Issue Brief

Shaping the U.S. Space Launch Market

Extending America's Advantage

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February 2025

Executive Summary

While rocketry may be centuries old, orbital space launch began with Sputnik in 1957. In the following decade, fueled by government funding and motivated by the "Sputnik surprise," American space launch had a burst of activity, with more than half a dozen companies attempting orbit.[1] In the decades since, however, the number of companies responsible for space launches has ebbed and flowed. Following the early burst of activity, the number of launches and companies responsible for them decreased. By the mid-2000s, a single firm dominated the field: the United Launch Alliance. ULA was slowly displaced by then-upstart SpaceX, whose pace exploded starting around 2017. Recently, a handful of would-be competitors have shown the ability to achieve orbit, successfully launching commercial and government satellites.

Today, the United States finds itself in the enviable yet challenging position of world leader in launch, yet with a relatively consolidated market. The country conducts 50 percent more launches than it did at the peak of the space race—but five of every six U.S. launches come from a single provider, SpaceX. With a tranche of new companies vying to challenge SpaceX's dominance, it will be crucial for federal officials to carefully calibrate policies that shape the market.

As with any national security-relevant market, concentration poses risks: supply chain disruptions can threaten military capability, while government bargaining power shrinks. Likewise, a more competitive market comes with the benefits of increased innovation incentives and improved resilience. Federal policies should pursue improved competition, but must balance those policies with current national security needs to reliably and rapidly launch growing numbers of defense and intelligence spacecraft. Policymakers must also ensure that domestic launch companies retain the flexibility and capacity to compete globally, outpacing their state-directed competitors.

In its evaluation of the American launch market's ability to meet critical U.S. national security and foreign policy needs, this paper finds the following opportunities and challenges:

Opportunities: The United States leads the world in space launch by nearly every measure: number of launches, total mass to orbit, satellite count, and more. SpaceX's emergence has provided regular, reliable, and relatively affordable launches to commercial and national security customers. It has also had a role in seeding talent in other startups. Alongside SpaceX is a small group of technically viable alternatives. This variety offers the country a measure of resilience in the face of national security threats. Extending this advantage could include further investment in strategically important areas such as responsive launch, in-space transportation, or small launch to particular orbits. Leveraging and expanding the U.S. advantage not only enhances national security but compounds market resilience by building a viable avenue for new market entrants.

Challenges: Competition is important for resilience and incentivizing innovation—but today's market consolidation and the capital requirements necessary to develop rockets make it difficult for new competitors to break in. Simultaneously, the People's Republic of China (PRC) has shown the ability and willingness to invest the level of capital needed to create international competition for the United States. Navigating these dual challenges will involve careful steering by U.S. policymakers.

This paper makes the following recommendations to protect U.S. national security interests and ensure an enduring American advantage in launch:

1. **Congress should fund and the U.S. Department of Defense and NASA should conduct research and strategic investment in transportation technologies in space through grants, government demonstration missions, and agreements to purchase commercial transportation services.**

2. **The DOD, intelligence community, and NASA should regularly execute small satellite missions and expand purchases of small launch vehicle services in order to cheaply test technology and encourage a competitive future launch market.**

3. **Congress should fund, and the DOD and NASA should implement, expanded launch infrastructure capacity, dispersion, and resilience to improve U.S. launch capacity in peacetime and safeguard it in case of conflict.**

4. **The federal government should promote competition in the commercial space launch industry by continuing to allocate launches among multiple competitive vendors, thereby ensuring resilience and innovation.**

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Introduction

Sputnik's launch in 1957 shocked the American public.[2] The U.S. government responded to the "Sputnik surprise" by making substantial investments in satellite technology, rockets, and organizations to prevent future strategic surprises. Even though this moment has now long passed, the United States finds itself in a fierce new race that also winds together threads of technology, industry, and the space frontier.

Since 1957, space launch has remained an industry with strategic implications. Motivated by the importance to national security of the commercial launch industry, this paper identifies the technology, policy, and market trends that together have developed today's launch industry. The analysis reviews launch trends from 1957 through 2023, using data from the publicly available Gunter's Space Page, and also explores trends in the space launch market using data from PitchBook Data, Inc.[*] Finally, this study identifies challenges and opportunities in the market and offers recommendations for ensuring a launch market that will meet U.S. national security needs.

What Is Space Launch?

Space launch is the placement of spacecraft into orbit using launch vehicles—rockets. These vehicles place satellites high above Earth while accelerating them to the speed required to stay in orbit. While the loud and fiery vehicles get much of the attention, launch also includes the infrastructure, workforce, laws, and processes required to safely operate the rockets and protect the public when things go wrong.

A typical space launch is the combination of a launch vehicle, consisting of multiple rocket stages and engines, and the payload, which can be a satellite, scientific instrument, crewed spacecraft, or other cargo.

[*] This report's appendix provides details regarding these sources and analysis.

Motivation

Having defined launch, it is important to consider three factors that drive this study of the industry: federal government requirements, national security concerns, and economic value.

Government Requirements

The 2020 National Space Policy states that "access to space depends in the first instance on assured launch capabilities."[3] While adopting a policy that most government spacecraft should be launched on U.S.-built vehicles, the policy also identified the need to:

- **Work with allies:** Permit launches of U.S. spacecraft on U.S.-built vehicles from the territory of "allied and likeminded nations"
- **Modernize:** Invest in "the modernization of space launch infrastructure" such as launch pads, radars, and launch ranges
- **Advance capability:** Support the rapid development of additional "commercial capabilities and services" when they do not exist
- **Deliver resilient launch services:** Provide timely launch for DOD and intelligence community customers while pursuing "commercial space capabilities and services to the maximum practical extent," including the ability to "reinforce or reconstitute priority . . . space capabilities in times of crisis and conflict"

Beyond just policy, U.S. law (51 USC § 50131) also requires the federal government to use U.S.-based commercial launch providers.[4]

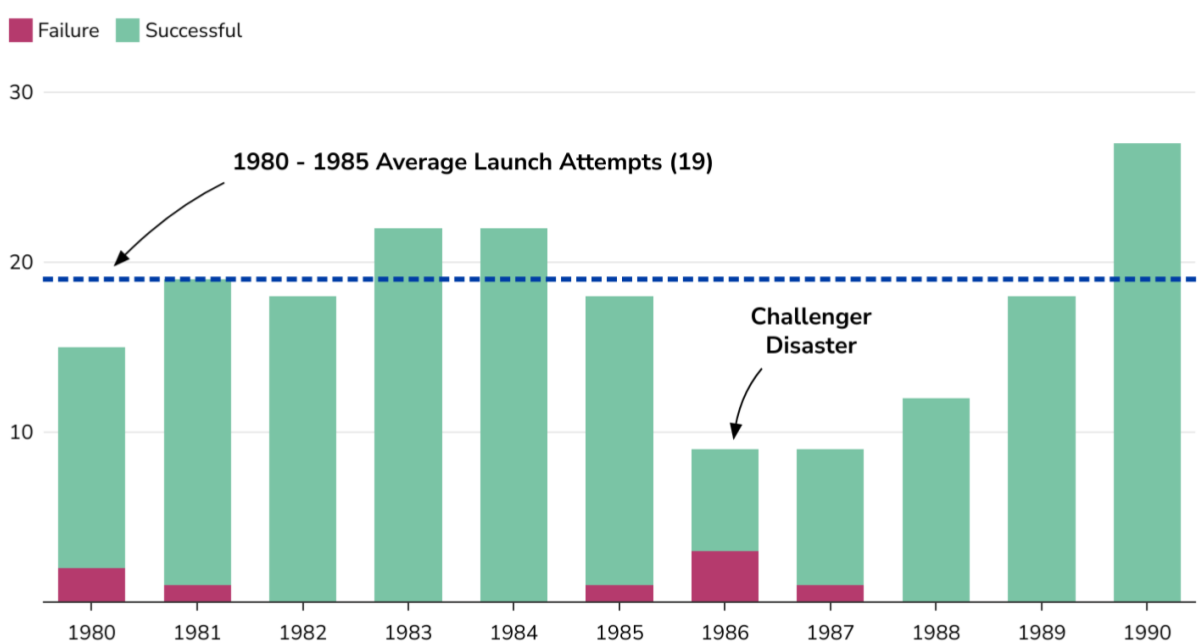
National Security

These laws and policies are motivated by national security interests in a robust and resilient launch industry.

Any country lacking the ability to launch its own vehicles from its soil is dependent upon other nations for space access, whether for economic, scientific, exploratory, or national security purposes. The U.S. purchase of seats on the Russian Soyuz spacecraft for access to the International Space Station (ISS) between the 2011 Space Shuttle retirement and the first commercial crew mission in 2020 is indicative of the risk in the human spaceflight arena. For national security missions, being dependent on a historically adversarial nation for access to space is not an option.[5]

Capability, though, is not enough: resilience and redundancy to maintain capacity in the face of crisis are also wise. The 1986 *Challenger* tragedy, along with the subsequent grounding of the Space Shuttle for nearly three years, is instructive: the average U.S. launch rate fell to roughly two per quarter, or less than 10 per year for the two years following the disaster, with only a minor recovery by the end of 1988 (Figure 1).[6] That rate compares with U.S. launch numbers twice as high earlier in the decade. It took three years to return to near the 19-launch average, and four years to start reducing the satellite launch backlog (Figure 1). Because the Shuttle was intended as the primary launcher for U.S. government customers, its capability was difficult to replace at a moment's notice.[7]

Figure 1: U.S. Launches per Year, 1980–1990



Source: Gunter Krebs, "Chronology of Space Launches."

Economic Value

Diminished launch capability in the late 1980s meant the United States deployed fewer scientific and national security missions. It also meant U.S. companies deployed fewer satellites, harming their businesses. Similar capacity losses today would mean far fewer deployments of remote sensing satellites, fewer satellite internet spacecraft, and fewer positioning, navigation, and timing satellites.

Without viable alternative launch vehicles, a single launch failure poses a risk to both launch companies and the satellite companies that depend on their services. After a launch failure, it may take months to years to find and mitigate the newly discovered faults in a class of launch vehicles.[8] Given the hundreds of billions of dollars of economic value derived from the space economy, a robust, resilient launch market provides financial security.[9]

A resilient market has independent rocket designs so that a single part failure cannot ground multiple launch vehicles simultaneously; it has numerous vendors with competitive prices and the ability for the federal government to negotiate reasonable contract costs; it delivers technical innovation and has a sufficiently low barrier for entry to new solutions. The U.S. launch market demonstrates some of those qualities today, but policies and investments are required to keep the U.S. edge in a more competitive world, while still safeguarding human life and public safety.

History and Legislation

Given the motivating factors of government needs, national security implications, and economic benefits, understanding the history of the industry is vital to understanding the factors that guide its development. Government investment and legislation have driven the American space launch market.

The first successful U.S. launch lofted the Explorer 1 satellite in January 1958. The Juno-1 rocket carrying Explorer 1 into orbit was derived from a U.S. Army ballistic missile program.[10] Under President Dwight D. Eisenhower, the U.S. Air Force had two separate intercontinental ballistic missile (ICBM) programs and a shorter-range intermediate-range ballistic missile program.[11] Those programs used a "parallel development" approach: separate contractors for each rocket subsystem, and multiple rockets. Besides reducing the risk of failure, the approach "expanded . . . the industrial base for missile research and development."[12] Many of the companies contracted in the missile effort, including the Martin Company, Douglas, and Convair, were the same that fielded the earliest American space launch vehicles.[13] These designs and their derivatives flew for decades, and their manufacturers formed the space industrial base.

