for relay satellites choosing frequency plans and routing logic, or navigation payloads defining their timing source and coordinate frame. These choices are rational at the program level, but they accumulate into system-level divergence. Once a few missions fly with a given design, the design becomes “heritage,” suppliers align to it, and future programs adopt it to reduce risk. At that point, alternatives are evaluated on compatibility with what already exists. The practical window that exists now is the period before these first-generation designs harden into default interfaces through repetition and flight qualification.

By 2076, these early design choices show up in day-to-day operations. A new lander arrives, draws power through a standard external bus, locks onto a shared timing reference, and routes data through whatever relay has line of sight. Interfaces are predictable, so missions plan around performance instead of compatibility workarounds. In a different configuration, each

connection point becomes a tailor-made engineering problem. Power hookups require adapters, navigation data must be translated across reference frames, and communications depend on prearranged network access. The delta between those environments appears directly in mission timelines, integration cost, failure modes, and the number of actors who can realistically operate beyond demonstration scale.

For the United States, long-term influence in cislunar space flows from setting the interfaces others choose because they lower risk and speed up missions. That leverage sits in concrete decisions (e.g. a defined surface power interface that multiple providers implement, a common time and coordinate standard that navigation services anchor to, and a relay protocol that allows traffic to move across networks without prior negotiation. When those pieces are adopted in flight hardware and procurement language, they become the default. Suppliers build to them, partners align to them, and switching away carries real cost.

Viewed through that lens, cislunar strategy turns on compatibility. The entities that specify how systems connect shape how activity expands and who can join it. Those choices live in connector geometries, voltage ranges, timing signals, message formats, and certification requirements that rarely make headlines. Elevating those specifications to a core concern of spacepower is what determines whether operations in 2076 proceed through routine integration or constant reinvention.

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Spacepower 2076: Why Logistics Became the Foundation of American Spacepower

Jondavid DuVall

When Americans look back from 2076, they may conclude that the decisive breakthrough in national security space was not simply bigger rockets, better sensors, or more satellites. It was the moment the United States learned to treat space as a theater for sustained operational effect. Spacepower matured when it stopped being defined only by access and launch, and started being measured by persistence, responsiveness, and the ability to project support from orbit to any point of need.

That future is already visible in the ideas emerging across the United States Space Force, the Department of War, and the commercial space sector. The central question for the next fifty years is not whether America can continue to develop space capabilities. It is whether America can organize, supply, defend, and regenerate combat power through space faster than any adversary can disrupt it. By 2076, the answer must be yes.

A Story That Signals the Future

A useful way to think about that future comes from fiction. In my article, “Space Logistics: Guardians of Hope”, a commercial orbital logistics enterprise is relied upon during a devastating typhoon response in the Philippines. From an Orbital Warehouse, the team uses digital twins, precision reentry pods, and vertical take off and landing drones to deliver medical supplies, food, water, and shelter materials. Later, the same architecture supports a military response. The strategic lesson is real. The same systems that save lives in crisis can sustain combat power in conflict.

That dual-use flexibility should shape how America thinks about spacepower in 2076. The strongest spacepower will belong to the nation that can turn orbital presence into operational outcomes. That means the future of spacepower will be inseparable from space logistics. Prepositioned cargo, responsive launch, in-space maneuver, autonomous transfer, digital command and control, and precision delivery from orbit will matter as much as surveillance or communications. Space superiority will still be vital, but superiority without sustainment will be temporary.

Building a Space Sustainment Architecture

By 2076, the United States should aim to field a fully integrated space sustainment architecture. That architecture will likely include orbital depots, standardized cargo interfaces, reusable transfer vehicles, autonomous inspection and servicing systems, reentry-enabled delivery packages, and common data layers that connect combatant commands, field operators, depots, and commercial partners. The United States will not win by building a single perfect system. It will win by building a resilient logistics ecosystem with enough interoperability, redundancy, and speed to absorb shock and continue operating.

This is where today’s foundations matter. For decades, America’s space enterprise prioritized access, exquisite payloads, and launch cadence. The next era requires a broader mindset centered on mission sustainment. That means planning for repair, resupply, reconstitution, and recovery from the start, not as afterthoughts. It means designing systems that can be serviced, replenished, upgraded, and tactically repositioned. It means seeing a space weapon system not as a satellite alone, but as an operational web of launch infrastructure, cyber pathways, ground stations, logistics nodes, and command networks.

In 2076, commanders should be able to move supplies across domains with the same confidence that earlier generations moved fuel and munitions by airlift or sealift. In some cases, that will mean rapid terrestrial transport to launch sites and onward delivery to orbit. In other cases, it will mean moving cargo within orbit to sustain maneuvering spacecraft, lunar infrastructure, cislunar surveillance networks, or remote expeditionary nodes. In the most demanding scenarios, it will mean precision delivery from orbit back to Earth or to austere operating locations, where time matters more than efficiency and where contested conditions make traditional routes too slow or too vulnerable.

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Beyond Warfighting: Dual-Use Spacepower

This vision is bigger than warfighting alone. By 2076, the nation will expect spacepower to serve as both shield and connective tissue. The same architecture that sustains forward forces in crisis can also support humanitarian response, disaster recovery, and homeland resilience. That dual-use character is not a distraction from deterrence. It is one of the clearest demonstrations of American strength.

Commercial and allied integration will determine whether this vision succeeds. The United States will not build the future space logistics enterprise by itself, nor should it try. Commercial industry is already moving faster in launch, autonomy, data analytics, in-space servicing, and platform reuse. Allies bring geography, access, legitimacy, industrial capacity, and operational depth. By 2076, the most effective American space architecture will likely be a federated one: government owned where necessary, commercially enabled wherever possible, and allied by design.

That federation will require organizational maturity. Over the next fifty years, the United States must refine who sets requirements, who commands logistics effects, who manages commercial surge capacity, and who owns reconstitution across military, civil, and industrial actors. America has solved hard organizational problems before. It will need to do so again in space, because elegant technology without clear authorities will still fail under pressure.



U.S. Air Force Staff Sgt. Samuel Becker, Space Launch Delta-45 non-commissioned officer in charge of command information raises his right hand and recites the Oath of Reenlistment beneath a Falcon 9 rocket carrying the Starlink 6-101 mission as it successfully launches from Space Launch Complex 40 at Cape Canaveral Space Force Station, Florida, on Jan. 30, 2026. (U.S. Space Force photo by Gwendolyn Kurzen)

Command, Control, and the Digital Backbone

The command and control dimension will be just as important as the hardware. Also, in “Guardians of Hope”, a Spaceport of the Future Common Operating Picture is relied upon as a digital twin that visualizes every depot, pod, drone, and trajectory in real time. That concept should evolve into a defining feature of future spacepower. By 2076, digital twins, predictive analytics, and AI-enabled logistics tools should allow commanders to see the health, location, priority, and projected supportability of critical space and terrestrial nodes in near real time. They should help operators rehearse options, identify bottlenecks, model adversary disruption, and restore tempo faster than a competitor can adapt.

But information alone will not be enough. The United States must train leaders who can trust data without becoming captive to it. The future force will need logisticians who understand orbital mechanics, operators who understand sustainment, acquisition professionals who understand how design choices affect endurance, and commanders who can integrate joint, allied, and commercial capabilities under pressure. Exercises and wargames must force leaders to think beyond launch and ask harder questions: how long can forces endure, how quickly can they recover, and what happens when logistics becomes the target?

