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Key Points

Today, all U.S. military services and operations rely on space capabilities and effects delivered from the on-orbit architecture. Assured access to space and robust launch infrastructure is a critical foundation for sustaining space superiority.

Launch operations remain a challenging mission and must not be taken for granted.

The U.S. Space Force (USSF) must take steps to increase launch confidence, capacity, and cadence while reducing costs to deliver the space architecture needed for great power competition and contesting space superiority.

Despite a historic launch rate and multiple potential launch providers, national security space launch (NSSL) is currently less robust than many realize.

USSF can help reach its launch goals by diversifying both launch providers and launch sites, continuing its research and development investments in rocket technology, and actively monitoring the launch supply chain. These efforts should be a national priority.

Launch: The Fundamental Prerequisite for Space Superiority

by Col Charles S. Galbreath, USSF (Ret.)
Senior Fellow for Space Studies, the Mitchell Institute Spacepower Advantage Center of Excellence

Abstract

As the Chief of Space Operations (CSO) Gen B. Chance Saltzman established at this year's Mitchell Institute Spacepower Security Forum, "For our service, space superiority is the first core function. It is the ability to contest and, when necessary, control the space domain at the time and place of our choosing." At the most fundamental level, the Space Force must have assured access to space to leverage the benefits of the space domain. For systems to create desired effects in, from, and to space, they must first get to space. Moreover, the relationship between the scale and scope of necessary on-orbit architectures and the scale and scope of launch infrastructure is interconnected. Consequently, the nation requires a robust set of launch options. This, in turn, demands developing a national launch enterprise with the right levels of confidence, capacity, cadence, and cost. Achieving these goals necessitates commitment from Department of Defense leadership and Congress when it comes to both policy and budget decisions. It also compels the U.S. Space Force (USSF) to smartly accept greater levels of risk and to weather inevitable failures inherent on the path to progress. The service must retain a diverse set of launch providers, expand options for launch locations, continue to invest in rocket research and development (R&D), and maintain awareness of consequential supply chain issues. Given the importance and ubiquity of space-based capabilities to both everyday life as well as to the most basic of military operations in support of global safety and security, these efforts should be a national priority.

Figure 1: An Atlas V rocket launches from the Space Launch Complex (SLC-41) at Cape Canaveral Space Force Station, FL with two satellite payloads for the USSF-12 mission.

Credit: U.S. Space Force Photo, DVIDS

Introduction

When the U.S. Space Force was established in December of 2019, it was a heralding that leadership recognized both the criticality of space and that, without it, not only would the country struggle to maintain a credible deterrent but it would also be difficult to defend our way of life. It signaled a recognition of a real and growing threat and that space is a national security imperative. For the U.S. Space Force to deliver on its mission to "secure our Nation's interests in, from, and to space," it must have assured access to space. No nation or power on Earth can organically leverage capabilities in, from and to the space domain if they cannot reach orbit. Assured access to space demands a robust launch infrastructure and is critical as the nation manages a series of threats around the globe, especially China. The technical challenges of launch operations must not be taken for granted; the United States must always maintain the ability to deliver space capabilities and generate space effects at a pace and scale sufficient to achieve national objectives ahead of competitors. That is why it is urgent for U.S. decision-makers to ensure the viability of the country's launch enterprise with a diverse set of providers and locations. Failing to do this risks ceding the space advantage that enables all military operations and allowing bad actors to deny or even control the space-based capabilities that underpin our freedom and prosperity.

To have a war-winning space architecture, the United States must have a war-winning launch infrastructure. Unfortunately, despite multiple potential providers, the United States currently has a single launch provider for medium and heavy national security space launch missions.[1] Moreover, the relationship between on-orbit architectures and launch capability is dynamic and multi-faceted, but discussions about the former are often disconnected from the latter. This invites unnecessary risk. The United States has the on-orbit architecture it does because of available launch capabilities, which are a result of balancing needs with four key launch factors: confidence, capacity, cadence, and cost.[2] There is tremendous interplay between these variables.