After the space race wound down, budget realities in the 1980s heavily shaped the executive branch and congressional approach to launch.[14] That approach solidified with 1984's Commercial Space Launch Act.[15] The Act promoted commercial launch providers by building a licensing scheme for launches, launch sites for U.S. companies, and launch operations for U.S. citizens worldwide.[16] It also established timelines for license issuance, liability insurance requirements, and, importantly, stated that the United States would permit leases of surplus launch infrastructure to commercial players.[17]

Amendments to the Act in 1988 further defined liability requirements and limitations; the Department of Commerce established the Office of Space Commerce the same year.[18] Ten years later, the Commercial Space Act of 1998 required the government to purchase launch services from commercial providers.[19]

Congress became more directive starting in the 2000s, working primarily, though not exclusively, through NASA Authorization and Appropriations Acts (Table 1). First encouraging NASA to use commercially available launch vehicles for science missions, Congress eventually fully supported a commercial option for more technically complex space station resupply missions. With the Space Shuttle program ending in 2011, Congress embraced the Commercial Crew program, for the first time entrusting American astronauts to privately developed U.S. vehicles, thereby ending the reliance on Russian launchers. National Defense Authorization Acts of this period also contained language supportive of commercial launch, including pertaining to the elimination of Russian-origin engines in U.S. vehicles and to the supply of surplus government rocket motors to commercial launch providers.[20]

Table 1: Selected NASA Authorization and Appropriations Acts

Year & Act	Key Elements
2005 Authorization[21]	• NASA to use U.S.-owned launch vehicles • NASA administrator to "encourag[e] the work of entrepreneurs who are seeking to develop new means to launch satellites, crew, or cargo"
2008 Authorization[22]	• NASA must build a strategy to acquire commercial launch services • NASA must study U.S.-built engines[23] • Congressional endorsement of Commercial Cargo program under way to use U.S.-built rockets for ISS resupply
2010 Authorization[24]	• Investment in commercial cargo and commercial crew programs is directed to service the ISS • Modernization of ground infrastructure for those companies is directed • Space Launch System program begins
2017 Authorization[25]	• Moon-to-Mars exploration support • Continued support for commercial cargo and commercial crew programs to service the ISS
2021 Appropriation[26]	• Moon-to-Mars exploration plan is maintained across administrations • Investment in satellite servicing and fuel transfer
2022 Authorization[27]	• Establishes commercial provider need for lunar and Mars exploration

With the 2010 Authorization Act (Table 1), Congress directed NASA to begin the Space Launch System (SLS) program—a super-heavy lift launch vehicle designed for human exploration.[28] Primarily built with an eye toward exploration missions, the Act also hedged against the risk of commercial failure by mandating that the SLS have the capability to supply the ISS with cargo and crew.[29] It also explicitly stated its intent to retain the vibrant aerospace workforce that had supported the Space Shuttle, and that traced its heritage back to the Apollo era. Once again, government investment was used to build workforce capacity, as it was during the Eisenhower administration.

Finally, in addition to laws listed in Table 1, 2015's Commercial Space Launch Competitiveness Act revamped the launch regulatory framework. The Act updated liability and insurance methodology to balance government costs and commercial burdens; allowed experimental launch permits; established exclusive federal court jurisdiction for failures; and directed work on a space industry consensus for safety standards.[30] Each of these measures lowers financial risks for new commercial entrants.

Altogether, a consistent thread of government action has laid the groundwork for the launch industry, from ICBM investments in the 1950s to more recent government purchases of launches for national security and space exploration to legislation supportive of the modern space launch industry.

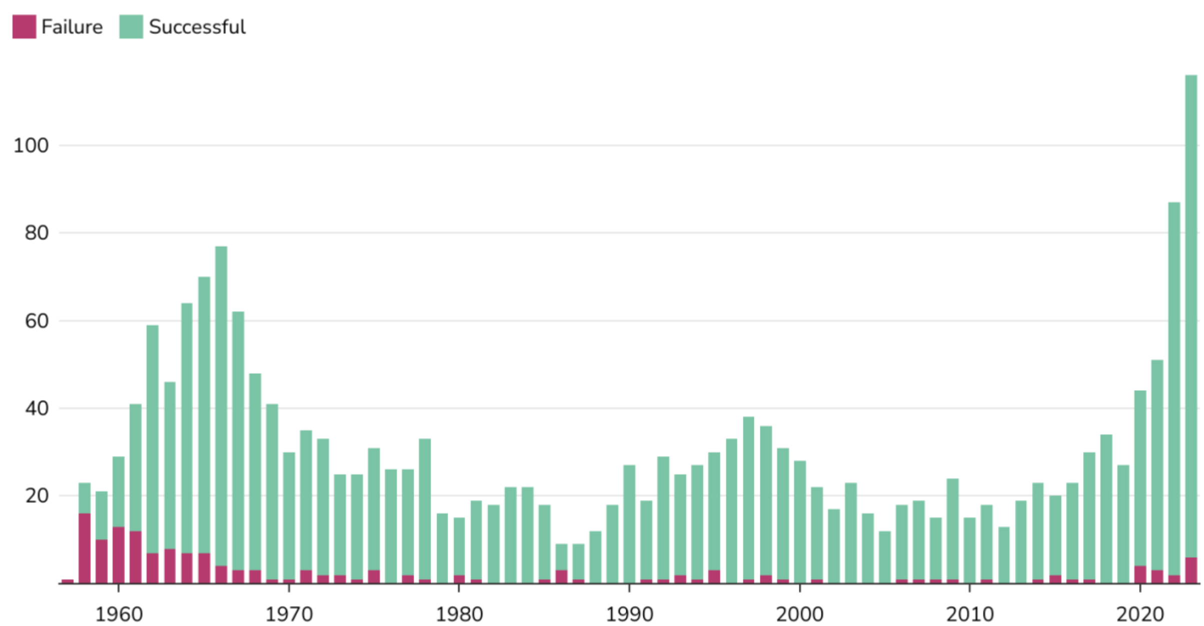
Industry and Technology Trends

With government investment and legislative attention, the industry has evolved since the first successful launch of Explorer 1. The trends in that evolution often match the ebb and flow of the broader aerospace and defense industry during the Cold War and postwar periods.

Launch Industry Development

Within the United States, the launch industry can be split into two eras: a competitive early era, and the consolidated later era. The early years of the Space Age saw high launch rates: well over 40 on average in the 1960s, and more than 20 annually through nearly all of the 1970s (Figure 2).

Figure 2: U.S. Launches per Year, 1957–2023

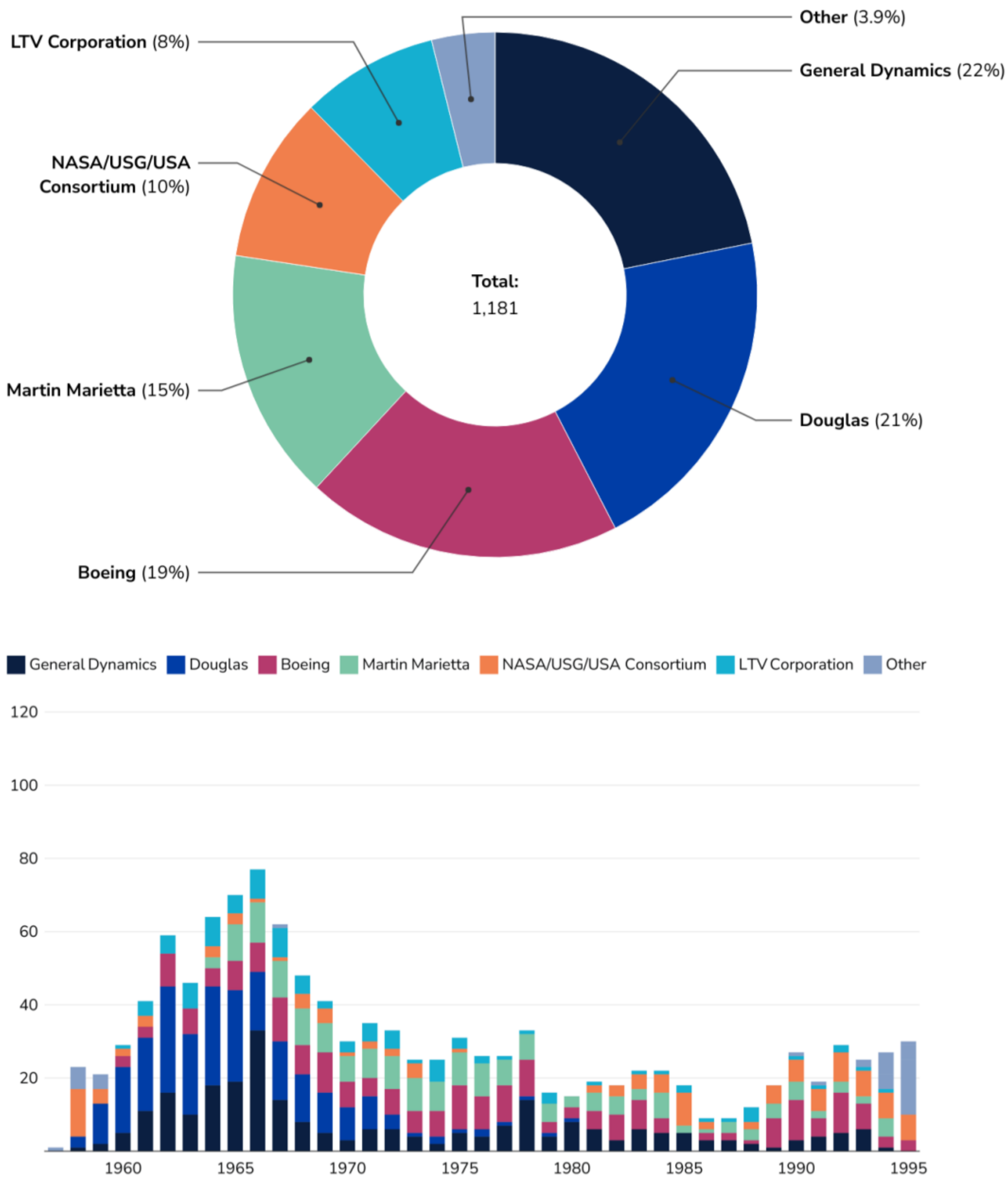


Source: Gunter Krebs, "Chronology of Space Launches."

In these boom years, no company had more than 50 percent of the annual launch total in any year (Figure 3B), with any company passing the 40 percent mark just six times.[31] While a few large firms competed for most launches, smaller ones tried their hand as well. During the 1980s, companies began grabbing larger market shares, correlated with a shrinking launch rate. No single organization, however, dominated for long. Continuing through 1990s, launches were well distributed among multiple organizations: setting aside crewed government missions, General Dynamics, Douglas, Boeing, and Martin Marietta regularly jockeyed for share, with the Ling-Temco-Vought (LTV) Corporation providing smaller launch capability.

In the 1990s, the market began to consolidate.

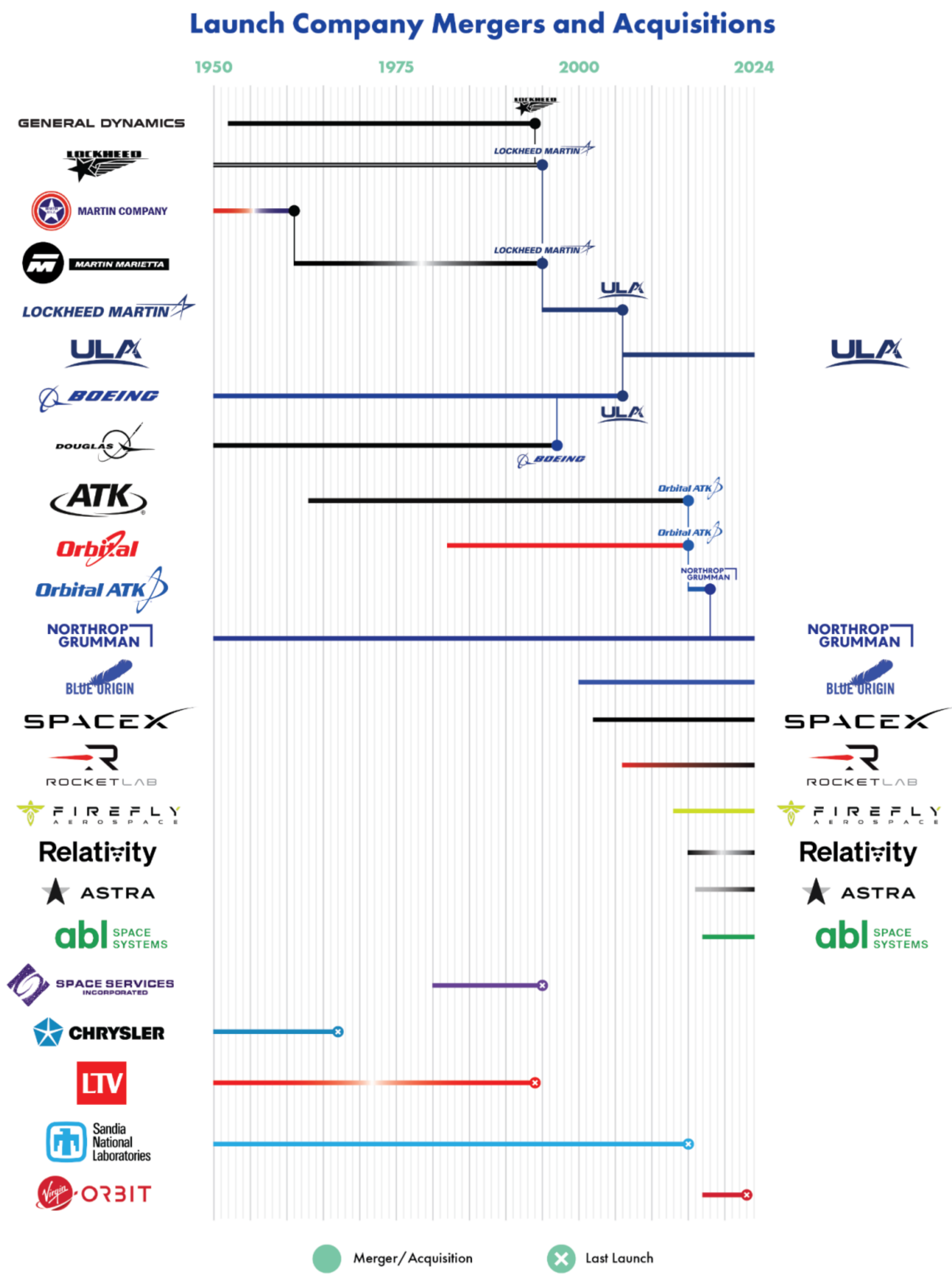
Figures 3A and 3B: U.S. Launch Company Domestic Market Share (1957–1995)[32]