The Human Element of Enduring Advantage

Workforce development may be the most overlooked requirement of all. The Space Force must continue building a culture that treats sustainment as operational power, not rear-area administration. America’s 300th anniversary should find a cadre of space-minded logisticians, engineers, operators, cyber professionals, and commercial integrators who speak a common mission language. They should be educated to think across orbit, link, ground, industry, and allied networks. The nation that learns fastest will sustain advantage longest.

The United States also needs a moral framework for this future. The point of spacepower is not to admire technical elegance in orbit. It is to secure peace, preserve freedom of action, protect national interests, and support people under pressure. In 2076, success should not be measured only by what the nation can strike or surveil, but by what it can sustain, defend, and restore.

America 250 and the Spacepower Imperative

At America’s 300th anniversary, the story of U.S. spacepower should be one of maturation. The nation that first reached the Moon should also be the nation that learned how to remain present, useful, and resilient across the full spectrum of competition, crisis, and conflict. If we build wisely now, future Guardians will inherit more than constellations and launch pads. They will inherit an operational system that can hold the line in war, support allies in crisis, and deliver hope when distance and disruption seem overwhelming.

That is the real promise of spacepower over the next fifty years. Not simply to go farther, but to remain ready. Not simply to dominate the high ground, but to sustain the fight and the future from it.

Jondavid DuVall is the Space Logistics Officer, Space Systems Command, focused on operationalizing space mobility, mission sustainment, and contested logistics within the national security space enterprise. He writes on the future of space logistics, operational readiness, and the partnerships required to sustain U.S. spacepower across competition, crisis, and conflict. The views of the author are his own and do not represent those of the USSF.

A Modernized Approach to Command and Control of Our Space Domain

Samantha Louque

The space domain is rapidly evolving, with a record number of objects launched into orbit in 2025. That creates a great deal of uncertainty in space. The European Space Agency estimates that 140 million unclassified objects are currently in orbit, including a possible 9,300 active payloads. With our adversaries also ramping up their launches with unknown intent, the United States Space Force and our allies are operating in an increasingly confusing battlespace.

To ensure the U.S. and our allies stay ahead in this contested and congested environment, the Space Force recently released two documents defining what it will become: "The Objective Force 2040" and the "Future Operating Environment 2040". In an interview with the Space Force Association, Gen. Chance Saltzman, Chief of Space Operations, stressed the importance of collaboration and speed to meet this future vision for 2040 and beyond.

One Space Systems Command (SSC) program has already been prioritizing building collaboratively at the speed our joint forces need to stay ahead. As we look ahead to America's 300th anniversary, the Kronos program serves as a model for the type of innovation we need to maintain and modernize U.S. space superiority.

Kronos: A Modern Solution

The Kronos program seeks to modernize our space battle management and intelligence to provide operators with the tools they need to protect our assets on orbit. This includes fusion of real-time data to support awareness, planning, and deconfliction in an ever-growing, congested warfighting domain in space.

In late 2025, the Space Force published a commercial solution to bring in a broad range of solutions to support the Kronos family of systems. The three main focus areas -- defined by Space Systems Command -- include:

- Battle Space Intelligence: Develop and integrate space intelligence capabilities that support space superiority -- at speed and scale.
- Battle Space Management: Deliver critical services and applications that enable warfighters to make timely, high-quality decisions across the space battlespace.
- Command and Control: Provide critical capabilities that bring critical services to our warfighters to facilitate timely, quality-driven battlespace decisions for the space domain fight.

Moving quickly, the Kronos program awarded its first contracts in April 2026, and they're just getting started. To succeed in a modern space domain, the Kronos program will need to collaborate closely with industry and other government partners. Together, innovators supporting Kronos will continue to improve and adapt this fluid program as we head into a new era of space power.

Space is a Team Sport

Space Force acquisitions have traditionally followed a fixed pattern. The government publishes requirements, prompting industry partners to spend months or years crafting the perfect solution. That limits innovation, according to Gen. Saltzman. Looking ahead, he shared that the Space Force aims to partner "with industry in a more collaborative fashion."

Kronos is one program leading the charge towards more collaborative solutions. In a recent webinar, Kronos program manager Lt. Col. Colin Greiser said they're "encouraging as much non-traditional and commercial innovation as possible." Instead of detailing rigid requirements, the Kronos program will publish problem statements and encourage industry partners to develop solutions in hand. Those that add value will have the opportunity to integrate into the Kronos family of systems. Ultimately, industry teams will work with the government to create a comprehensive battle management and intelligence network to meet the needs of tomorrow's joint forces.

That collaborative approach accelerates the delivery of essential technology solutions. Traditionally, most space intelligence work has been done at the classified level. Opening these problems to industry partners at the unclassified level allows for rapid innovation. "It's really impressive the speed at which good ideas come out," Lt. Col. Greiser shared.

Support from the SDA TAP Lab

To help find the right industry partners for the program, Kronos leadership will turn to the SDA TAP Lab. For the past two and a half years, the SDA TAP Lab has published problem statements and invited industry partners to come and solve them. Over 400 companies have participated, ranging from one-person startups to large defense contractors.

Thanks to a recent program shift, the SDA TAP Lab will now directly support the Kronos program. The Lab will foster companies who have prototype solutions relevant to Kronos and facilitate collaboration between those companies. That way, no one is building their solution in a silo. Rather, industry battle management and intelligence tools are designed to work together, making it easier to integrate them into a program of record.

Laying the Foundation for Success

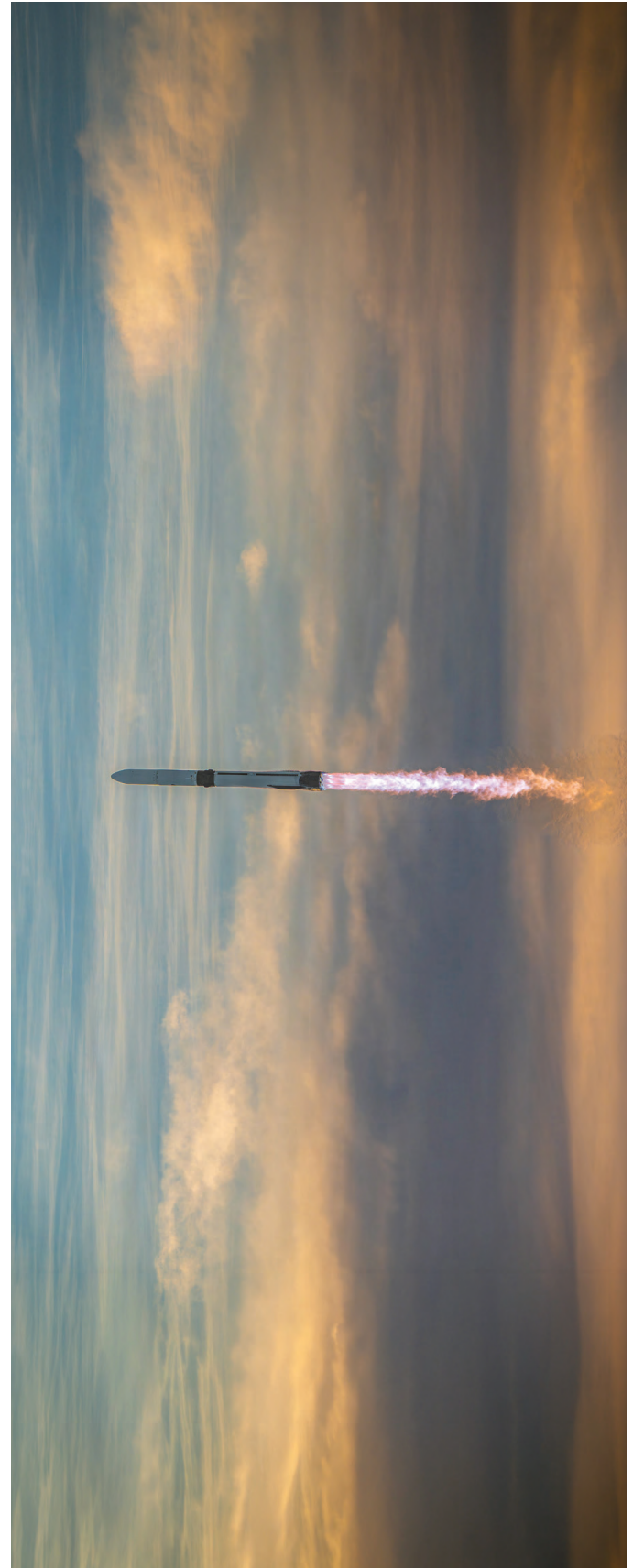
Kronos is just one example of a larger trend: the future of space is collaborative. As we head out of America's 250th anniversary towards our next milestone, our Space Force leaders will increasingly rely on innovation from industry and academic partners.