A better understanding of the relationships between confidence, capacity, cadence, and cost can help optimize future operational and investment decisions, ultimately defining the United States' ability to achieve space superiority. To illustrate how these factors interact, consider an example that starts with a notional large, billion-dollar satellite that took over 10 years to design and manufacture. Such an investment would increase the importance of launch confidence and capacity, allowing increases in cost to accommodate a higher level of

Understanding Confidence, Capacity, Cadence, and Cost

Confidence, or level of assurance, is the degree to which the risk of failure is minimized. Satellite owners who spend millions or billions of dollars and years of effort to build a satellite want to have a high degree of confidence it will reach the proper orbit.

Capacity is the size and mass limitations of the launch vehicle. A combination of rocket performance and payload fairing dimensions, capacity creates upper limits on spacecraft size and capability. Until on-orbit manufacturing and assembly become routine, the majority of spacecraft must continue to follow the constraints dictated by the launch vehicle.

Cadence, or launch rate, is the time interval between launch opportunities. Planners of satellite constellations will factor launch cadence into the design life of vehicles and constellation size. More frequent launch opportunities can enable lower design life and a larger constellation size.

Cost is the capital required for the booster, fuel, range, and operations necessary to achieve orbit. Naturally, the goal is to increase confidence, capacity, and cadence while decreasing cost, all to an acceptable level.

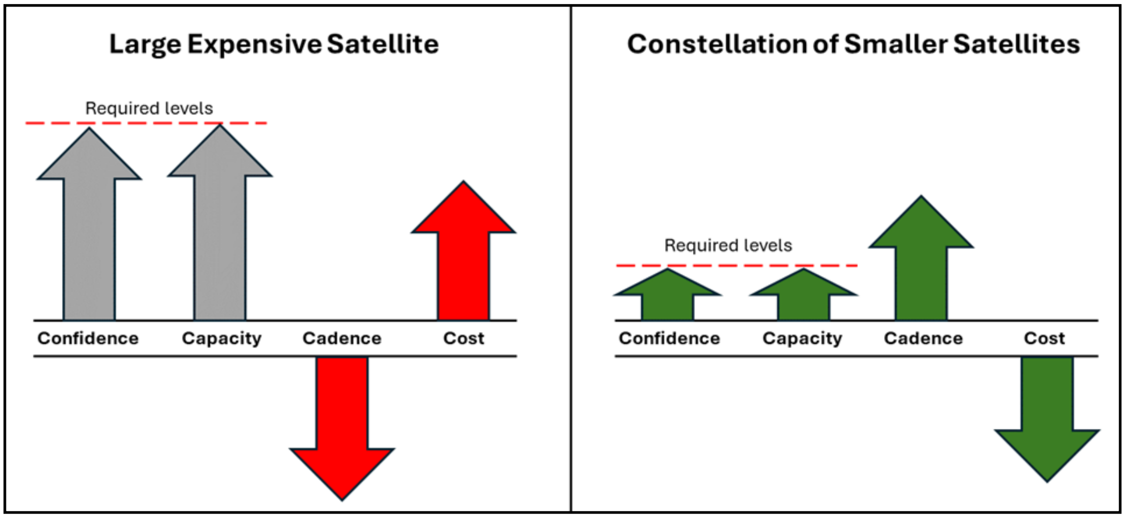

Figure 2: Comparison of two launch paradigms. The first drives low cadence and high cost to achieve necessary confidence and capacity levels. The second, with reduced confidence and capacity requirements, enables increased cadence and decreased cost.

Credit: Mitchell Institute

launch assurance and size. This will also likely increase the time to prepare the launch vehicle to decrease the risk of failure, thus decreasing the cadence of launch. While this may be acceptable for a one-of-a-kind satellite, it could preclude the launch of a large constellation. Now, instead of a single large, expensive satellite, consider a large constellation of smaller, cheaper satellites. The calculus shifts to enable a decreased level of confidence in any one launch to decrease the cost and increase the launch rate. Further, the decreased satellite size now enables smaller launch vehicle options, potentially from multiple locations, or manifesting multiple satellites on a single launch. Conversely, a large constellation of small satellites would not be feasible without a launch capability with a high enough cadence and low enough cost factors. The linkage is undeniable. As the Space Force makes significant adjustments to make its on-orbit architecture more resilient, it must also increase the resilience of its launch enterprise.