Source: Gunter Krebs, "Chronology of Space Launches," authors' analysis.

The decade saw a number of merger activities after the so-called Last Supper hosted by the Secretary of Defense and Deputy Secretary of Defense in 1993.[33] Indeed, mergers relevant to launch included the May 1994 purchase of General Dynamics' launch business by Lockheed, followed less than a year later by the March 1995 merger of Lockheed and Martin Marietta to form Lockheed Martin—which is today the world's largest defense contractor (Figure 4).[34]

Figure 4: Launch Company Corporate Foundings, Mergers and Acquisitions[35]



Source: Dates via Crunchbase and company websites.

After 1995, U.S. launch became a two-company near-duopoly between Lockheed Martin and Boeing, with Orbital Sciences rockets and the government-owned Space Shuttle handling much of the remainder, as shown in Figure 5B.

The consolidation culminated in 2006, however, when market leaders Boeing and Lockheed Martin combined their launch divisions to create the United Launch Alliance.[36] From then on, the joint venture dominated the industry, regularly hitting a 60–80 percent domestic market share. Considering that around 20 percent of the remaining market consisted of Space Shuttle launches, there were few other options for the U.S. government or commercial satellite companies to launch from the United States.[37] This dominance was concurrent with a relative trough in total launch numbers—fewer companies fighting over a smaller total market.*

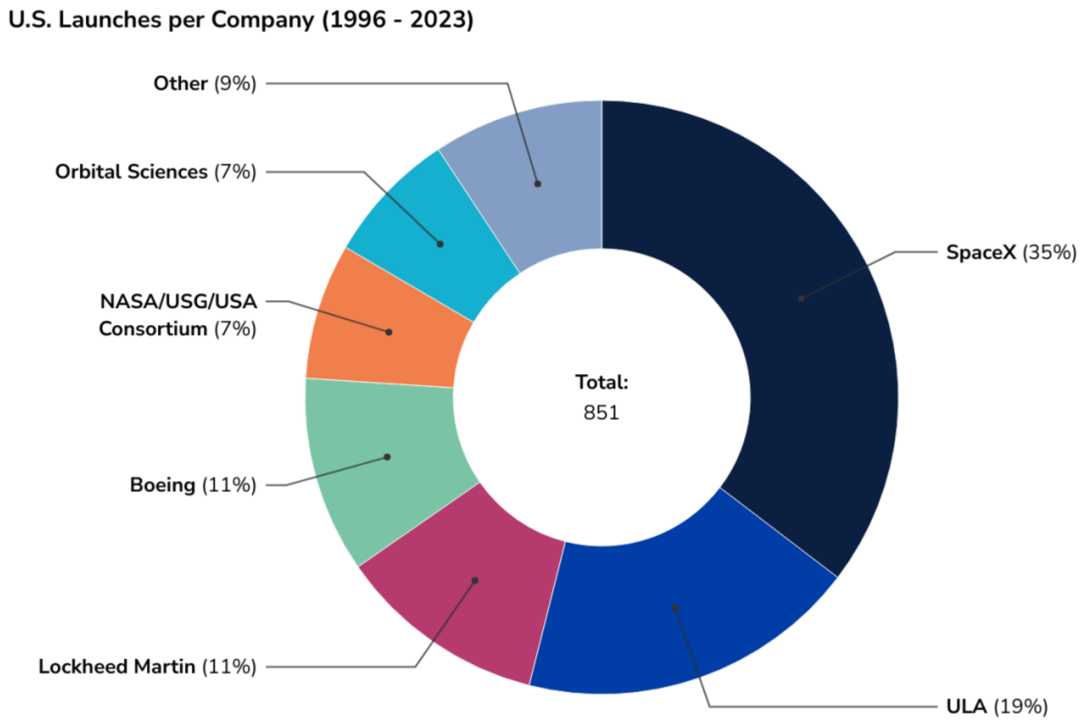
Around 2014, SpaceX began to take noticeable (though not dominant) market share from ULA. In 2018, while SpaceX began to significantly displace ULA, it also expanded the total number of launches. SpaceX's rapid progress benefited from its pioneering rocket reusability technology, reaping cost savings when deployed at scale. Massive venture funding helped too.[38] Importantly, this was not just Starlink-driven volume, as those would not launch until 2019, and double-digit numbers of Starlink launches would come only in 2020.[39] Partial reusability is, of course, not the only factor in SpaceX's success. Production-scale operations, vertical integration, and a rapid design-test-iterate strategy backed by significant financial resources are all contributing factors. Reusability, however, is a key element in the feedback loop that powers their market success

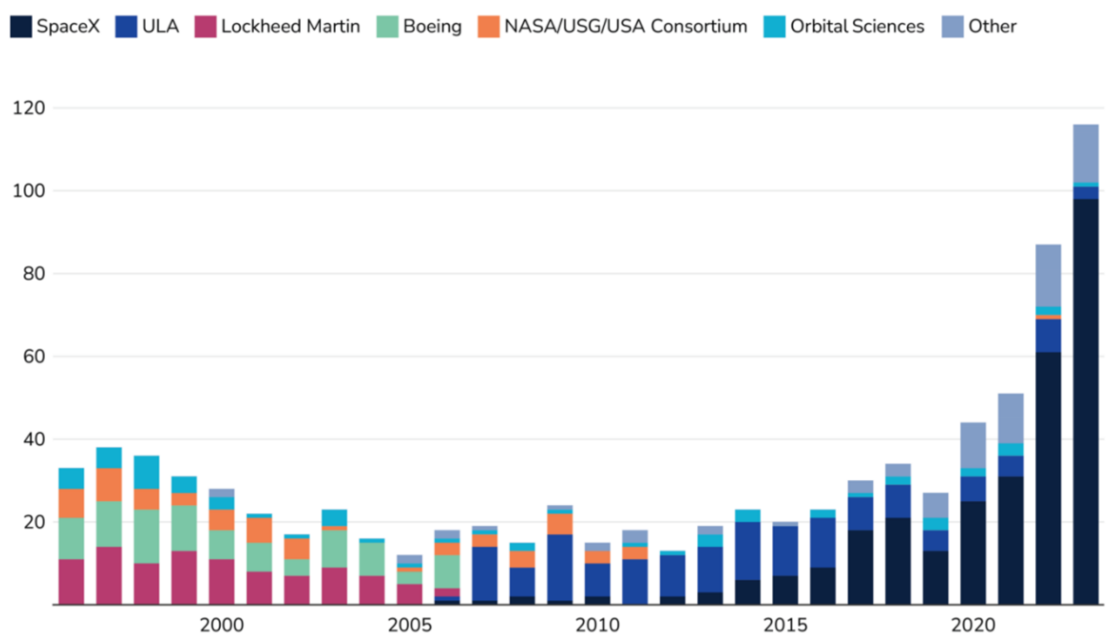
While SpaceX marked a second year out-launching ULA in 2018, its far smaller competitor Rocket Lab also notched successes. The New Zealand-founded, California-headquartered company had its first three successful orbital launches that year, and doubled the number in 2019.

The number of other U.S.-headquartered launch companies also rapidly grew, as displayed in Figure 8. In the period after 2018, these other American companies averaged more launch attempts than the entire market supported in the latter part of the 2000s (Figure 5B). Companies including Relativity Space, Firefly Aerospace, Virgin Orbit, ABL Space Systems, and Astra Space all made their debuts (Table 2).[40] Despite the progress of competitors, however, SpaceX remained dominant over this period.

* Foreign launch providers, especially in Europe and Russia, found success in launches for U.S. commercial satellites. U.S. defense and intelligence launches were required to use domestic launch providers, but civil launches occasionally flew on partner rockets.

Figures 5A and 5B: U.S. Launch Company Domestic Market Share (1996–2023)





Source: Gunter Krebs, “Chronology of Space Launches,” authors’ analysis.

Table 2: Selected U.S.-Based Company Launch Failure Rates through 2023[41]

Company	Launch Vehicles	First Launch	Success Rate	Success Fraction	Launch Trend*
SpaceX	Falcon 9, Heavy	2006	98%	294/301	
United Launch Alliance (ULA)	Atlas V, Delta IV	2006	100%	174/174	
Rocket Lab	Electron	2017	90%	37/41	
Virgin Orbit	Launcher One	2020	67%	4/6	
Astra Space	Rocket-1, -2, -3	2020	29%	2/7	
Firefly Aerospace	Firefly	2021	75%	3/4	

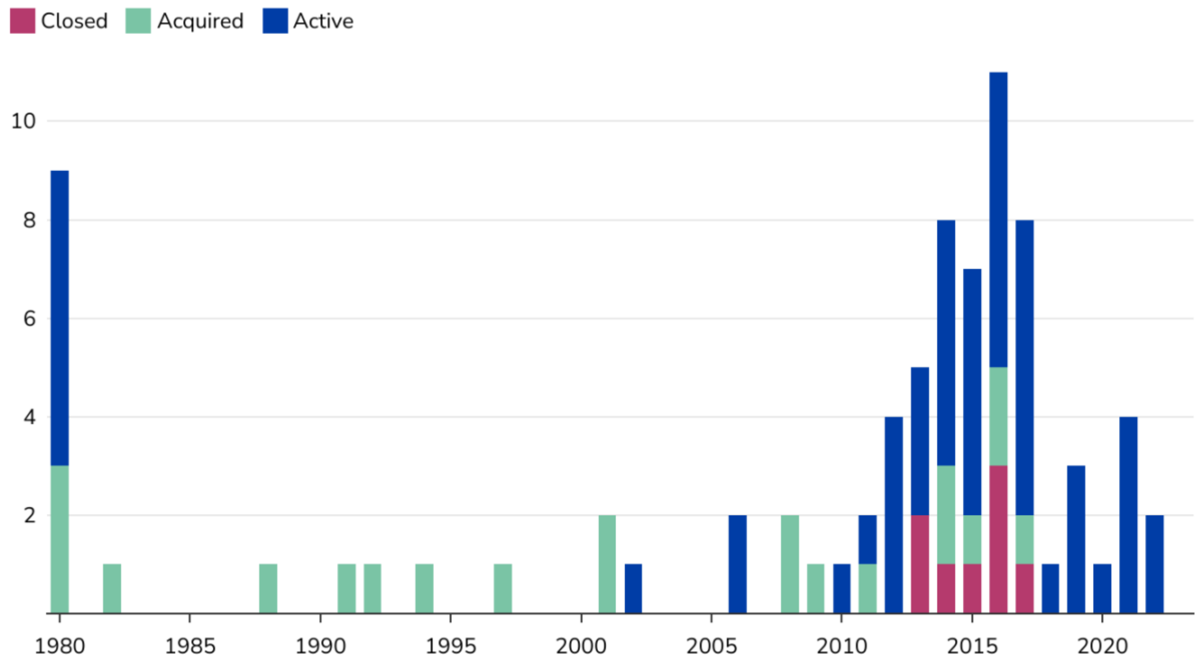
Source: Gunter Krebs, "Chronology of Space Launches," authors' analysis.