At the Innovation Hub sponsored by VT-ARC in Colorado Springs, that cross-sector collaboration happens daily. Over 30 government teams -- including the Kronos program and SDA TAP Lab -- leverage resources and collaborate to solve tomorrow's space problems.

No one truly knows what space will look like in 50 years. If programs like Kronos and the SDA TAP Lab succeed in creating a collaborative environment where industry and government can innovate together, then the U.S. can maintain space superiority in 2076 and beyond.

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Samantha Louque is the lead marketing and outreach project coordinator at the Innovation Hub in Colorado Springs. The Innovation Hub is a collaboration facility established as a partnership between the Virginia Tech Applied Research Corporation, Space Systems Command, and the Air Force Office of Scientific Research.



A New Glenn rocket carrying the BlueBird 7 mission successfully launches from Space Launch Complex 36 at Cape Canaveral Space Force Station, Florida, on April 19, 2026. Following liftoff, New Glenn began its ascent carrying AST SpaceMobile's BlueBird 7 satellite toward low Earth orbit. (U.S. Space Force photo by Gwendolyn Kurzen)

The Cislunar Mandate: Securing the High Frontier for 2076

Cmdr. Jacob Yates, USN (Ret.), Doug Ruby, Maj. Chris Hill, USAF (Ret.)

Introduction: The 2026 Inflection Point

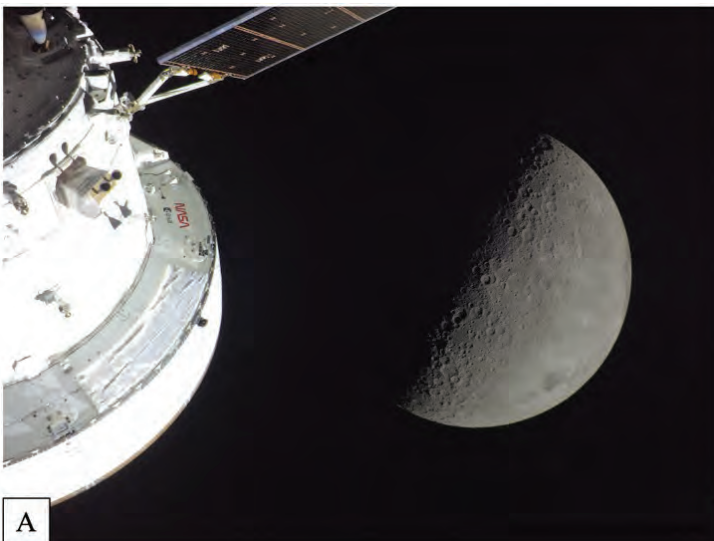
In April 2026, the strategic landscape of the high frontier underwent a fundamental shift. While NASA's Artemis II mission captured the public imagination with its crewed return to the lunar vicinity, the United States Space Force initiated a more permanent pivot: the standing up of the Cislunar Acquisition Task Force (also known as the Cislunar Coordination Office). This move signifies that the Space Force has transitioned from observing the lunar domain to actively "organizing, training, and equipping" to secure it. The mission of 2026 is no longer just discovery; it is Competitive Endurance, preventing operational surprise and denying first-mover advantage in the vast volume between Earth and the Moon.

PNT: The Foundational Utility of the High Frontier

Just as GPS underwrites nearly every facet of modern life on Earth, independent cislunar Positioning, Navigation, and Timing (PNT) will be the digital backbone of the 2076 lunar domain. Currently, the Space Force provides GPS for all of humanity with only a fraction of the Department of War budget, yet this terrestrial utility is insufficient for the high-cadence traffic and precise maneuvering required for lunar surface operations and Lagrangian staging. The 2026 Task Force's primary mandate — creating a lunar-centric PNT roadmap — is a strategic imperative. Without the ability to "know where things are," the Space Force cannot protect its interests "in, to, and from" space.

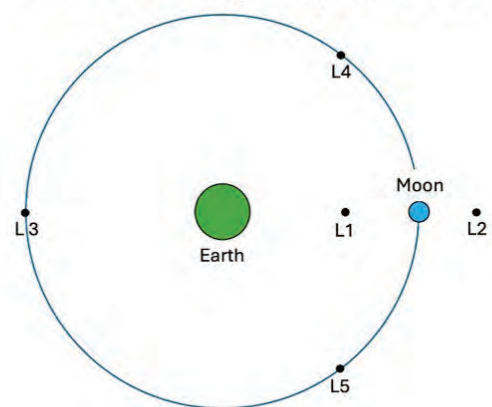
The Strategic High Ground: Lagrangian Points and the Surface

Strategic utility in 2076 is dictated by the physics of the Earth-Moon gravity well. The 2026 pivot marks the first institutional recognition that the "high ground" has migrated from geostationary orbit (GEO) to the Earth-Moon Lagrangian points (L1 and L2). These points are the strategic harbors of the high frontier, ideal for fuel depots, logistics hubs, and surveillance platforms required for the next 50 years.



A The View of Discovery: Captured April 4, 2026, during Flight Day 4 of the Artemis II mission, featuring the sunlit near side of the Moon with Orion hardware visible in the foreground. (Photo courtesy of NASA)

Earth – Moon Lagrangian Points



B Schematic: Representation only; sizes and distances are not to scale

The Map of Security: A strategic schematic representing the Earth-Moon Lagrangian points (L1–L5), identifying the "Strategic Harbors" discussed in Section III.