As another example, consider the relationship between confidence and cadence. Given that launches occasionally experience technical failure, some have joked that launch vehicles are the greatest natural predators to satellites. While the remark may be humorous, it is grounded in reality. Today, even very successful launch providers still have issues. Case in point: after over 300 successful launches, sometimes two in a week, a SpaceX Falcon 9 experienced a failure resulting in 20 Starlink satellites deploying to an unusable, shallow orbit.[3] This resulted in a halting of operations for a month as crews researched the root cause and implemented corrective action. Similar delays have occurred after other failures and impacted multiple families of launch vehicles that contained common components. As an example, the Space Shuttle program stood down for two years and eight months after the Challenger disaster and two years and five months after Columbia.[4] While these were driven by safety concerns related to human space flight, it clearly illustrates the fundamental relationship between confidence and cadence.

In the United States, flight safety, with its inherent impacts on confidence and cadence, is of utmost importance. But the same cannot be said of its nearest launch competitor, China. With four land-based and one sea-based launch site and a dozen variants of the Long March rocket, China boasts an impressive launch capability.[5] In 2023, China conducted 67 launches, with plans for 100 in 2024.[6] While the United States enjoys the advantage in geography, enabling it to launch safely over water rather than populated areas for a wide range of orbits, China's launch options include flight profiles over land, including populated areas. A recent incident involving a launch that Chinese officials deemed a "complete success" rained debris on a village.[7] China's launches also have an increased probability of generating orbital debris. In its first launch of a proliferated low Earth orbit (pLEO) constellation, the Chinese booster broke up into a cloud of over 700 pieces of debris.[8] In both cases, China is continuing to press forward rather than correct an issue that did not preclude the payload from reaching orbit. This is not to suggest that the United States should adopt the Chinese model by any stretch, but it does highlight the high priority China places on becoming a space leader. This mindset suggests a potential fifth factor: criticality.

As China continues to demonstrate today, the criticality of becoming a leader in space can override all other factors. Existential interests are in play. A similar mindset existed in the United States during the early days of the first Space Race. Establishing on-orbit capability in the race against the Soviet Union was a powerful motivator and meant persisting after multiple failures despite the great cost. The USSF today could similarly adopt a culture that accepts some inevitable failures as progress toward success. While the United States will steadfastly pursue the safety of astronauts and citizens on the ground, the recognition that some satellites and missions can accept a higher level of risk is transformative. Considering the stakes of great power competition, the United States must make responsible risk acceptance decisions for launch because the consequence of ceding space superiority is catastrophic. Without the benefits of space capabilities, not only does the basic fabric of 21st-century life begin to unravel but it would also blunt the ability of the United States to project power globally, thus removing a restraint against Chinese and Russian military aggression.

Historical Context for Space Launch

Before addressing where the United States should head with its launch enterprise, it is important to understand its origins and current state. At the beginning of the Space Age, the United States leveraged rockets originally developed as Intercontinental Ballistic Missiles (ICBMs) for space launch duties assigned for both NASA and military missions. Systems like Atlas, Thor, and Titan were a few of the ICBMs turned into launch capabilities. The only exceptions to this were the Saturn IIB and Saturn V rockets as part of the Apollo program. It was not until the 1990s that Air Force Space Command initiated a new class of Evolved Expendable Launch Vehicles (EELV), which achieved operations with the Atlas V in 2002 and Delta IV in 2004. While Lockheed Martin developed the Atlas V and Boeing the Delta IV, United Launch Alliance (ULA) took over launch operations for both vehicles in 2006 to reduce overhead.[9] While these vehicles served as the primary military access to space until the mid-2010s, other options did exist, such as the Minotaur launch vehicle, which uses a Minuteman Missile as a first stage.[10] Importantly, all of these launch designs, whether borrowed from a missile rocket inherently meant to terminate or bespoke for space launch but still expendable, were strictly one-time-use systems. This fact has always driven high launch costs and lower launch frequency, or cadence.