Modern Launch Industry Dynamics

The launch industry has become less exclusively driven by geopolitical factors in recent years, despite the return of great power competition. Instead, new commercial investments and commercial space demand has begun to shape the dynamics of the modern launch industry. Market concentration is among the most persistent of those dynamics. While concentration is difficult to attribute to particular causes, there are two coincident factors: increasing demand for launch and the time and capital required for a company to move from founding to consistent performance.

First, the combination of investment capital and an expanding satellite market (Figure 6) meant greater demand for launches. Moreover, many satellite companies were fielding smaller spacecraft in larger numbers to form constellations—increasing launch demand and cost sensitivity. For rockets operating between 2000 and 2015, worldwide costs often hovered between $10,000 and $20,000 per kilogram for Low-Earth Orbit.[42] SpaceX's ability to reduce that cost by four to eight times and still meet the demand helped earn it more market share. Other companies took different approaches. Rocket Lab, for instance, has priced launches below $10 million: more than SpaceX per kilogram, but far cheaper per launch and able to deliver directly to a specific orbit.[43]

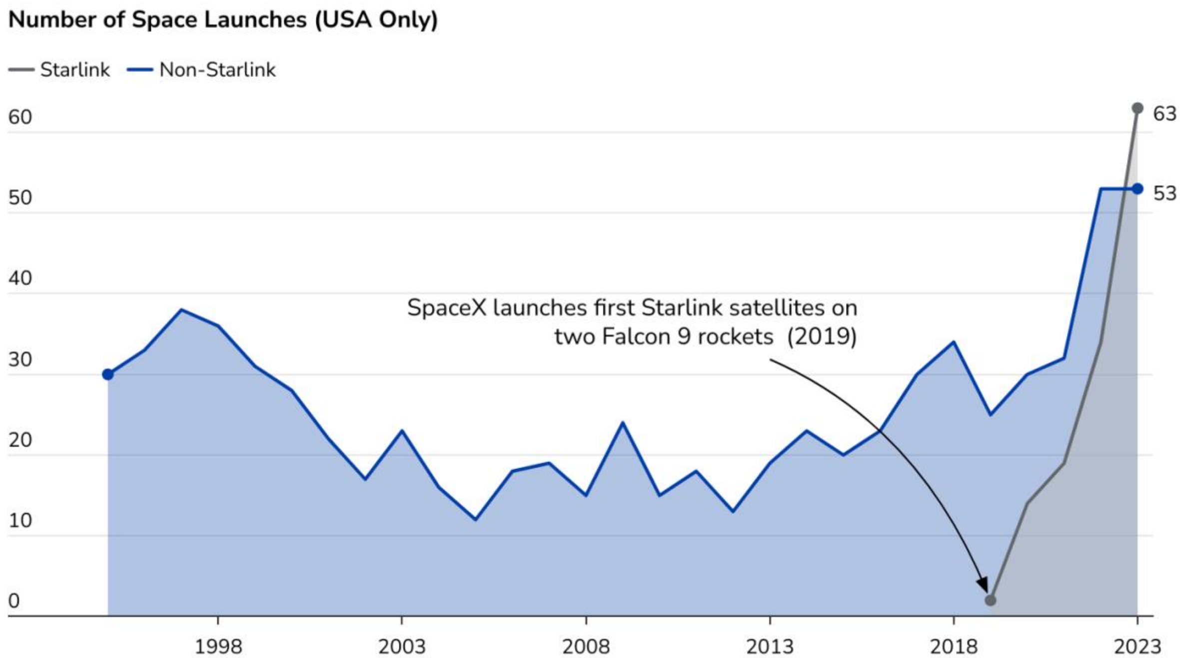
Figure 6: Satellite Companies: Founding Dates and Operating Status[44]

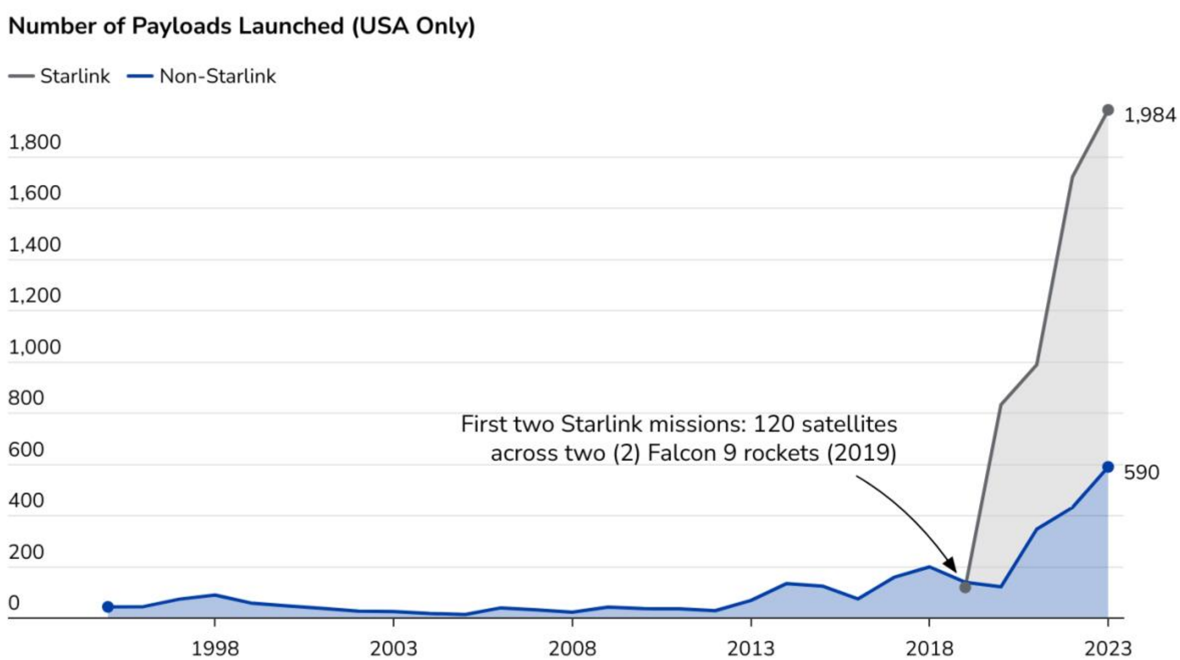


Source: PitchBook Data, Inc.

As launch costs decrease, the quantity of launches demanded should increase; that trend is apparent in Figure 7A, and is reflected also in Figure 2. With the growth in satellite companies looking for launches, there may be room for more launch companies to compete, creating a positive feedback loop between the two.

Figures 7A and 7B: U.S. Rockets and Payloads Launched, Starlink Breakout[45]

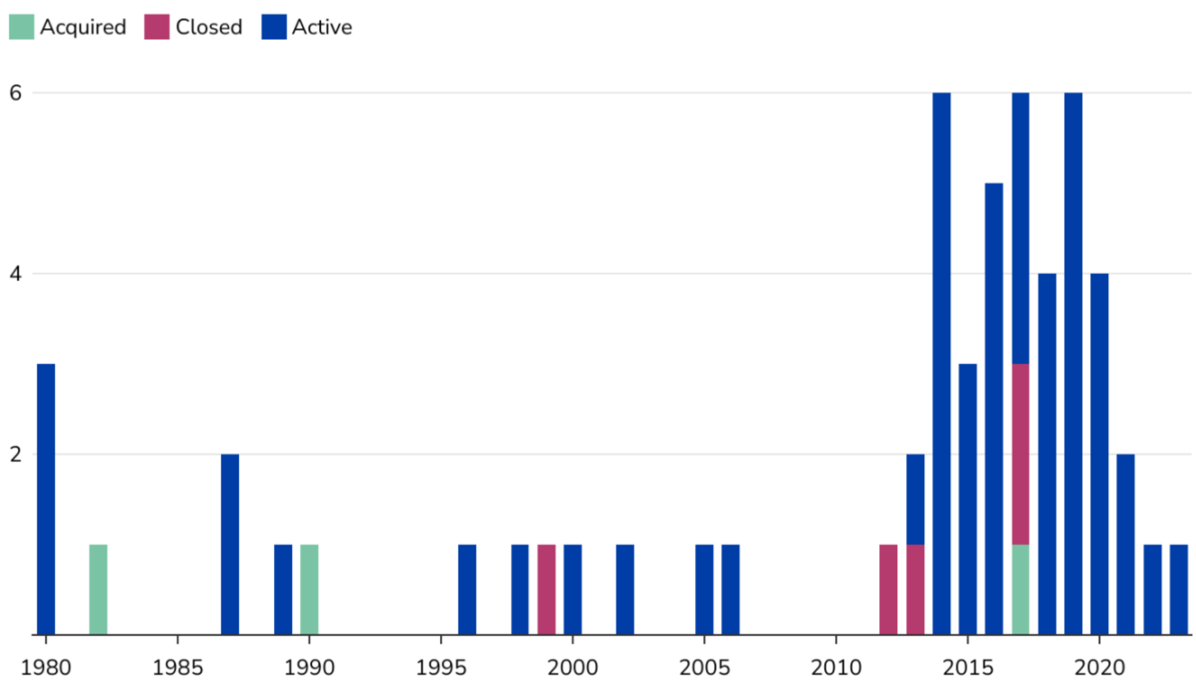




Source: Gunter Krebs, "Chronology of Space Launches," authors' analysis.

Indeed, the number of companies in the launch market starts to expand at nearly the same time as does the satellite market: a major bump in 2010, with another jump in 2014 (Figure 8). While the list of "launch companies" includes some that broker rides between satellite vendors and existing launch providers, and others may have gone into hibernation without formally closing, most of the active companies shown in Figure 8 are developing launch vehicles.[46]

Figure 8: Launch Companies: Founding Date and Operating Status[47]



Source: PitchBook Data, Inc.

The second factor to consider is the time and capital required to move from idea to consistent market performer.

For example, SpaceX, today's dominant market performer, was founded in 2002, but had its first successful launch six years later (Table 3). Not until 2013 did the company launch more than twice per year, and it took until 2017 to capture more U.S. launch market share than its primary competitor, ULA.[48] As of 2023, the company conducted just under 85 percent of all U.S. launches—helped by more than $9.5 billion in investment capital.[49]

Table 3: SpaceX Market Milestones

2002	2008	2013	2017
Company founding	First successful launch	First year with three or more launches	50% market share

This 10-year approximate timeline to consistent performance and 15 years to scale is not a SpaceX-only phenomenon. For Rocket Lab, it took 12 years from founding to the first successful (three) launches, and another five years to gain 50 percent of the non-SpaceX market share (Table 4).[50] Rocket Lab has benefited from a working rocket, but also more than $700 million of investment.[51]

Table 4: Rocket Lab Market Milestones

2006	2018		2023
Company founding	First successful launch	First year with three or more launches	50% market share (excluding SpaceX)

For companies such as Firefly (founded in 2013), Astra (2016), ABL (2017), and others, recent history suggests that if they can survive and develop their capabilities through the middle of the 2020s, they could become significant players in the launch market.[52]