The Economic Engine: Building Industrial Depth

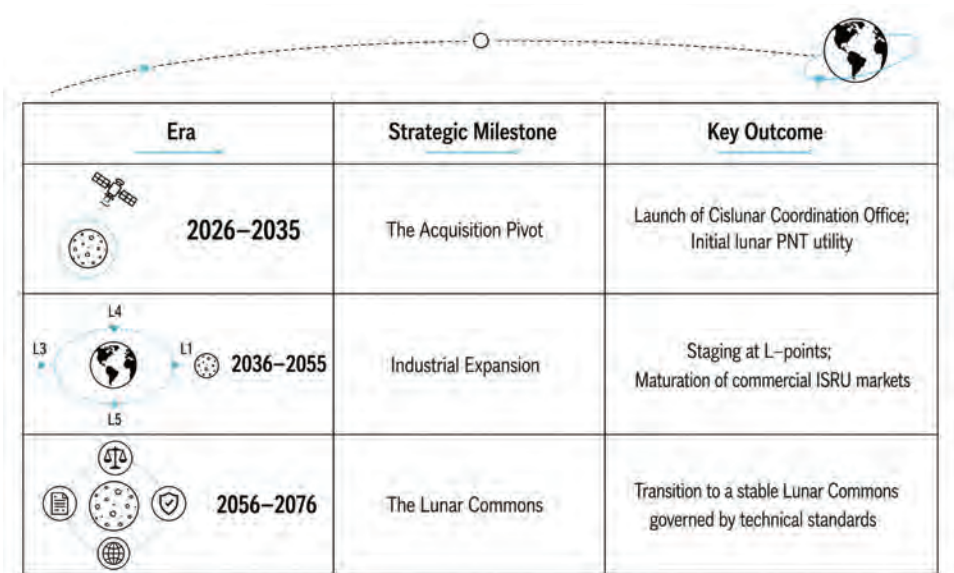
A resilient space power requires a thriving commercial ecosystem. The transition from “discovery” to a self-sustaining economy is underpinned by Section 10 of the Artemis Accords, providing the legal framework for resource utilization. In the 2076 vision, the lunar surface is an industrial hub where in-situ resource utilization (ISRU) provides the propellant for persistent presence. By serving as an “anchor tenant” for cislunar services, the Space Force creates a “value loop” that de-risks private investment.



Synthesis: Establishing the 2076 Lunar Commons

The 2026 acquisition pivot aims to preserve the Lunar Commons. This domain is governed by technical standards — such as PNT and docking protocols — and the persistent presence established by the United States and its Artemis Accord signatories. By providing foundational utilities and securing strategic Lagrangian “high ground,” the Space Force guarantees the domain remains safe, secure, and sustainable for the next century.

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Strategic Gains in Cislunar Evolution (2026–2076). This timeline illustrates the transition from foundational acquisition to a stable, sovereign Lunar Commons.



NASA artist Jimmy Catanzaro's rendering of a mature lunar settlement, representing the sovereign and stable “Lunar Commons” envisioned for 2076. (Photo courtesy of NASA).

Conclusion

The standing up of the Cislunar Coordination Office in 2026 is the starting gun for the tricentennial era. As the nation celebrates its 250th year, the roadmap to 2076 is clear: by prioritizing the “Triple Crown” of PNT, strategic positioning, and economic depth today, the United States ensures that American spacepower remains the stabilizing force of the high frontier through 2076 and beyond.

The lead author acknowledges Doug Ruby and Maj. Chris Hill, USAF (Ret.), for their foundational technical insights regarding cislunar PNT architecture and strategic economic modeling. Additionally, the authors extend their sincere gratitude to SMSgt. Mika Beckley, USSF (Ret.), President of the Space Force Association San Diego Chapter, for her leadership in identifying this strategic opportunity, and to Col. Brian “Yosh” Yoshimoto, USAF (Ret.), for his invaluable expertise regarding cislunar strategies and domain-specific challenges. Their collective commitment to professional development and community outreach was essential to this work

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When America Turns 300: The Stars as the New American Frontier

Dan Dant

The fireworks not only illuminate the skies of Philadelphia and Washington when America commemorates her tercentennial in the year 2076. It will also be sparkling in the stars. The moment could be marked by orbital light displays in time with the “Star-Spangled Banner,” laser displays visible in the Moon, and drone constellations in the shape of 2076 in low Earth orbit.

The space domain, which earlier was the realm of scientists and dreamers, has turned out to be the latest and biggest arena of power, rivalry, collaboration, and trade to mankind. Starting with the first-of-its-kind beep of Sputnik in 1957 and the footprints of Apollo 11 in 1969, it has since grown into a sprawling, self-defeating ecosystem: orbital factories, lunar industrial bases, asteroid-mining fleets, interplanetary logistics node, and armed satellite constellations silently patrolling the kingdom above.

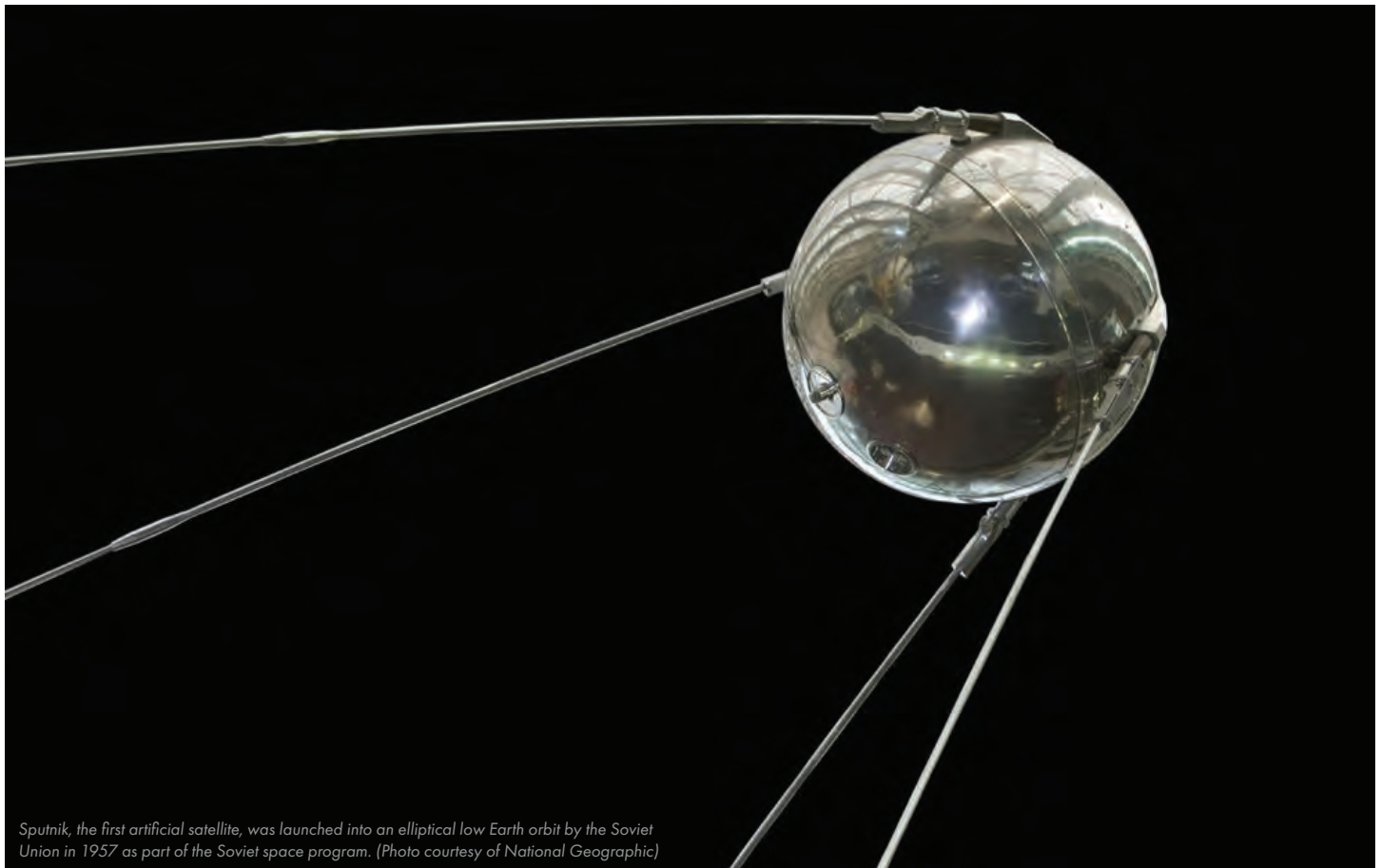
The space domain will cease to be an afterthought,