The drive to lower cost and boost cadence has driven a pursuit of rocket reusability. Concepts in this vein include reusable first stages, upper stages, and fully reusable systems. Results have yielded varying degrees of success. The earliest example was the 1960s X-20 Dyna-Soar, originally intended as a piloted hypersonic glide vehicle but redesigned for orbital flight.[11] While never flown, it does represent the start of an ongoing quest. From 1981 to 2011, the

United States operated the Space Shuttle with reusable solid rocket boosters and orbiters.[12] Another approach for reusability could be considered the air-launched Pegasus rocket, which has been operational since 1991 for payloads up to 1,000 pounds.[13] While considering an aircraft as a first stage is not a traditional view, it does afford an element of launch flexibility. The Space Force currently operates the X-37B, Orbital Test Vehicle, which is basically a reusable upper stage.[14] The SpaceX Falcon 9 and Falcon Heavy, with reusable first-stage boosters, are the current standards for reusability and have achieved significant decreases in cost and increased cadence. SpaceX is now pursuing a fully reusable super heavy launch vehicle, Starship, flown from Texas.[15]

Whether expendable, partially reusable, or fully reusable, a reliable launch capability is only part of the equation for assured access to space—the range is the other significant piece. The United States enjoys geography that enables over-ocean launches from both the East and West Coasts. The Eastern Range, located at Patrick Space Force Base in Florida, is the busiest U.S. range, with 72 orbital launches in 2023 and a projected 111 missions in 2024.[16] The Western Range at Vandenberg Space Force Base in California conducted 30 launches in 2023, with 34 planned in 2024.[17] Both sites offer distinct advantages: launches from the Eastern Range use the Earth's rotation to gain a velocity boost, and launching from the Western Range enables better access to polar orbits. But both sites also have limitations. Weather, such as frequent tropical storms on the East Coast and low visibility from fog on the West Coast, can have a significant impact on launch cadence. For example, from 1990 to 2008, there was an average of 21 launch delays per year due to weather at Kennedy Space Center on the Eastern Range.[18] Weather at the two primary launch locations remains a schedule-impacting factor today.

Sea Launch

In an effort to increase flexibility while not launching on a path above populated areas, the company Sea Launch operated a platform and command ship out of Long Beach, California from 1995–2014. They successfully conducted 32 launches during that time. However, the company filed for bankruptcy before mothballing both the platform and ship.

Source: "What Ever Happened to Sea Launch?" *Space Daily*, October 31, 2017.

State of Modern Launch

The current Space Force launch capability falls under two main programs, National Security Space Launch (NSSL) and the Orbital Services Program 4 (OSP-4).[19] NSSL, formerly the EELV program, is now in its third phase and has contracted SpaceX, United Launch Alliance (ULA), and Blue Origin.[20] SpaceX is continuing their operations of the Falcon 9 and Falcon Heavy, while ULA and Blue Origin are bringing on new rockets after ULA's retirement of the Delta IV and Atlas V booster from national security space launch in 2024.[21] ULA's new entry to NSSL is Vulcan, an expendable rocket design, which completed its second, and final, certification launch on October 4, 2024.[22] Blue Origin's New Glenn is designed to be reusable, and its first launch is scheduled for late 2024. ULA and Blue Origin both use the BE-4 engine, with two on Vulcan and seven on New Glenn.[23] To foster innovation and reduce cost, the NSSL has two lanes for tailored levels of mission assurance, or confidence in a successful launch, with one for missions that can accept higher risk in exchange for lower cost or higher cadence and one for risk-averse missions.[24]

Unlike NSSL, OSP-4 includes options for small launch vehicles at launch sites extending beyond the Eastern and Western