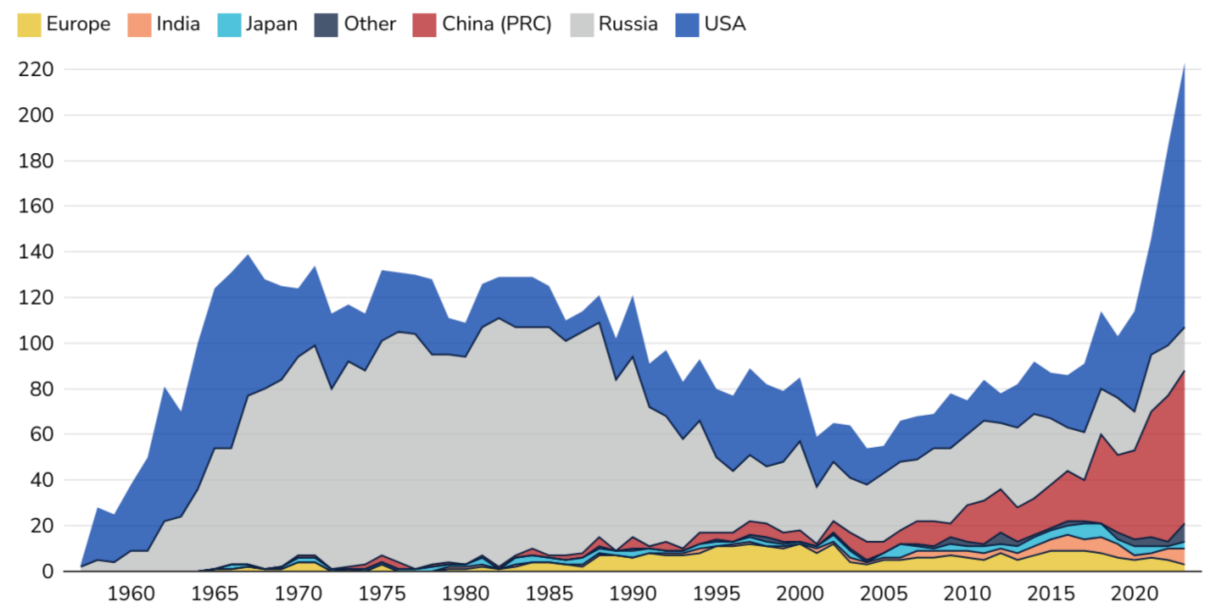
Government support has historically played a significant role in growing these companies from startups to market performers—and likely will continue to do so. Rocket Lab's third, fourth, and fifth launches were all for U.S. government customers.[53] SpaceX's first five launches of its now-workhorse Falcon 9 rocket were all under the auspices of NASA's Crew Resupply Services program. Long development times and up-front funding needs are areas where government buyers and venture investment mutually benefit one another: NASA and the DOD get early discounts and a more robust, resilient market to meet national security imperatives, and companies gain early revenue opportunities.[54]

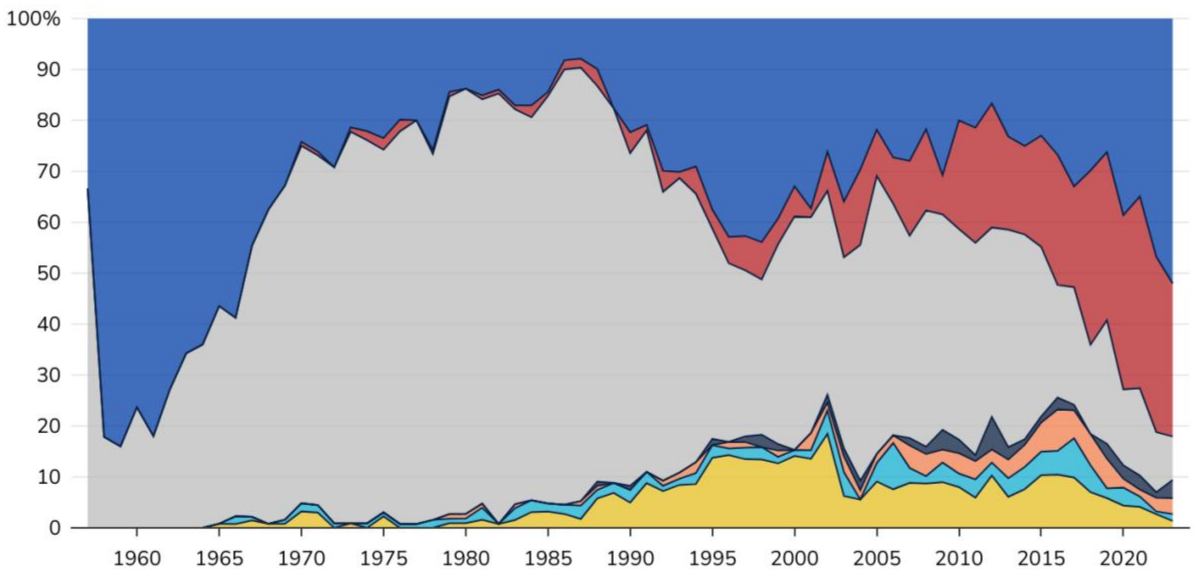
Nevertheless, beyond that single-company dominance, there appears to be room for competitors. Figure 7A shows that Starlink missions drive most of the launch growth.[55] However, non-Starlink missions are also up, and so too are non-SpaceX launches. Looking at the total number of satellite payloads (Figure 7B) rather than launches, the trend is even more clear. Most satellites launched are Starlinks—but a spike to nearly 600 satellites in non-Starlink payloads launched in 2022 and 2023 shows that there is still significant (and potentially growing) demand for launches of other satellites as well.[56]

This growth in the U.S. market is occurring in both absolute terms and relative to worldwide launch. Figures 9A and 9B show that China makes up the majority of the rest of the world's growth in space launches.

The expanding number of payloads launched on American vehicles is a net strategic advantage in the United States-China competition. It provides U.S., allied, and partner satellite companies (and militaries) more opportunities to get to orbit. It also provides revenue for U.S. companies instead of those in China, and reduces the risk of foreign disclosure to competitors of American satellite technologies.[57] Further, continued U.S. strength in the launch market may make it more attractive for international talent; if able to leverage immigration flows, this could further cement American advantage.[58]

Figures 9A and 9B: Launches by Company Nationality: Total and Ratio[59]



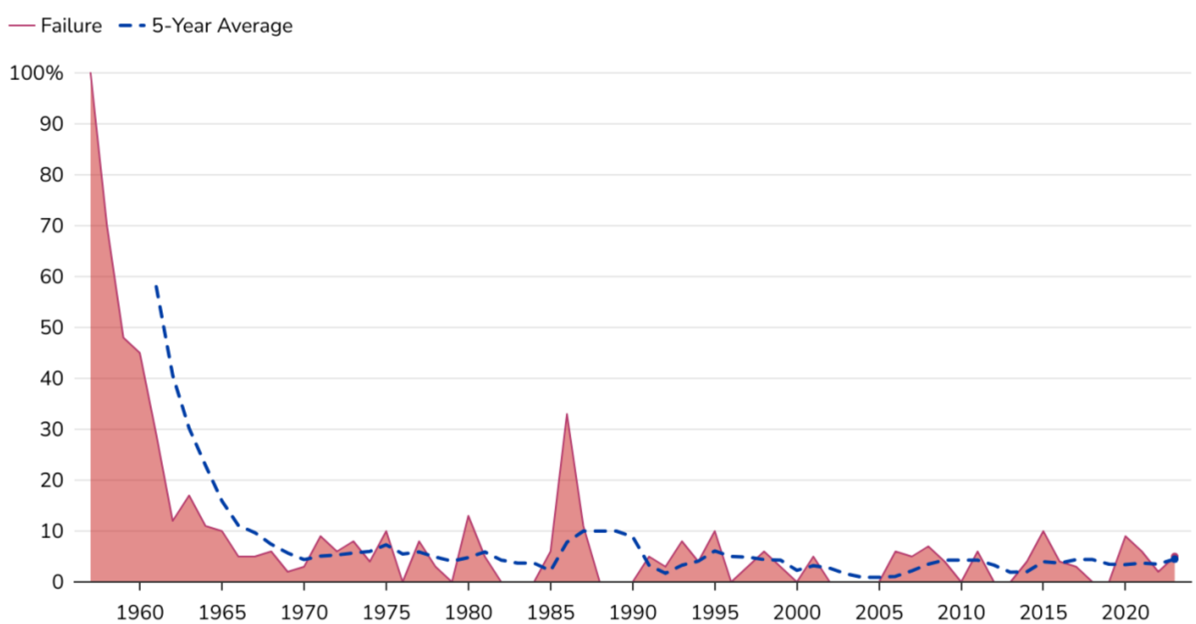


Source: Gunter Krebs, "Chronology of Space Launches," authors' analysis.

While SpaceX has a first-mover advantage in reusability, and the ability to leverage massive scale and capital, other companies are still competing in the market. Within the industry, each company will face three challenges to determine its long-term viability: reliability, capital, and capabilities.

First, satellite providers prefer to go on launch vehicles that they trust are unlikely to explode. So, while new launch vehicles can often provide great discounts to early customers, vendors must get past the nearly inevitable early failures (Table 2). Historically, failure rates hover around 5 percent (Figure 10), though this is a noisy measurement, with much of the variability appearing driven by new vehicles.[60]

Figure 10: U.S. Launch Annual Launch Failure Rate[61]



Source: Gunter Krebs, "Chronology of Space Launches," authors' analysis.

Second, space companies are capital-intensive. Even the *minimum viable product* takes a lot of accurate engineering, and the investment environment will drive new entrants. While it is only correlational, the low interest rate environment post-2000, and especially post-2008, may contribute to the expansion.[62]

Third, and perhaps most significantly (and obviously), the capabilities of competing companies will shape market opportunities. SpaceX currently launches Transporter missions that offer low-cost access to sun-synchronous polar orbits a few times per year, and is rolling out Bandwagon missions to lower inclination orbits.[63] As others have noted, this undercuts competitors at challenging price points. Instead, competitors must develop even cheaper launch vehicles or differentiate themselves with responsive launch (e.g., Firefly) or dedicated launches to precise orbits (e.g., Rocket Lab) that are not serviced under SpaceX programs. Alternatively, competitors could just offer reliable schedule availability, because launch slips can be costly to satellite customers.[64]

Despite the challenges of reliable engineering, capital needs, and finding a competitive advantage in the market, two macro factors are likely to benefit new market entrants: progress in electronics and the strategic nature of space.

First, while launch is an expensive venture, the miniaturization of electronics and U.S. workforce expertise in the space industry may mean that the expanded launch market is not as transient as it may have once been, and no longer driven primarily by military and intelligence satellite refresh rates. The virtuous cycle of increased launch capacity driving increased launch demand and expertise may loosen sensitivity to investment capital availability.

Second, the strategic nature of space access means that space launch is rarely treated like other industries. Given the individual launch failures and rocket groundings in 1986, around 1999, and intermittent groundings in the 2010s, decreased access to space is a real strategic risk to the U.S. diversification of launch providers. Thus, launch provider diversification is a reasonable strategic hedge for the government to pursue as a failure of one vehicle need not ground others (as could commonality in parts between ULA's legacy Atlas V and Delta IV vehicles).

Other factors will also weigh on the market, but in unpredictable ways: depending on the Starlink satellite technology refresh rate, after SpaceX fills its constellation, its launch rate may decrease, freeing additional capacity and driving down costs further.[65] SpaceX's new stainless steel rocket, Starship, is designed to be both fully reusable and refuellable on orbit, and could have the greatest payload mass-to-orbit of any vehicle yet built.[66] Its effect on launch and satellite costs could drive further market shifts, just as its partially reusable Falcon 9 has done. If Blue Origin's New Glenn rocket proves competitive to the SpaceX Falcon 9 family of launch vehicles, or if orbital transfer vehicles (so-called space tugs) prove their worth, or even if more exotic in-space refueling becomes common, the market could once again shift.[67] Nevertheless, the lower price of launch should support an increase in satellite vendors demanding services, leaving viable niches in the market for multiple launch companies.

Challenges and Opportunities

As with remote sensing, the space launch industry is rapidly changing. These changes offer some unique challenges and opportunities that policymakers must consider against the backdrop of national security and economic interests.