but a high frontier by the time the United States celebrates its 300th birthday. It will be a complete strategic environment of equal significance as land, sea, air and cyberspace—maybe even more. All significant international infrastructures, such as financial transactions, GPS time keeping, weather services, internet backbone traffic, and even power grids will rely on space-based assets. Without space control, even strategic deterrence will be unthinkable. The sophistication of this new space will be like nothing that was witnessed in the past epochs of warfare and collaboration. You need not look far to imagine this new reality, as was the case in the TV show, “The Expanse”.

The U.S. Space Force: Service to Strategic Linchpin

The emerging joint command structure and the rewrite of strategic deterrence theory have been made possible by the maturation of the U.S. Space Force, the first new branch of the military in 73 years. The organization that

Continued on pg 29



Sputnik, the first artificial satellite, was launched into an elliptical low Earth orbit by the Soviet Union in 1957 as part of the Soviet space program. (Photo courtesy of National Geographic)

began as a small one which concentrated on satellite protection has since expanded to have a 50,000-person force with its own unified combatant command, its own acquisition agencies and forward deployed forces on the surface of the moon.

In 2076, space operations combine AI-driven battle management systems capable of identifying and nullifying threats in milliseconds, swarms of autonomous satellites that crawl through broken spacecraft like mechanical swarms, and quantum-secure communications that cannot be intercepted or jammed. National security space is designed to be resilient: rather than having a small number of exquisite billion-dollar satellites, the force uses thousands of small and inexpensive and rapidly replaceable nodes in proliferated constellations. When a Chinese anti-satellite laser blinded a major U.S. missile-warning bird in 2062, our system was able to recycle itself in 48 hours with on-orbit 3D-printed spares and the quick-launch vehicles lifted off-mobiles into space.

This change in doctrine has been extensive. The previous focus on asset protection has been replaced by domain dominance. Space Force defenders now talk of dynamic space superiority --the capability to maneuver, deceive and reconstitute at a greater speed than any enemy. Scenarios in which U.S. forces can deny an adversary access to cislunar space over the course of weeks are routinely simulated in wargames conducted at the Schriever Space Force Base in Colorado as well as protecting commercial mega constellations which carry 90 percent of global data traffic.

Geostationary and Above Great-Power Competition

Great-power competition has long since spilled out of geostationary orbit into cislunar space and the asteroid belt. Strategic value of lunar industrial bases and interplanetary logistics centers cannot be overestimated; they have turned into the new high ground of the 21st century.

The Chang-e Industrial Zone in the lunar south pole that has been in operation since 2058 provides the helium-3 to be used in fusion reactors, rare-earth metals to be used in quantum computers and water ice, which is refined into rocket propellant. The United States, together with the Artemis Accords countries, runs the bigger Shackleton Industrial Complex in the area. These two are mere 40 kilometers apart, a very uncomfortable distance in case both have defensive directed-energy batteries. A close call was made in the year 2071 when the Chinese robotic mining rover flew above an unmarked boundary line; this incident led to emergency consultations through the newly formed Lunar Stability Commission and highlighted how much economic competition can turn into crisis.

Another layer has been added to the mining of asteroids. The trillions-annually worth of platinum-group metals is now mined by the U.S.-led consortium who seized and anchored the asteroid 2016 HO3 in lunar orbit in 2064. These materials have reduced the price of electric-vehicle batteries on earth and hypersonic vehicles. In the meantime, the Russian deep-space station close to the L2 Lagrange point acts as a resupply station to its nuclear-powered cargo tugs, which raises the issue of forward-based weapons in the Earth-Moon system. Space security and economic security are no longer different. In a case where 15% of the satellite fleet on Earth was temporarily incapacitated by a solar storm in 2069, the price of lithium shot up 400 percent overnight, due to the inability of orbital refineries to provide processed asteroid ore. Countries that lacked access to space resources were left in a strategically compromised position, evidence that management of the supply chain is now 384,000 kilometers distant.

Integration of Civilian and Commercial Space: The New Space Economy

The military field is not a vacuum. A civilian economy worth billions of dollars is also powered by space by 2076. Solar powered orbital data centers process exabytes of climate and health information on earth. The zero-gravity pharmaceutical factories of the private companies produce versions of insulin that are impossible to produce on the ground. Space tourism -- which used to be the recreation of a billionaire -- is now a middle-income holiday destination: a weekend at the Hilton Lunar Gateway or a honeymoon cruise to the rings of Saturn using nuclear-electric propulsion. These business processes bring about new weaknesses and openings. In 2073, the U.S. Space Force made the response of a non-state actor (later linked to a rogue orbital syndicate) who tried to hijack a pharmaceutical factory by employing a cyber-electronic soft kill, which just isolated the station and the private security contractors recovered control. This event resulted in the Orbital Commerce Protection Act that officially incorporated commercial operators into national defense planning.



A depiction of a future Artemis Moon Base Camp. (Photo courtesy of NASA)

The Policy Frameworks in the Age of Tearing Treaties

Older treaties drafted in the 1960s, the Outer Space Treaty, the Moon Agreement, have been worn down by the new realities to a great extent. More than 25 countries and three giant trading blocks are in operation in space. Non-state actors, such as asteroid-mining startups or orbital data brokers, have the power previously held by superpowers.

In 2076, deterrence will be based on a complex combination of hard and soft power. Hard power consists of orbital defense systems of high-energy lasers and co-orbital interceptor drones, and ground-based “rods-from-God” kinetic systems. Soft power is also critical: the extended Artemis Accords have 47 countries, and they impose uniform rules of the road to traffic control, debris control, and resource recovery. The forerunners of this technology are the annual International Space Stability Summit held in the United States, in which the norms against weaponizing

the polar ice of the Moon or the artificial creation of Kessler-syndrome events are negotiated in real time.

Space stability is still dependent on competition versus cooperation. Shared orbits (particularly the congested cislunar corridors) are operated in an AI-mediated construct by having the satellites (traffic cop) automatically deconflict paths. However, the wrong perception can grow at a fast rate: In 2067, a U.S. surveillance drone was flying over a Chinese cargo tug too closely, under the threat of escalating into an even larger conflict, until real-time video feeds and third-party confirmation by the European Space Agency cleared the issue.

Risk Scenarios and the Human Element

New risks are brought by the complexity of the domain. A solar superstorm the magnitude of the 1859 Carrington Event would wipe out space infrastructure worldwide in a few months. An intentional cyber–Pearl Harbor against mega constellations would cripple both

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current armies and economies at the same time. Even the unintentional crashes like the two dead satellites in 2059 that formed a debris cloud, causing a threat to the International Lunar Gateway, emphasize the vulnerability of the commons.