Company	Rocket	Category	Status	Confidence	Capacity	Cadence	Cost	Website
SpaceX	Falcon 9 and Falcon Heavy	NSSL	Operational	***	***	***	*	https://www.spacex.com/
ULA	Vulcan	NSSL	Testing+					https://www.ulalaunch.com/
Blue Origin	New Glenn	NSSL	Testing					https://www.blueorigin.com/
Rocket Lab	Electron	OSP-4	Operational	**	*	**	***	https://www.rocketlabusa.com/
Northrop Grumman	Minotaur	OSP-4	Operational	**	*	*	**	https://www.northropgrumman.com/space/minotaur-rocket
Firefly	Alpha	OSP-4	Operational	*	*	*	***	https://fireflyspace.com/
Relativity Space	Terran	OSP-4	Testing					https://www.relativityspace.com/
X-Bow	Bolt	OSP-4	Testing					https://www.xbowsystems.com/
Stoke	Nova	OSP-4	Testing					https://www.stokespace.com/
ABL Space Systems	RS1	OSP-4	Testing					https://ablspacesystems.com/
Aevum	RAVN X	OSP-4	Testing					https://www.aevumspace.com/space
Astra	Rocket 4	OSP-4	Testing					https://astra.com/launch-services/
ULA	Atlas V	NSSL	Retired	***	***	**	*	https://www.ulalaunch.com/rockets/atlas-v

Notes:

NSSL: National Security Space Launch for medium and heavy lift missions

OSP-4: Orbital Services Program Launch Contract for small lift missions

+ On 4 October 2024, Vulcan completed its second required certification launch. Certification is pending with two operational launches planned by end of 2024.

Status indicates whether the launch vehicle is still in development and testing or if it has delivered operational payloads to orbit.

Operational assessments represent a snapshot in time as of September 2024. Insufficient data exists to assess rockets still in testing.

Cost is assessed as a total launch cost and not dollars per mass to orbit to focus on operational mission parameters in the event a rideshare opportunity is impractical.

Confidence	High	***	<1/1000 chance of failure	Cadence	High	***	Frequent launches per week or per day
	Medium	**	<1/100 chance of failure		Medium	**	Launch on schedule, typically with weeks between launches
	Low	*	<1/10 chance of failure		Low	*	Infrequent launches, typically months between launch
Capacity	High	***	Supports largest/heaviest national security missions	Cost	High	*	>$50M per launch
	Medium	**	Supports medium or multiple small payloads		Medium	**	<$49M, and >$10M per launch
	Low	*	Supports small satellites only		Low	***	<$9M per launch

Figure 3: OSP-4 and NSSL launch providers.

Source: Mitchell Institute

Ranges. It is intended for the rapid launch of payloads as small as 400 pounds. A dozen companies are currently on contract through OSP-4: Blue Origin, Stoke, ABL Space Systems, Aevum, Astra, Firefly, Northrop Grumman, Relativity Space, Rocket Lab, SpaceX, ULA, and X-Bow.[25] While some are already demonstrating a pattern of successful launches, others have yet to achieve their first launch. The smaller class of booster enables launch operations from diverse locations, including Wallops Island, Virginia, and Kodiak, Alaska.

On the surface, the state of launch in the United States seems to be on a solid footing with multiple launch providers and locations. However, the state of launch is far more complex when looking at the details. Complacency and space launch are a dangerous combination. Space launch is hard—it is literally "rocket science." Failures early in development are common, and just when everything seems normalized, a catastrophic failure can occur, delaying launches and potentially sending ripple delays across multiple families of launch systems. In a time of renewed emphasis on space capabilities as part of the shift to great power competition, understanding the impact launch capabilities can have on the nation's on-orbit architecture adds increased emphasis to an already critical element of national security. Constant attention and investment are required to ensure the United States has the necessary launch confidence, capacity, and cadence at an acceptable cost to deliver the on-orbit architecture needed to deter conflict or win if deterrence fails.