Challenge 1: Market Competitiveness

The government has reasonable national security and economic interests in maintaining a diverse supply of launch vehicles to avoid another *Challenger*-like disaster that grounds large portions of launch capacity for months or years. Beyond resilience, market competition drives cost and technology benefits for space launch customers.[68] Competition encourages market leaders and near-leaders to innovate; it increases government bargaining power and avoids sole-source abuses.[69]

Today, SpaceX clearly leads the U.S. launch market, whether measured by the total number of launches, total available capacity ("upmass"), number of payloads launched, or number of boosters reused. In nearly all of these measures, SpaceX also dominates the world market. With the advent of its regular Transporter and Bandwagon rideshare launches delivering ever-cheaper launches for small satellites, new launch companies will be further challenged to compete.[70] Efforts to maintain a competitive market must contend with the current situation and recognize that nearly all of the market volume has generally been held by a single company since 2006—and the dominant company changed during the period 2012 to 2015.[71]

Challenge 2: China's Fast Followers

SpaceX's partial rocket reusability provides massive cost and reliability advantages with the number of launches it conducts. Many newer companies are following suit.[72] For international competitors, even those with significant state backing, reusability is a stretch. It requires significant upfront investment in research and development and test and evaluation and will not pay off without a high launch volume.[73] Unlike European Space Agency-affiliated nations, and especially unlike Russia, the PRC is both sufficiently motivated and capitalized to develop the technology in the near term. With its fast-follower approach, the PRC will catch up to American capabilities if those capabilities do not advance.[74]

If the PRC develops partially reusable rockets and can leverage the technology at scale, the lower costs will make Chinese-built rockets more attractive to buyers.[75] Maintaining a U.S. advantage requires continued innovation, including in unexpected ways (for example In-Space Mobility or full reusability). American technology innovation can keep operational costs down, giving U.S. companies an advantage as they seek an edge in global market share.

Opportunity 1: Strategic Support and Strategic Niches

The ability to launch cheaply at scale has been a fundamental need for decades. With the rise of smaller satellites, the United States also has a need to deliver them cheaply to particular orbits, and preferably do so responsively. With smart planning, the U.S. government can meet its strategic needs while enabling future economic opportunities.

Government launch acquirers already recognize the need for affordable total capacity. Many acknowledge the need for specific niche capabilities such as responsive launch. In designing strategic acquisition plans, decision makers should consider that the small launch market also has the lowest barrier to entry, and often serves as a stepping stone to competition in the medium- and heavy-lift market.[76] Launch acquisition planning that provides opportunities to small launchers and niche capabilities will meet immediate needs and provide future economic opportunities—all while enabling future competition.[77]

Opportunity 2: Current Advantage into Future Advantage

The size of the U.S. commercial and government launch market, along with venture investment, has allowed companies to develop novel rocket designs. SpaceX's in-development Starship is an archetypal example: the massive vehicle uses uncommon materials and promises full reusability. The resources required to test these new designs are a result of current American advantages—and should they succeed, they will make it far harder for international launch companies to compete.

Behind the technical capabilities of the U.S. launch market lies another advantage: talent. The combination of a skilled and educated workforce, the attractiveness of working for those market leaders, and a relative concentration of talent, all serve to make the United States an attractive destination for highly skilled workers.[78] Other countries certainly do leverage their own talented workforces.[79] However, the longer the American companies remain market leaders while staying innovative and attractive to talent, the harder it may be for international competitors to make up ground.

Talent matters for national competitiveness in space. Congress has acted to support talent retention in the past, when it authorized the SLS program in part to retain knowledge from the Space Shuttle program. Continuing calibrated support to retain launch industry talent, alongside policies that attract and retain international talent, will further entrench American advantage.

Opportunity 3: In-Space Mobility

Rockets have long delivered spacecraft to their final orbits, or close enough that a spacecraft can make final adjustments. The physics involved makes changing a satellite's orbit difficult. Today, however, companies are maturing the technology and business case behind systems that move satellites from one orbit to another after they have already launched.[80] The technology may reduce the number of launches needed, while also providing more maneuverable spacecraft. Such maneuverability may change the launch market, but also presents national security implications, because satellites can be less predictable in their orbits. In a world with more mobile satellites, a broader view of launch as one element of space mobility or space transportation is appropriate.

In this broad conceptualization, similar systems that can provide in-orbit refueling or servicing can also give the United States an economic and national security advantage.[81] As PRC-based companies move to develop their own reusable rockets, the United States can continue to maintain a capability advantage by pushing boundaries in post-launch transportation.[82] If the experience with rocket reusability is a reasonable comparison, being the first to field reliable in-space mobility services will provide a qualitative and quantitative U.S. advantage by comparison with foreign competitors—an advantage that could last for five to 10 years. Beyond that, a new comparative advantage must be found. Congress, in its 2021 Appropriations Act (Table 1) indicated a desire to advance development in this sector, including more than $200 million for a NASA robotic servicing mission, though the program was recently canceled due to programmatic challenges.[83] The U.S. Space Force has also expressed interest.[84] Continued congressional and executive branch interest and financial resources could help accelerate development.

Recommendations

Space launch has long been at the forefront of international competition in the space industry. The United States currently enjoys many advantages: world-leading technology, well-capitalized market leaders, and a willingness to innovate. There are, however, a number of issues to be worked through: fast-following international challengers and a concentrated domestic industry. The recommendations that follow are intended to help continue U.S. preeminence in launch, with the attendant national security benefits.

1. **Congress should fund and the DOD and NASA should conduct research and strategic investment in transportation technologies in space through grants, government demonstration missions, and agreements to purchase commercial transportation services.**

   In the 2021 NASA Authorization Act (§ 825), Congress appears to have a sense that commercial refueling and servicing technology are critical to develop. Congress should reemphasize the importance of commercial servicing, allocate research and grant funding toward it, and evaluate commercial complements to the recently canceled NASA-led On-orbit Servicing, Assembly, and Manufacturing 1 (OSAM-1) mission.[85] As with the commercial launch investments of the 2010s, the executive branch should continue to recognize the risk reduction derived from simultaneous commercial and government investments.

   In-space transportation has the potential to further reduce satellite lifecycle costs, but more importantly, it offers the potential to open up new orbit types and new capabilities to commercial users and exploration. For the purposes of national security, it is an enabling technology for more mobile and resilient satellites. As in other eras of technology development, government research and commercial purchase agreements speed the development of capital-intensive investments.[86] The United States should seize this opportunity.

2. **The DOD, intelligence community, and NASA should regularly execute small satellite missions and expand purchases of small launch vehicle services in order to cheaply test technology and encourage a competitive future launch market.**

   Many launch providers enter the market by first building small launchers. Some of these fill a niche not served by larger providers, including insertion in particular orbits or responsive launch timelines. Still others are able to launch small satellites more cheaply than their larger competitors.

The government also benefits from developing small satellites to test new technologies. Such satellites can complement larger flagship missions, but more importantly, they provide a regular cadence of opportunities to test technologies of the future. This test and experimentation will be necessary to keep U.S. national security technologies ahead of foreign competitors, while keeping costs low.

The complementary approach of launching small missions on small launchers helps to maintain a competitive environment, while also benefiting from the market niche these small launch providers offer.

3. **Congress should fund, and the DOD and NASA should implement, expanded launch infrastructure capacity, dispersion, and resilience to improve U.S. launch capacity in peacetime and safeguard it in case of conflict.**

   With two primary launch locations (Vandenberg Space Force Base and Cape Canaveral Space Force Station/Kennedy Space Center) and a handful of secondary locations (e.g., Wallops Island, Kodiak Island), and with U.S.-based launches averaging nearly one every three days and growing, physical infrastructure and human capital are strained. Automation can save resources, but cannot create more physical space. Additionally, enhanced cyber and physical resilience and dispersion provide national security benefits in competition with the PRC.

   NASA and the DOD have been working to improve redundancy at current launch locations.[87] Congress has recognized this, and recent legislation is a step in the right direction.[88] Nevertheless, further government-led study should identify how much more is required, and the results should inform the stand-up of new launch pads and locations. For the DOD in particular, in the face of national security challenges from international competitors, resilience and dispersion are critical elements of national security.[89]

4. **The federal government should promote competition in the commercial space launch industry by continuing to allocate launches among multiple competitive vendors to ensure resilience and innovation.**

   American overreliance on a single vendor or vehicle has previously risked U.S.-based access to orbit. SpaceX has shown an ability to innovate and deliver consistent success; but, as with any potential single point of failure, redundancy is valuable. Even successful companies can have supply chain challenges or be targeted by cyberattacks. Beyond resilience, economic competition can also promote innovation, economic growth, and lower prices.

In some ways, NASA has already embraced this multi-vendor approach, including contracting with launch company Blue Origin to provide a moon lander for the Artemis crewed lunar missions.[90] Beyond Artemis contracts, NASA and the DOD are positioned to jointly analyze whether a third major launch provider is economically viable while still allowing for enough capital to feed major innovations. From a strategic and economic view, having multiple vendors is necessary—whether two or more.

As explained in Recommendation 2, supporting small launch companies is also part of this investment strategy. Those small companies are the businesses whose innovation and continued presence will drive healthy competition and that will be ready to meet market demand should a leading company falter. Scrutinizing merger and acquisition activity and policing anticompetitive conduct across the commercial space launch industry will also help promote a more dynamic and resilient market.

Conclusion

The United States is in an enviable position: it leads in nearly all measures of launch market success—but nearly all of those are the measure of a single company. Still, there are many new launch entrants that have either demonstrated the ability to regularly deliver payloads, or that have begun to test their own vehicles. This success in companies large and small results from a mix of technology and innovation, available capital, and a strong workforce.

However, given the national security implications of the launch market, the United States must continue to encourage innovation and progress. Technologies such as reusability have provided a window of time for U.S. advantage. Continued innovation will be necessary to advance and sustain that advantage.

How the U.S. government responds to the launch market will shape its path for the future. Just as at the beginning of the Space Age, smart investments in research, infrastructure, and the workforce, along with the government's behavior as a major launch customer, will set the course for this industry so critical to national security.

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Acknowledgments

For their careful reviews, thoughtful comments, and constructive feedback, the authors thank Emelia Probasco, John Bansemer, Jack Corrigan, Margarita Konaev, and external reviewers Christine Fox and Ryan Conroy. Thanks also to Shelton Fitch for his editorial support, Christian Schoeberl for his data support, Rai Hasen Masoud for formatting support, Annie Rehill for editing support, and Jason Ly for his graphic design talents.

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Document Identifier: doi: 10.51593/20240017

Appendix: Methodology Details

The goal of this publication is to capture the history and current status of the space launch subsector of the broader space economy, given its relevance to policymakers and the national security community.

The analysis leverages two data sources: the first is PitchBook Data, Inc., and the second is Gunter's Space Page. PitchBook provides rich information about corporate financial and investment fund activity for public and private companies, while Gunter's Space Page provides a record of launches, including dates, launch site, launch vehicle, payloads, and more.

Pitchbook Data, Inc.

PitchBook's insight into corporate finance allows fine-grained analysis of various industries and companies, along with how those industries change through investments and mergers and acquisitions. PitchBook provides industry assignments for companies covered within its dataset, which this study uses to select companies relevant to the space economy. The authors then assign each of the 543 companies in the "Space Technology" vertical to appropriate subsectors.[91] The company assignments are based on the authors' professional knowledge and a detailed review of the company description, websites, and news reports from PitchBook.[*] For example, the following criteria are used to assign companies to the space launch subsector:

Primary Question	Secondary Question / Note	Subsector "Tag"
Does the company provide launch services or re-entry services?	None	"Launch/Reentry"

Companies may belong to multiple subsectors or none at all. The authors also note whether the company conducts reentry or entry/descent and landing activities.[92]

[*] Additional criteria are used to assign companies to other subsectors. For further detail, please contact the authors.

Once companies are assigned, data related to each company's founding date, operating status, and merger activity are acquired from PitchBook. In this publication, the authors assign 56 companies to Launch/Reentry.

There are limits to the data. While a data aggregator such as PitchBook is unlikely to identify every space company, this study's ultimate goal is to provide analysis and trending of key corporate metadata including foundation year, business status, acquisition status, and investment health. Using manual annotation of companies provides a human check on the relevance to the analysis of a company. Further boosting confidence in the data and analysis, the team found that other research, commercial data sets, and internal sampling showed similar trends.[93]

Additionally, given the developing nature of the space economy, companies may grow or shrink their product portfolios. The data represents a current snapshot of the space economy to maximize usefulness to policymakers and the national security community today. Future work should continue or expand the annotation process to ensure continued accuracy.