Nonetheless, people are still at the center stage. The children born and who grew up in lunar gravity or in orbital stations will be the first generation of space natives and will reach their adulthood in the year 2076. Their views of sovereignty, property rights, and environmental custodianship will upset Earth-centric assumptions. Will they see the Moon as an Earth province or a frontier world?

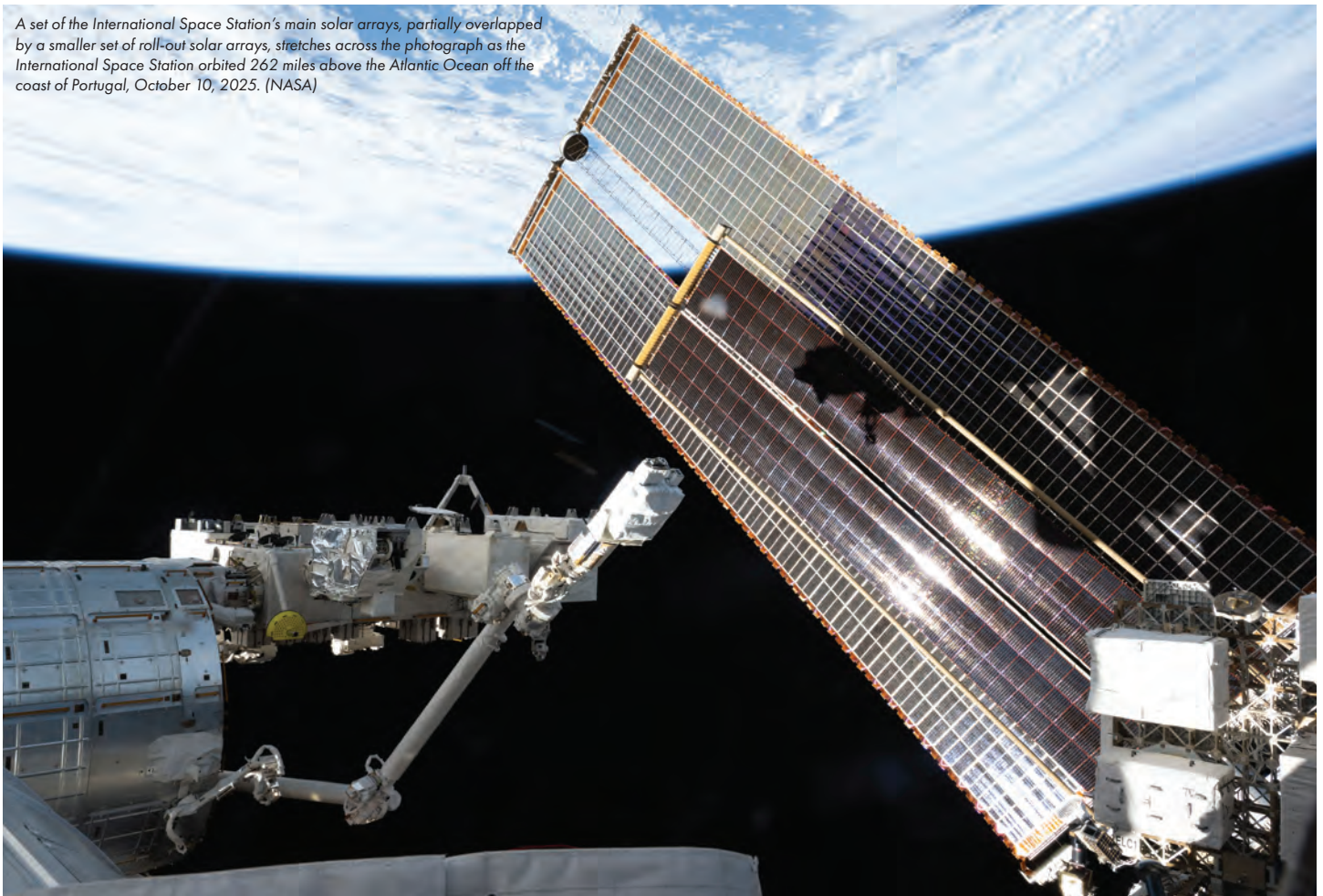
Lasting Leadership: Tradition and Transformation

Finally, the U.S. space policy in 2076 is both a continuation and a revolution. The art of space as a warfighting domain is indispensable; no serious leader can deny the fact that in the future the battle can be won or lost--or even avoided--by the possession of the high ground. However, what will be required of enduring American leadership is something more ambitious; the capacity to create a sustainable, rule-based order outside of the planet.

Balancing security and stewardship, power and principle, will mark the next century of American space power. Should the United States be able to use its innovative spirit, its democratic alliances, and its historical dedication to the rule of law, the tercentennial fireworks of 2076 will not be only another birthday celebration of a nation. They will be the sign of the time when humanity finally became a multi-planetary race, when US leadership stood in the light of the steadfast, leading stars.

Daniel "Sphinx" Dant is a retired USAF Colonel and space weapons officer. He is Vice President for Strategic Initiatives at KBR, sits on the Board of Directors of Maritime Resilient Solutions, and supports the Space Force Association's National Spacepower Center as an Executive Committee Member.

A set of the International Space Station's main solar arrays, partially overlapped by a smaller set of roll-out solar arrays, stretches across the photograph as the International Space Station orbited 262 miles above the Atlantic Ocean off the coast of Portugal, October 10, 2025. (NASA)



The Orbital Intelligence Revolution

Jes Kalmanson



AI generated illustration courtesy of Jes Kalmanson

We stand at the threshold of an orbital intelligence revolution. Where there is a convergence of AI, quantum computing, and autonomous space infrastructure so impactful it will blur the boundary between Earth and space, transforming the cosmos from a destination into a seamless extension of our civilization. This is not a distant future; it is already underway and gaining momentum at an exponential rate. These are not endpoints, but a door opening to something far greater. The evidence is visible in laboratories orbiting Earth, in quantum technology insertion, and in AI and autonomous operations being fielded. What emerges next is not a collection of isolated breakthroughs, but a convergence that, taken together, redefines what is possible for every person on Earth and beyond.

In the future, critical medical drugs are being manufactured in microgravity aboard commercial space stations enabling crystal structures impossible to create on Earth, accelerating delivery and making necessary treatments accessible to everyone. In that same microgravity environment, material science is being re-imagined. Fiber optic cables are pulled in space faster and purer than possible on Earth. Alloys and composites formed in the absence of gravity achieve structural properties that Earth-bound

manufacturing cannot replicate, opening entirely new possibilities for aerospace, medicine, and construction. Quantum computing untangles the complex molecular code of cancer, compressing drug discovery timelines from decades to months.

The same computational power unlocks the science for synthetic biology and food replication, enabling synthesized nutrition that could end food scarcity for a civilization spanning two worlds. Space-based solar arrays are engineered to beam clean, unfiltered solar energy back to Earth with the potential to supply the world with a transformative source of clean, renewable energy. Microreactors, engineered for on-orbit asset maneuvering, having been perfected now provide autonomous power that enables continuous operations from Earth to Mars.