Of the twelve launch providers on the OSP-4 and NSSL contracts, four are currently operationally placing payloads in orbit and only one is certified for national security space launch missions.[26] Evaluating these four against the metrics of confidence, capacity, cadence, and costs identifies that challenges remain to achieve the type of robust launch infrastructure necessary to support a war-winning on-orbit architecture. Additional effort is required to achieve a robust and resilient launch enterprise capable of responding to warfighting demands driven by crises or conflict.

Recommendations

Continue to Increase Launch Provider Diversification: Despite having three providers in NSSL and twelve in OSP-4, there is still a need to identify additional launch possibilities to improve confidence, provide a range of capacity and cadence options, and decrease costs. Both the Vulcan and New Glenn are new boosters, and challenges will likely emerge through continued testing and operations. The fact that both utilize the same rocket engine also raises concerns about potentially grounding two of the three NSSL providers if an issue with a single engine arises. Similarly, of the twelve OSP-4 providers, only six have conducted successful launches, and some have suffered significant failures.[27]

By continuing to pursue multiple launch providers, the Space Force can increase confidence in its ability to achieve assured access to space.

First, in the unfortunate event of a failure, other launch providers will be available to meet the resulting demand (assuming they do not share a failed component).

Second, and relatedly, having different providers means each is potentially relying on different supply chains and manufacturing processes. This limits an issue from grounding all space launches. In some cases, companies are employing in-house manufacturing of components, which can greatly increase the confidence in the quality of the part. Additionally, having options enables a tailored risk acceptance model to meet the desired assurance level of a given mission. This can help reduce costs and open the door for additional launch options to meet capacity and cadence demands.

Naturally, depending on the size and weight of a satellite, multiple launch providers may be able to offer the required capacity and cadence. If this is the case, satellite owners seeking to place multiple vehicles in orbit could leverage a diverse set of providers resulting in a higher aggregate launch cadence than possible with a single provider.

Finally, having multiple providers will drive down costs. Fundamentally, competition is good for consumers. Providers will seek efficiencies and partnership arrangements to maximize their business, thus providing cost savings to a user, such as the Space Force. Competition will also encourage companies to pursue innovations to increase their viability to gain new business. Novel approaches to launch processing and vehicle development, such as additive manufacturing, will likely lead to decreased costs.

Expand Launch Site Diversification: With only two primary launch locations for most NSSL missions and two for smaller launches, it is understandable that members of the House Armed Services Committee are calling for greater launch site flexibility.[28] In the advent of a significant natural disaster, such as an earthquake in California or a hurricane in Florida, the nation's assured access to space could be severely affected. In the event of a conflict with a near-peer, the possibility of an adversary targeting the handful of launch complexes at only two primary locations cannot be ignored. Risk mitigation measures, including emergency response and security, will help, but so will establishing a greater number of launch locations. In a similar tack to the pursuit of increased resilience through a proliferated on-orbit architecture, having multiple launch location options will also bolster confidence in the nation's assured access to space. Climatically dispersed locations can also help mitigate delays due to weather or capacity on a given range.

Perhaps most importantly, having alternate launch sites will enhance the ability of the nation to expand its launch cadence. By significantly increasing the rate it fields satellites, the United States can deliver the on-orbit architecture to meet the challenges of the ongoing competition with China. Whether launching large numbers in a single constellation or multiple constellation types, the increased throughput enabled by multiple launch locations can help drastically shape the on-orbit architecture and concepts of operations. Dispersed parallel processing and launch could become a reality, preventing bottlenecks at single-digit launch pads. As confidence in the reliability of launch vehicles grows, this could enable flights over land in addition to the already proven air and maritime launch options to augment operations at the existing Eastern and Western Ranges, Wallops Island, and Kodiak.

Continue to Invest in Rocket Research and Development: As the saying goes, "No bucks, no Buck Rogers."[29] To foster continued innovation to further increase confidence, capacity, and cadence while reducing cost, the Space Force should continue to invest in rocket research and development. Achieving the next plateau of launch capability requires continual R&D, and breakthroughs in technologies and operational concepts require stable, continuous funding. Two prime areas stand out for further development.