Gunter's Space Page

Gunter's Space Page (GSP) is a website run for 29 years by a hobbyist. Despite the limited staff size, the site catalogs current and historical launch activity and describes launch vehicle and satellite designs. The data matches well with other sources, including those of the U.S. Space Force, NASA, and others.[94]

The key element of GSP used in this analysis is the list of orbital launches. From the website list, the authors gathered the launches from 1957 through the end of 2023. The team processed each entry to clean and label the data, including determining:[*]

- Launch site nationality from launch site name
- Launching company from launch vehicle name[95]
- Launch company nationality from launch company
- Payload count from the list of payloads
- Success or failure from the launch ID number

[*] For further detail on this process, please reach out to the authors.

Using the launch list with the calculated data, the authors analyzed and provided supporting visualizations on international launch rates, national launch failure rates, vehicle failure rates, company launch activity over time, and more.

Despite the thoroughness of the data, there are limitations. It includes only payloads and launches that are publicly known, and relies on reporting of success or failure of those launches. It also includes only launches through December 31, 2023. Given the continued historic pace of launch, trends should still hold in 2024, but future analyses should continue to add more recent data.

Endnotes

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[3] Presidential Documents, "The National Space Policy," *Federal Register* 85, no. 242 (December 16, 2020), 81769, https://www.govinfo.gov/content/pkg/FR-2020-12-16/pdf/2020-27892.pdf.

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[6] John Uri, "35 Years Ago: STS-26 Returns the Space Shuttle to Flight," NASA, September 27, 2023, https://www.nasa.gov/history/35-years-ago-sts-26-returns-the-space-shuttle-to-flight/.

[7] National Security and International Affairs Division, *Military Space Programs: An Unclassified Overview of Defense Satellite Programs and Launch Activities* (Washington, DC: General Accounting Office, June 29, 1990), https://www.gao.gov/assets/nsiad-90-154fs.pdf. Note that the report points out there were also two separate *Titan* expendable launch vehicle failures, in 1985 and 1986.

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[11] Jacob Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945–1960* (Washington, DC: Office of Air Force History, 1990), 119–25, https://apps.dtic.mil/sti/citations/ADA439957.

[12] Neufeld, *The Development of Ballistic Missiles in the United States Air Force, 1945–1960*.

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[14] T. A. Heppenheimer, “A Shuttle to Fit the Budget,” in *The Space Shuttle Decision: NASA’s Search for a Reusable Space Vehicle* (NASA SP-4221, NASA History Series, 1999, https://nss.org/the-space-shuttle-decision-chapter-8/.

[15] Commercial Space Launch Act, Pub. L. No 98-575, 98 Stat. 3055 (1984), https://www.congress.gov/bill/98th-congress/house-bill/3942/text.

[16] Separate from the 1984 Land Remote Sensing Act that would later be modified by the 1992 Remote Policy Sensing Act. Smartly, but perhaps unexpectedly, it also clarified that the act of launching a spacecraft did not count as an export, presumably to reduce the impact that the International Traffic in Arms Regulations and other export control regimes could have on the industry. Much of this was required per the Outer Space Treaty of 1967. 18 U.S.T. 2410 610 U.N.T.S. 205, 61 I.L.M. 386 (1967), https://www.unoosa.org/oosa/en/ourwork/spacelaw/treaties/introouterspacetreaty.html.

[17] It also offered surplus ICBMs for use as launch vehicles.

[18] Commercial Space Launch Act Amendments of 1988, Pub L. 100-657, 102 Stat. 3900 (1988), https://www.congress.gov/bill/100th-congress/house-bill/4399; Legal and Departmental Authorities of the Office of Space Commerce, U.S. Code Title 51, Chapter 507 (2015), §§ 1 et seq.

[19] The “sense of Congress” in the bill expressed this intent, but so too did a section stating that the government “shall acquire space transportation services from United States commercial providers whenever such services are required in the course of its activities. To the maximum extent practicable, the Federal Government shall plan missions to accommodate the space transportation services capabilities of United States commercial providers.” While the exceptions are broad, requiring government missions to accommodate the capabilities of commercial launchers should have greatly reduced the need for Shuttle launches. Commercial Space Act of 1998, Public L. No. 105-303, 112 Stat. 2843 1998), https://www.congress.gov/bill/105th-congress/house-bill/1702/text.

[20] National Defense Authorization Act for Fiscal Year 2017, Public L. No. 114-328, 130 Stat. 2000 (2016), https://www.congress.gov/bill/114th-congress/senate-bill/2943.

The analysis directed in the 2017 National Defense Authorization Act resulted in a Government Accountability Office report that identified benefits and drawbacks to the sale of government motors. Ultimately, few motors were used for commercial launch, while companies serving the small launch market appeared (e.g., Rocket Lab). See GAO, *Surplus Missile Motors: Sale Price Drives Potential Effects on DOD and Commercial Launch Providers* (GAO-17-609, August 2017), https://www.gao.gov/assets/gao-17-609.pdf.

[21] National Aeronautics and Space Administration Authorization Act of 2005, Public L. No. 109-155, 119 Stat. 2895 (2005), https://www.govinfo.gov/app/details/PLAW-109publ155.

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[28] "SLS Fact Sheets," National Aeronautics and Space Administration, January 24, 2024, https://www.nasa.gov/humans-in-space/space-launch-system/sls-fact-sheets/.

[29] The budget within the 2010 Act provided $10.8 billion in Fiscal Years 2011–2013 for SLS and its crew vehicle ($6.9 billion for SLS alone), while just $1.6 billion was included for Commercial Cargo and Crew missions. See National Aeronautics and Space Administration Authorization Act of 2010. The law required the SLS to support ISS missions should commercial or partner options fail. Because SLS has a budget nearly seven times larger than commercial crew, this is an unusual risk reduction approach.

[30] U.S. Commercial Space Launch Competitiveness Act, Public L. 114-90, 129 Stat. 704 (2015), https://www.govinfo.gov/app/details/PLAW-114publ90. Outside of launch, it also provided early direction of relaxation of remote sensing licensing requirements; directed a study of wider sharing of space situational awareness data, as well as a study of the possible transition of so-called Space Traffic Management responsibilities from the DOD; and, while not at play yet, it also established that within U.S. law, the use of resources in space by U.S. citizens and corporations was authorized without contravening the 1967 Office of Science and Technology's language that celestial bodies were not subject to claims of sovereignty.

[31] Douglas had 49%, 49%, 48%, and 42% from 1961 through 1964, respectively, while General Dynamics notched 43% in 1966 and 42% in 1978.

[32] Percentages in Figure 3A do not sum to 100 percent due to rounding. The NASA/U.S. Government/U.S. Army Consortium covers vehicles contracted by the U.S. government to multiple companies. The USG Consortium includes, for example, the Space Shuttle Orbiter, Solid Rocket Motors, External Tank, and Main Engines, all built by different companies. Additionally, while Chrysler built the Juno I (1958) and Juno II (1958–61) rockets, they are listed under USG as the designer.

[33] Jonathan Chang and Meghna Chakrabarti, "'The Last Supper': How a 1993 Pentagon Dinner Reshaped the Defense Industry," WBUR On Point, March 1, 2023,

https://www.wbur.org/onpoint/2023/03/01/the-last-supper-how-a-1993-pentagon-dinner-reshaped-the-defense-industry.

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https://en.wikipedia.org/wiki/Virgin_Orbit#/media/File:Virgin_Orbin_company_logo_2017.png.

[36] "Missions," United Launch Alliance, https://www.ulalaunch.com/missions/8. Other mergers would continue, for example the series of purchases and mergers of Thiokol into ATK, ATK into Orbital Sciences to form Orbital ATK, and finally the purchase of that business by Northrop Grumman.

[37] The Space Shuttle (and SLS and Saturn-series rockets) are categorized as NASA/USG vehicles. While the orbiter was built by Rockwell, which was eventually sold to Boeing, the large number of other major contractors (e.g., Thiokol solid rocket boosters), and the heavy involvement of government engineers and program managers, meant that allocating the Shuttle to a single company would potentially be problematic. Instead, it is allocated to the USG. From 1996 through ULA's first launch in 2006, Boeing and Lockheed combined for more than 60% of the market every year, exceeding 75% three times, and peaking at 94% of the market in 2004. For the 10 years 2007 though 2016, ULA conducted more than 60% of U.S. launches six times. The four other years saw 47% (2008), 53% (2010), 58% (2013), and 52% (2016).

[38] Both Crunchbase and PitchBook put the venture funding for SpaceX at approximately $9.7 billion.

[39] Starlink is the name of SpaceX's satellite internet business, as well as of the internet-providing satellites themselves. SpaceX had its first two Starlink launches in 2019, and 14 in 2020.

[40] Virgin Orbit achieved a respectable record of four successes in their first six attempts, but they ultimately went out of business. ABL has had one launch attempt, but is not included in the table for clarity and simplicity.

[41] Percentages do not sum to 100 percent due to rounding. Launch Trend shows each company's annual trend and should not be compared across companies, i.e., SpaceX and Rocket Lab did not have the same number of launches in 2023, but in 2023 both had the largest number of launches in company history. A large portion of SpaceX failures are Falcon 1 (three failures) and Starship (two failures) rockets. Each rocket was undergoing development and not considered operational at the time of the failure. This table also gives Firefly credit for two partial failures where satellites were delivered to orbit, even though it was not the correct orbit, and in one case, low enough that the satellites deorbited a week later. See Jeff Foust, "Firefly Says Alpha Launch a Success despite Payload Reentries," SpaceNews, January 23, 2023, https://spacenews.com/firefly-says-alpha-launch-a-success-despite-payload-reentries/. ULA formed as a joint venture between Lockheed Martin and Boeing. Each brought its own launch vehicles to the venture, which is why ULA was founded in 2006 even though its launch vehicles debuted earlier. Some Atlas V and Delta IV missions are tagged in the data as partial failures; they are counted here as successes. Also note that while Lockheed Martin, Boeing, and their predecessors did have launch failures, as a joint venture, and using the current vehicles, there are no outright failures listed in the data set. While the remainder of launch data in this report ends in 2023, ULA's Vulcan did have a successful launch on January 8, 2024. Rocket Lab's Electron data includes failure on its maiden test flight.

[42] GAO, *Surplus Missile Motors: Sale Price Drives Potential Effects on DOD and Commercial Launch Providers*, 30. The GAO's listed cost for the Russian Proton M rocket is well below other data sources and out of family with similar rockets (see "Cost of Space Launches to Low Earth Orbit," Our World in Data, Accessed November 21, 2024, https://ourworldindata.org/grapher/cost-space-launches-low-earth-orbit.

[43] Ashlee Vance, "A Small-Rocket Maker Is Running a Different Kind of Space Race," Bloomberg, February 3, 2020, https://www.bloomberg.com/features/2020-astra-rocket/.

[44] In Figure 6, companies formed before 1980 are binned into 1980. Satellite companies here are defined as unique U.S.-based companies within the PitchBook data set (Space Technology vertical) that our analysis labeled as Remote Sensing, Communications, or Satellite Manufacturing companies. In simple terms, these are firms building and operating many of the satellites in space today. While this PitchBook-sourced data may not capture all satellite companies, trends are expected to hold.

[45] Authors' analysis of Krebs, "Chronology of Space Launches." First launches of production design versions.

[46] Jeff Foust, "Small Launch Startup Leo Aerospace Suspends Operations," SpaceNews, January 23, 2023, https://spacenews.com/small-launch-startup-leo-aerospace-suspends-operations/.

[47] In Figure 8, the companies formed before 1980 have been binned into 1980. PitchBook Data, Inc., is not exhaustive, but trends are generally reliable. A comparison to another commercial data set, Crunchbase, shows the same trends, though the absolute numbers are higher.

[48] Authors' analysis of Krebs, "Chronology of Space Launches."

[49] PitchBook, Crunchbase. Note that this amount includes all of SpaceX's capital raised, including for Starlink.

[50] Authors' analysis of Gunter D. Krebs, "Chronology of Space Launches.".

[51] PitchBook Data, Inc., and Crunchbase.

[52] PitchBook Data, Inc., and Crunchbase show that each of these companies has received nearly half a billion in venture investment. Firefly has between $300 and $500 million, Astra has $390 million, and ABL has $420 to $480 million.

[53] NASA, Defense Advanced Research Projects Agency, and the U.S. Air Force, respectively. "Missions Launched," Rocket Lab, Accessed November 21, 2024, https://www.rocketlabusa.com/missions/missions-launched/.