This is the inflection point that changes everything, and not for a few but for all humans. Humanity has been limited by the tools we have, only sailing as far as our ship could take us, discovering only as much as our instruments could measure, and only curing what our chemistry could reach. By 2076, when tools become autonomous, persistent, and self-sustaining, the ceiling on human efforts will not just bend, it will disappear

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entirely. These new tools will not just usher in a transformative new era but will remove the constraints that have always bound the outer edge of human ambition. Intelligent, autonomous systems will manage the sensing, communications, and decision-making infrastructure that underpins modern civilization not just for national security, but for medicine, energy, climate, and exploration. The same microreactors that are powering on-orbit assets will power permanent settlements on the Moon. Quantum-AI networks will process data at speeds that make today's supercomputers look primitive. Persistent, self-healing constellations will operate without human intervention across cislunar space and beyond, freeing humanity not from responsibility, but from limitation.

When autonomous systems handle the infrastructure of space, human attention and human genius are unleashed for those questions that machines cannot answer. These are the questions that define civilizations, the ones that require curiosity, courage, and the willingness to venture into the unknown without a guaranteed answer waiting at the other end. What cures remain locked in the biology of microgravity that we have not yet thought to ask or new materials to discover in deep space that pivot medicine forever? What do we discover when we push beyond Mars, beyond the asteroid belt, into the deeper solar system not because we have to, but because for the first time in history, we finally can? The answers to these questions are not yet written, and the orbital revolution will give humanity the capability to choose the answer without limitations.

This, above all else, is the promise of the orbital intelligence revolution. Not that technology replaces human genius, but that it amplifies it. The space infrastructure of 2076 will not be the destination. It will be the foundation from which humanity's greatest leaps are launched in medicine, in energy, in exploration, and in the enduring pursuit of what lies beyond the next horizon. America's 250 years of ingenuity, sacrifice and relentless curiosity have brought us to this threshold of explosive innovation, a moment unlike any in our history. The Orbital Intelligence Revolution, built on this moment, will define the next 50 years, not by the technology we build, but by the boldness and ferocity of those who refuse to let the moment pass.

Jes Kalmanson, Ph.D., is Vice President and Chief Technology Officer for Space Systems and Solutions at Peraton, where she leads technology strategy and innovation across the nation's most critical space and intelligence missions. A recognized thought leader at the intersection of space systems, autonomous technology, and artificial intelligence, she has brought nearly two decades of experience shaping enterprise technology strategy across the Intelligence Community, Department of War, and defense industry. She holds a Ph.D. in Mechanical Engineering from the University of Maryland and has contributed to more than 19 peer-reviewed publications.



This image, released on June 26, 2026, features the globular cluster NGC 6723, sometimes called the Chandelier Cluster. Like its namesake, it sparkles with countless lights. However, each 'lightbulb' in this chandelier is an individual star 27,000 light-years away in the constellation Sagittarius. (ESA/Hubble & NASA, A. Sarajedini, G. Piotto)

The Cislunar Anchor: Securing Operational Reach Through Self-Sustaining Autonomy

Sydney Ngo

On April 1st, 2026, four astronauts achieved liftoff into space from Launch Pad 39B at NASA's Kennedy Space Center. After swinging around the Earth, the Orion spacecraft carried them as they looped around the Moon and returned home on April 10, 2026. The mission lasted 9 days, 1 hour, and 32 minutes. This event is not only significant because it is the first crewed mission beyond low Earth orbit (LEO) since Apollo 17 in 1972, but also because it signals the need to pivot from a geocentric regime to a cislunar one.

While geocentric technologies and operations remain essential to current defense infrastructure, the gateway to sustaining United States dominance lies in cislunar spacepower. Cislunar space is a largely uncharted domain, where the rules have not been clearly defined. This presents an opportunity for the U.S. to be the nation that shapes humanity's presence in space.

As of now, a leading driver of this endeavor is commercial integration, where U.S. space exploration has benefited from public-private partnerships. The Artemis II mission that was mentioned is a recent example of that. However, what happens when public and private sectors diverge, and such systems fail? Will partnerships that were once efficient turn into a vulnerability? These risks cannot be ignored. For the U.S. to project dominance and maintain its presence across a 270,000-mile cislunar radius, the United States Space Force must set a balance between fostering engineering capabilities for self-sufficiency and integrating commercial technologies into system architecture.

To establish operational reach and space domain awareness (SDA) in the cislunar regime, the Space Force should prioritize the Earth-Moon Lagrange points, L1 (between the Earth and Moon) and L2 (behind the Moon). L1 has the advantage of mitigating solar "exclusion zones," a volume of space where the sun is so bright that it prevents spacecraft from being detected by optical sensors. However, placing sensors and tracking technology at L1 would provide additional coverage of potential threats from adversaries attempting to conceal space-based weapons in places that are difficult to detect or track.

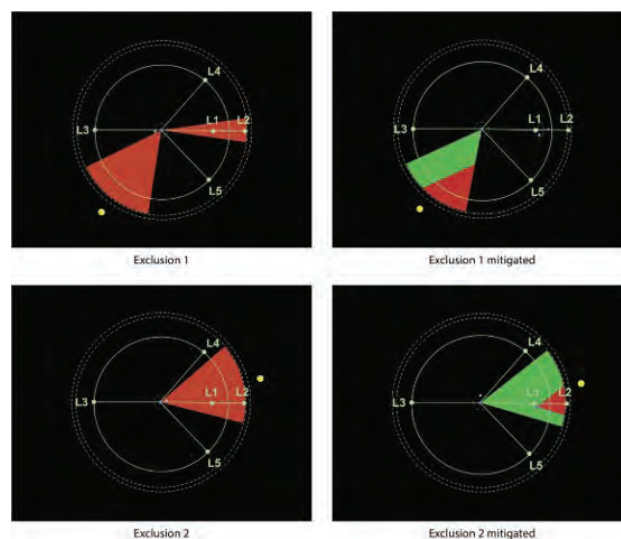


Figure 1: The red cones in the images on the left depict unmitigated solar exclusion zones. The green areas in the right images depict the potential mitigation and gained observability of placing a sensor at L1. In all images, the yellow dot represents the sun. (Image credit "Understanding Space Frontier Areas: Strategy in Cislunar Space and Beyond")

Additionally, L1 and L2 would allow for constant lunar surveillance and future "GEO-like" lunar missions. This is because L1 and L2 maintain a constant position relative to both the Earth and Moon as they orbit. In other words, surveillance at these points would provide a constant view of the same area on the lunar surface. China has already used this to its advantage. To land a spacecraft on the far side of the moon (where L2 is located) is difficult due to the Moon blocking communication. China's Queqiao-1 launched in 2018 and is currently orbiting at L2. This allowed China to communicate on the far side of the Moon, leading to Chang'e-4 being the first spacecraft to successfully land on that side. Queqiao-2 was launched in 2024, giving China the ability to support missions across the whole of the Moon. This signals further urgency for the U.S. and the Space Force to establish cislunar operations at L1 and L2.

In 2024, the Joint Commercial Operations (JCO) began collaboration with the 19th Space Defense Squadron to explore and experiment with commercial SDA capabilities in tracking orbits for extra-GEO and cislunar regimes, with plans to adopt these capabilities across their satellites in 2025. While commercial integration allows the Space Force to reduce mission completion times and manpower by exploiting outside expertise, it could lead to internal technical stagnation. Furthermore, with the rise of

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private control over space operations, there is a greater risk that the private sector’s financial troubles, technical setbacks, and internal disputes could disrupt the Space Force and government operations.