First, computer design and material manufacturing have already started to transform the launch and space industry but are still in their initial stages. Advances in these fields will promote design and assembly process innovation that can simultaneously increase confidence and decrease cost. Additional investment focusing on manufacturing is needed to improve cadence and cost levels to enable the fielding of a resilient on-orbit architecture. Computer design can also speed up the certification process because it enables distributing models with ease to provide timelier insight on designs.

Second is the long-standing goal of launch reusability. The Falcon 9 has reached a new level of launch cadence, but it is not the end. While there is considerable interest in the reusability of larger rockets such as Starship and New Glenn, the prospect of reusability in small launch systems is also compelling. Small launch is already a much cheaper option for small satellites and typically has a faster cycle time than traditional expendable boosters. Integration of reusability for small vehicles can bring about improved operational cadence and decreased cost. However, it will not be easy. Smaller launch vehicles have smaller margins and less available fuel reserves for use in recovery. This means alternate methods to recover a small booster may be necessary if the intent is to reuse it.

Actively Monitor the Supply Chain of Critical Components: The quality and timing of ingredients often dictate the success of the final product. This is also true for space and space launch. The Space Force must have confidence that the supply chain will have the capacity to deliver components at the cadence and cost to meet the demands of a robust launch enterprise. The importance of the availability of quality components and materials cannot be overstated. Even with launch provider diversification, there will still be common components or materials. Ensuring the quality of these elements is an integral part of traditional launch mission assurance to increase confidence in a successful mission. Government and independent third-party pedigree reviews and lot acceptance testing are common practices to assure the quality of components.[30] As part of tailored mission assurance, leaders may choose to waive such efforts. This places increased trust in the launch provider, but it also decreases the level of insight the government will have into the status of a supply chain. Supply chain issues, such as quality breaches or low availability, become harder to track and manage. Equally important is the timely delivery of these quality products at a tempo to meet the required launch cadence. The right part at the wrong time can be just as devastating to military operations as a launch failure. By maintaining a higher level of insight, the government can interject and provide corrective actions to avoid potential supply chain confidence and cadence issues that could derail the nation's assured access to space.

Conclusion

Space launch and the assured access to space that it represents are foundational to shaping and delivering the United States' space architecture. For the Space Force, having the right confidence, capacity, cadence, and cost in its launch enterprise is a prerequisite for space superiority and maintaining a distinct space advantage over competitor nations. Ultimately, it plays a critical role in safeguarding U.S. economic interests and ways of life dependent on space. Space launch remains a technically challenging and often risky venture, so steps must be taken to ensure the Space Force continues to have assured access to space. The service must retain a diverse set of launch providers, expand options for launch locations, continue to invest in rocket R&D, and maintain awareness of potentially crippling supply chain issues. Providing the Space Force with the resources and personnel to accomplish these recommendations should be a national priority. Failure to do so risks not just space launch but the entire set of space capabilities and services upon which the nation relies. ✪

Endnotes

1 At time of writing, only SpaceX is certified for NSSL missions and after a booster landing mishap was grounded for three days by the Federal Aviation Administration. Jeff Foust, "SpaceX resumes Falcon 9 launches after brief FAA grounding," *SpaceNews*, August 31, 2024. Falcon 9 was grounded again in early October after a malfunction during its launch of two astronauts to the International Space Station. Joey Roulette, "US FAA grounds SpaceX's Falcon 9 rocket after second-stage malfunction," *Reuters*, September 30, 2024.

2 Typically, assurance and launch rate are used instead of confidence and cadence, but the pneumonic of four "C's" is useful to better frame the important launch factors.

3 Joey Roulette, "SpaceX's Falcon 9 grounded after failure dooms batch of Starlink satellites," *Reuters*, July 12, 2024.

4 "Space Shuttle Launches," KSC Historical Report No. 1B (KHR-1B), NASA.

5 "China 2024: Metrics of a Rising Power," BryceTech infographic, current as of March 31, 2024.