[54] Anecdotally, professionals in this area say that when government buys from companies in the early investment stage, private capital puts in an order of magnitude more funding than the government commits, enabling the development of capabilities that would otherwise be prohibitively expensive. Nevertheless, due diligence is appropriate in the proposal phase to mitigate risks of a performer encountering delivery issues.

[55] Starlink does have customers paying for the service, but it is unlikely that few launches are actually externally funded. See Sandra Erwin, "SpaceX Providing Starlink Services to DOD under 'Unique Terms and Conditions,'" SpaceNews, November 27, 2023, https://spacenews.com/spacex-providing-starlink-services-to-dod-under-unique-terms-and-conditions/.

[56] Those numbers include launches by SpaceX of Starlink competitor OneWeb: 40 satellites in 2022 and 95 in 2023.

[57] As recently as 2017, U.S. partner India launched nearly as many spacecraft as did the United States, though many were CubeSats from the U.S.-based company Planet Labs. As a low-cost option, Russian rockets were moderately popular before 2014. The People's Republic of China similarly seeks available commercial opportunities. Delivering a satellite to another country very clearly makes it vulnerable to exploitation by the host nation. See one example from 1959: "Lunik on Loan: A Space Age Spy Story," Central Intelligence Agency, 1959, https://www.cia.gov/readingroom/collection/lunik-loan-space-age-spy-story.

[58] Jack Corrigan, James Dunham, and Remco Zwetsloot, "The Long-Term Stay Rates of International STEM Ph.D. Graduates" (Center for Security and Emerging Technology, April 2022), https://cset.georgetown.edu/publication/the-long-term-stay-rates-of-international-stem-phd-graduates/.

[59] Authors' analysis of Gunter D. Krebs, "Chronology of Space Launches.".

[60] Likely a corollary to Spacecraft Design Law 39. See "Akin's Laws of Spacecraft Design," Space Systems Laboratory, Department of Aerospace Engineering, University of Maryland, https://spacecraft.ssl.umd.edu/akins_laws.html.

Christopher T.W. Kunstadter, "Space Insurance Update," AXA XL, January 10, 2022. https://www.nasa.gov/wp-content/uploads/2022/10/04_kunstadter_space_insurance_update_axa_xl_scaf_220111.pdf?emrc=9426ea.

[61] Authors' analysis of Gunter D. Krebs, "Chronology of Space Launches."

[62] "Federal Funds Effective Rate," Federal Reserve Economic Data, , Federal Reserve Bank of St. Louis, updated October 1, 2024, https://fred.stlouisfed.org/series/FEDFUNDS.

[63] Jeff Foust, "Small Launch Companies Struggle to Compete with Spacex Rideshare Missions," SpaceNews, October 18, 2023, https://spacenews.com/small-launch-companies-struggle-to-complete-with-spacex-rideshare-missions/; Ramsha Khan, "SpaceX Introduces Bandwagon Rideshares for Potential Commercial Space Travel," Open Access Government, August 14, 2023, https://www.openaccessgovernment.org/spacex-introduces-bandwagon-rideshares-commercial-space/165045/. Polar missions such as Transporter provide orbits that go over the poles, offering global coverage; however, some missions are better suited for missions that do not fly over the poles but stay closer to the equator. Bandwagon appears to target orbits inclined 45 degrees, which puts the northernmost and southernmost points in their orbit halfway between the poles and the equator.

[64] Jeff Foust, "Small Launch Companies Seek Niches to Compete with Spacex Rideshare," SpaceNews, February 8, 2024, https://spacenews.com/small-launch-companies-seek-niches-to-compete-with-spacex-rideshare/.

[65] Shorter lifetimes mean satellites need to be replaced more often, hence more launches. Similarly, if satellites are replaced or "tech refreshed" faster, then more launches are needed.

[66] Clive Simpson, "How SpaceX's Starship Stacks Up to Other Rockets," SpaceflightNow, April 17, 2023, https://spaceflightnow.com/2023/04/17/how-spacexs-starship-stacks-up-to-other-rockets/.

[67] While Blue Origin appears to have only between $160 million (Crunchbase) and $500 million (PitchBook) in investor funding, its ownership by Jeff Bezos, founder and former CEO of Amazon, means that it is likely isolated from actual changes in the venture capital environment.

[68] Office of the Under Secretary of Defense for Acquisition and Sustainment, *State of Competition within the Defense Industrial Base* (Department of Defense, February 2022), https://media.defense.gov/2022/Feb/15/2002939087/-1/-1/1/STATE-OF-COMPETITION-WITHIN-THE-DEFENSE-INDUSTRIAL-BASE.PDF.

[69] Philippe Aghion, Nick Bloom, et al., "Competition and Innovation: An Inverted-U Relationship," *Quarterly Journal of Economics* 120, no. 2 (2005): 701–28, https://www.jstor.org/stable/25098750; Matt Stoller and Lucas Kunce, "America's Monopoly Crisis Hits the Military," *The American Conservative*, November 13, 2019, https://www.theamericanconservative.com/americas-monopoly-crisis-hits-the-military/.

[70] This study makes no attempt to evaluate the competitive intent of those missions, nor to evaluate within any other framework but the analysis already made.

[71] Talent may also be a limiting factor. SpaceX alumni have founded multiple other companies, including some nascent competitors. All of these will need their own skilled workers, from engineers to technicians and machinists. With space industry labor demand growing worldwide and in the United States, there will be a growing competition for labor.

[72] "Reusable Rockets," Rocket Lab, https://www.rocketlabusa.com/launch/reusable-rockets/.

[73] Andrew Jones, "Europe Won't Have Reusable Rockets for Another Decade: Report," Space.com, May 4, 2023, https://www.space.com/europe-no-reusable-rocket-until-2030s; Mike Wall, "Russia Planning to Go Reusable in 2026 with New Amur Rocket," Space.com, October 14, 2020, https://www.space.com/russia-announces-reusable-rocket-amur.

[74] Andrew Jones, "Chinese Company's Reusable Rocket Prototype Aces Launch-and-Landing Test," Space.com, February 4, 2024, https://www.space.com/chinese-company-expace-reusable-rocket-test.

[75] Martin Placek, "Average Hourly Earnings in U.S. Manufacturing from 2006 to 2021," Statista, September 28, 2022, https://www.statista.com/statistics/187380/hourly-earnings-in-us-manufacturing-since-1965/; Einar H Dyvik, "Manufacturing Labor Costs per Hour for China, Vietnam, Mexico from 2016 to 2020," Statista, February 2, 2024, https://www.statista.com/statistics/744071/manufacturing-labor-costs-per-hour-china-vietnam-mexico/.

[76] Alan Mackey, "Survival of the Fittest: Saturation in the Space Launch Industry," SpaceWorks Enterprises, Inc., August 19, 2022, https://www.spaceworks.aero/survival-of-the-fittest_launch_industry/.

[77] Sandra Erwin, "Space Force Keeping the 'Responsive Launch' Dream Alive," SpaceNews, September 14, 2023, https://spacenews.com/space-force-keeping-the-responsive-launch-dream-alive/.

[78] "Talent Attractiveness 2023," Organization for Economic Co-operation and Development, https://www.oecd.org/migration/talent-attractiveness/; "What Is the Best Country for Global Talents in the OECD?" Organization for Economic Co-operation and Development, March 2023, https://web-archive.oecd.org/2023-03-09/652850-What-is-the-best-country-for-global-talents-in-the-OECD-Migration-Policy-Debates-March-2023.pdf; Corrigan, Dunham, and Zwetsloot, "The Long-Term Stay Rates of International STEM PhD Graduates"; Joseph Parilla, "Talent Is America's Most Precious Resource—It's Time Economic Development Organizations Focus More on Developing IT," Brookings, March 9, 2022, https://www.brookings.edu/articles/talent-is-americas-most-precious-resource-its-time-economic-development-organizations-focus-more-on-developing-it/.

[79] Alex Travelli, "The Surprising Striver in the World's Space Business," *The New York Times*, July 4, 2023, https://www.nytimes.com/2023/07/04/business/india-space-startups.html.

[80] Jason Rainbow, "Space Tugs as a Service: In-Orbit Service Providers Are Bracing for Consolidation," SpaceNews, January 23, 2023, https://spacenews.com/space-tugs-as-a-service-in-orbit-service-providers-are-bracing-for-consolidation/.

[81] Stephen Clark, "NASA Says SpaceX's Next Starship Flight Could Test Refueling Tech," Ars Technica, December 6, 2023, https://arstechnica.com/space/2023/12/nasa-wants-to-see-gas-stations-in-space-but-so-far-its-tanks-are-empty/.

[82] Andrew Jones, "Chinese Startup Aims to Debut New Reusable Rocket Next Year," Space.com, May 8, 2023, https://www.space.com/china-galactic-energy-pallas-1-reusable-rocket.

[83] This mission was called RESTORE-L in the 2021 Appropriation, and later renamed OSAM-1. It has recently been canceled by NASA, allegedly for contract performance issues. It remains unclear what a future program will look like, but it is one of only two programs specifically identified for funding in the space technology section of the appropriation.

[84] Sandra Erwin, "Space Force Eager to Harness Satellite-Servicing Technologies," SpaceNews, June 13, 2023, https://spacenews.com/space-force-eager-to-harness-satellite-servicing-technologies/; Sandra Erwin, "Space Force to Industry: Prove Value of New Commercial Space Services," SpaceNews, April 23, 2023, https://spacenews.com/space-force-to-industry-prove-value-of-new-commercial-space-services/.

[85] OSAM-1 cancellation was initiated as this paper entered review. Nevertheless, the cancellation appears to be due to a number of project-specific elements unrelated to congressional interest or industry interest in servicing; rather, the particular contract structure and technical approach are factors. See "Update on Status of NASA's OSAM-1 Project," NASA Communications, March 1, 2024, https://www.nasa.gov/missions/update-on-status-of-nasas-osam-1-project/; and Stephen Clark, "NASA Cancels a Multibillion-Dollar Satellite Servicing Demo Mission," Ars Technica, March 5, 2024, https://arstechnica.com/space/2024/03/nasa-cancels-a-multibillion-dollar-satellite-servicing-demo-mission/#page-2.

[86] Theresa Condor, "The Power of Government as an Anchor Customer," Via Satellite, February 14, 2020, https://interactive.satellitetoday.com/the-power-of-government-as-an-anchor-customer/.

[87] Stephen Clark, "SpaceX's Workhorse Launch Pad Now Has the Accoutrements for Astronauts," Ars Technica, March 21, 2024, https://arstechnica.com/space/2024/03/spacexs-workhorse-launch-pad-now-has-the-accoutrements-for-astronauts/#page-2.

[88] Courtney Albon, "Policy Bill Backs New Revenue Streams for U.S. Space Force Launch Ranges," C4ISRNet, December 19, 2023, https://www.c4isrnet.com/battlefield-tech/space/2023/12/19/policy-bill-backs-new-revenue-streams-for-us-space-force-launch-ranges/.

[89] Safety has historically driven U.S. launch sites to the coast. That does make them vulnerable if competition becomes conflict.

[90] Claire A. O'Shea, "NASA Selects Blue Origin as Second Artemis Lunar Lander Provider," NASA, May 19, 2023, https://www.nasa.gov/news-release/nasa-selects-blue-origin-as-second-artemis-lunar-lander-provider/.

[91] Our team used the "Space Technology" vertical to generate candidate companies prior to manual review. The use of labeled verticals improves comparisons between industries over other methods. See "What Are Industry Verticals," PitchBook, https://pitchbook.com/what-are-industry-verticals.

[92] The labeling options for launch companies is: 1: Re-entry/EDL 2: If Launch only, leave blank.

[93] E.g., Erik Kulu, "Satellite Constellations," NewSpace Index, https://www.newspace.im/; Erik Kulu, "Nanosats," Nanosats Database, https://www.nanosats.eu/.

[94] "Space-Track.org," 18th Space Control Squadron, https://www.space-track.org/auth/login; "NASA Space Science Data Coordinated Archive," Goddard Space Flight Center, https://nssdc.gsfc.nasa.gov/nmc/; "eoPortal," Committee on Earth Observation Satellites, https://www.eoportal.org/.

[95] Company ownership was adjusted to account for merger and acquisition activity over time; Rocket Lab is a unique dual-nation case, but the analysis treats it as a U.S. company since it is incorporated in the United States.