One recent example of this was in June 2025, when Elon Musk threatened to decommission SpaceX’s Dragon spacecraft after a dispute over government contracts, which NASA depended on to transport astronauts into orbit. It is of the utmost priority to prevent a similar situation from occurring in the Space Force.

	Efficiency Model (market-optimized)	Resilience Model (security-optimized)
Main goal	Lower cost, faster deployment	Continuity of capability under stress
Market structure	Consolidated, winner-takes-most	Diversified providers with overlapping capability
Cost	Lower, short-term expenditure	Higher upfront investment to insure against disruption
Shock absorption	Disruption can cascade across the system	Alternatives available to absorb and contain shocks
Leverage risk	Elevated when one firm dominates	Diffused across multiple actors
Strategic implication	Efficient but potentially fragile	Structurally durable, preserving sovereignty

Figure 2: Adopting a resilience model could help the Space Force operations recover during setbacks and maintain dominance in outer space. (Image credit Svetla Ben-Itzhak and The Conversation U.S.)

One recommendation to create a more resilient infrastructure is for the Space Force to further advance its robotics capabilities. In the context of a cislunar regime, this could include technology for in-space resource utilization (ISRU) and autonomous repair. Investments in these areas have enormous benefits for the Space Force, such as the ability to repair damaged weapons and sensors without the need for human intervention. Materials used for parts could be mined from lunar regolith and manufactured using space-based 3D printers. To help transport and operate these printers, solutions such as cable-driven parallel robots are being tested for feasibility and durability in the lunar environment.

Ultimately, security capabilities in 2076 and beyond will depend on self-sustaining readiness and resilient infrastructure. This does not mean that all outside collaboration should end, because without it, overall progress would slow dramatically. What it does mean is that US leadership in the cislunar regime and beyond needs to have a solid foundation to fall back on if external capabilities fail.



MarCO-B, one of the experimental Mars Cube One (MarCO) CubeSats, took this image of Mars from about 11,300 miles (18,200 kilometers) away shortly before NASA’s InSight spacecraft landed on Mars on Nov. 26, 2018. (NASA/JPL-Caltech)

Enlisted Education as Deterrence in Space: Signaling Adaptation and Endurance

Chief Master Sergeant Amber A. Abramowski

The views expressed are those of the authors and do not reflect the official guidance or position of the United States Government, the Department of Defense, the United States Air Force, or the United States Space Force.

Deterrence in the space domain extends far beyond the threat of direct physical attack on satellites. Space competition is characterized by ambiguity, rapid technological change, and the inherent fragility of orbital systems. In this environment, deterrence increasingly hinges on how adversaries assess a state's ability to adapt, regenerate, and sustain space operations under pressure (Jervis, 1979). Education, when deliberately structured and visibly integrated into space operations, functions as a latent form of space power that shapes these assessments.

Unlike terrestrial domains, space operations unfold under persistent competition rather than clear thresholds of war. Interference, disruption, and signaling often occur below the level of armed conflict, where attribution is contested and escalation risks are high. In such conditions, what matters most is not only what capabilities a state possesses today but whether it can learn faster, reorganize more effectively, and respond more creatively than its competitors (Mazaar, 2018). Education directly informs these perceptions. Specifically, enlisted education in the space domain is paramount to this theory.

The Enlisted Corps as a Space Power Capability

In space, education does not deter by threatening punishment as in classical deterrence theory (Lupovici, 2023). Rather, it contributes to deterrence by denial, eroding adversary confidence that interference or escalation will produce lasting advantages (Schelling, 1966). Well-designed space education systems communicate three strategically important signals:

1. **Credible Future Capability:** Space technologies, concepts of operation, and command-and-control arrangements evolve more quickly than most acquisition timelines. Adversaries thus assess whether a state can generate operators, analysts, and strategists capable of adapting architecture, doctrine, and employment concepts as conditions change (Morgan, 2012). A focused, dedicated enlisted education pipeline signals that a nation's operational advantage will not fade with the next technological shift.
2. **Resilience and Regeneration in a Vulnerable Domain:** Space systems are difficult to repair, replace, or reconstitute quickly. A state that can regenerate expertise, rebuilding operational understanding, planning capacity, and decision-making processes after disruption reduces the effectiveness of attrition strategies aimed at degrading space advantage over time (Lupovici, 2023; Schelling, 1966).
3. **Strategic Uncertainty:** A highly educated enlisted force is less predictable. Their advanced understanding allows them to respond in novel ways, reconfigure architectures, and execute tactics that complicate an adversary's planning. This tactical unpredictability creates strategic uncertainty, raising the perceived risks for any aggressor (Jervis, 1979; Schelling, 1966).

Translating Enlisted Education into a Deterrent Effect

For education to act as a deterrent, it must be visible and credible. An adversary must observe that the enlisted force is not only well-trained but also educated to integrate into key operational roles and decision-making processes. This requires a clear and demonstrable link between education, force design, and operational authority.

When an adversary sees a force that consistently produces technically masterful enlisted personnel and empowers them

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with operational influence; it must adjust its assessment of that force's ability to manage escalation, absorb disruption, and sustain a long-term competition.

Institutionalize Space Education as a Deterrence Instrument

Leaders at all levels need to explicitly recognize space-focused education as a core component of space deterrence strategy and integrate it into force development, operational planning, and strategic signaling.

1. **Strategic Space Infrastructure:** Space education pipelines should be treated as strategic infrastructure. Education relevant to space operations, intelligence, cyber, doctrine, and escalation management should be integrated into space strategy and resourcing decisions, signaling that human capital is foundational to sustained space power. Enlisted education pipelines should be resourced and protected as critical infrastructure, signaling that the human capital of the enlisted corps is foundational to enduring space power.
2. **Mission-Aligned Space Pathways:** Establish mission-aligned space education pathways that visibly connect education to operational roles. These pathways should move personnel directly from advanced education into positions that reinforce credibility by demonstrating that learning translates into operational capability.
3. **Incorporation into Deterrence Assessments:** Space education outcomes should be incorporated into deterrence and readiness assessments. Indicators such as space-domain expertise, cross-functional fluency, and adaptive planning capacity should be considered as measures of deterrence by denial rather than workforce development alone.
4. **Leveraging Space Education for Strategic Signaling:** Advanced enlisted education needs to be recognized as a core component of its space deterrence strategy. Space education investments should be used for strategic signaling. Public-facing programs, international military education exchanges, and competitive selection processes should be framed as long-term commitments to space resilience and adaptive advantage, shaping adversary expectations about U.S. capacity to sustain operations in a contested domain. This should also leverage University Partnerships with world-class institutes enhancing the legitimacy of education.
5. **Integrate Education into Readiness Assessments:** Deterrence and readiness assessments must include metrics related to the enlisted force's expertise, such as cross-functional technical skills and adaptive problem-solving capabilities, treating them as key indicators of deterrence by denial.

Conclusion

In space education, deterrence is less about threatening destruction and more about denying adversaries the confidence that interference will yield decisive advantage. Adversaries must believe that disruption will not result in lasting gains, that escalation will be managed rather than exploited, and that adaptation will outpace interference. Enlisted education, when deliberately structured, integrated, and signaled serves as a quiet but powerful form of space deterrence. By shaping perceptions of resilience, adaptability, and uncertainty, education strengthens space security while reducing incentives for conflict in this increasingly contested domain.

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