6 "China Shoots for 100 Space Launches in 2024, Challenges US Space Supremacy," *Space and Defense*, March 25, 2024.

7 Nectar Gan, Yong Xiong, and Isaac Yee, "Suspected Chinese rocket debris seen falling over village after launch, video shows," *CNN*, June 24, 2024.

8 Andrew Jones, "Chinese rocket stage breaks up into cloud of more than 700 pieces of space debris," *SpaceNews*, August9, 2024.

9 "About," ULA.

10 "Minotaur," Northrop Grumman.

11 Roy Franklin Houchin II, "The Rise and Fall Of Dyna-Soar: A History of Air Force Hypersonic R&D, 1944-1963," dissertation, Auburn University, Auburn, AL, 1995.

12 "Space Shuttle," NASA, updated September 5, 2024.

13 "Pegasus," Northrop Grumman.

14 "Department of the Air Force scheduled to launch seventh X-37B mission," *U.S. Space Force News*, November 8, 2023.

15 "Starship," SpaceX.

16 Richard Tribou, "Space Coast launch schedule," Orlando Sentinel, updated October 8, 2024.

17 "Vandenberg SFB Launch Schedule," RocketLaunch.org.

18 "The Impact of Weather on Launch Delays at Cape Canaveral and Kennedy Space Center," *New Space Economy*.

19 "U.S. Space Force's Space Systems Command Awards Three Contracts for National Security Space Launch Phase 3 Lane 1," Space Systems Command media release, June 13, 2024; and "U.S. Space Force's Space Systems Command Issues Solicitation for On Ramp to OSP-4 Launch Contract," Space Systems Command media release, July 3, 2024.

20 "U.S. Space Force's Space Systems Command Awards Three Contracts for National Security Space Launch Phase 3 Lane 1."

21 Sandra Erwin, "End of an era: Delta 4 Heavy soars one last time," *SpaceNews*, April 9, 2024; and Mike Wall, "Atlas V rocket launches its final national security mission for US military (video)," *Space.com*, July 30, 2024.

22 Jeff Foust, "Vulcan competes second flight despite SRB anomaly," *SpaceNews*, October 4, 2024.

23 "Vulcan," ULA; and "New Glenn: The Foundation for a New Era," Blue Origin.

24 "U.S. Space Force's Space Systems Command Awards Three Contracts for National Security Space Launch Phase 3 Lane 1."

25 "U.S. Space Force's Space Systems Command Issues Solicitation for On Ramp to OSP-4 Launch Contract."

26 While ULA's Vulcan has completed its final certification launch, insufficient operational data exists to evaluate it at this time.

27 Jeff Foust, "ABL Space Systems blames RS1 launch failure on loss of power," *SpaceNews*, January 18, 2023; and Jeff Foust, "Astra identifies cause of last failed Rocket 3.3 launch," *SpaceNews*, March 3, 2023.

28 Courtney Albon, "Space Force should consider alternative launch sites, lawmakers say," *C4ISRNet*, May 14, 2024.

29 The motion picture, "The Right Stuff," 1983.

30 John W. Welch, Flight Unit Qualification Guidelines, a report prepared for the Space and Missile Systems Center (The Aerospace Corporation, June 30, 2010).

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About the Author

Charles S. Galbreath is a Senior Resident Fellow for Space Studies at the Mitchell Institute's Spacepower Advantage Center of Excellence (MI-SPACE). Charles is a retired United States Space Force Colonel; a Command Space Operator with expertise in Missile Warning, Space Control, Space Launch, and ICBM operations; and a Senior Materiel Leader with experience developing advanced technology demonstration and prototype systems. Prior to joining Mitchell, Charles served as the Deputy Chief Technology and Innovation Officer on the Headquarters United States Space Force staff. Charles earned a Masters of Administrative Science from the University of Montana, a Masters Degree in Space Operations from the Air Force Institute of Technology, and a Master of Military and Operational Art and Sciences from Air University as part of Air Command and Staff College where he was a Distinguished Graduate and won the Space Research Award.