COMMERCIAL SPACE
FEDERATION

SCRUBBED: America's Launch Capacity Challenge

Potential U.S Launch Demand and Considerations for Improving Launch Capacity

May 2026

Authors:
Thomas J. Colvin, Moon J. Kim, and Akhil Rao

Rational Futures

Rational Futures was founded to help make critical decisions for the betterment of humanity.
For questions: research@rationalfutures.com

Executive Summary

U.S. orbital launch demand has surpassed 180 launches per year, straining infrastructure that must be developed years in advance of its need. Existing launch demand forecasts rely on simple growth rates and overlook mission-specific parameters like orbital destinations, azimuths, inclinations, and payload masses–leaving stakeholders unable to confidently assess whether current capacity can meet future needs. In this paper, we attend to these mission-specific parameters to characterize conditions under which gaps between launch demand and site capacity may emerge. We are not predicting future supply or demand levels but instead quantifying the implications of various assumptions readers may hold. We also provide qualitative considerations for how traditional, inland, and sea-based spaceports could address potential shortfalls.

Potential Demand for Satellites

To assess potential demand for U.S. launch services, we first created three scenarios that build to progressively larger potential demand for U.S.-operated satellites that will require space launch services. Satellite data was primarily gathered from applications to the Federal Communications Commission (FCC) for licenses to operate under their Part 25 authority. **Scenario A** contains demand from U.S. government customers, commercial demand for launches to GEO, and spacecraft that are approved by the FCC for operation under Part 25. **Scenario B** includes the same satellites and adds in satellites that have applied to the FCC within the last five years but have not yet been approved. This scenario excludes proposals for new space data centers. **Scenario C** adds in the data centers that have applied for FCC approval. With over one million data center satellites proposed, this represents a unique step change in the potential demand for space launch.

Assessing Launch Capacity in the Near Future

We assessed launch capacity by using five categories of vehicles, ranging from Micro to Ultra vehicles, which deliver 300 kg and 100,000 kg to LEO, respectively. To assess launch capacity for each category of vehicle, we used the annual number of licensed launches as the constraint on launch supply. We also included licensed launch amounts that have not yet been approved, but that are in the process of being adjudicated. We developed a simple algorithm that allocates satellites to launch vehicles from the specific launch sites where they are permitted. Our algorithm is designed to satisfy as much of the satellite demand as possible given orbital mechanics considerations, with no reference to launch prices or other business considerations. This approach reasonably reproduces launch data seen in 2025; however, over-estimates the number of launches on smaller-sized launchers and lacks key variables related to customer behaviors that are beyond the scope of this report.

Our results are summarized in Figure ES-1, which shows our estimated number of annual launches, broken out by launch vehicle size for Scenarios A, B, and C. In the top row, all satellites are assumed to have their reported mass; we see Ultra vehicles essentially reaching their capacity in Scenario A. In the middle row, all constellations with over 1,000 satellites are assumed to be only 30 percent of the mass that they are reported; this level of mass reduction aligns with some relevant mass reductions seen in the data. For this case, we see that smaller launch vehicles are at capacity, but larger vehicles don’t start to reach capacity until the one million satellites are added in Scenario C.

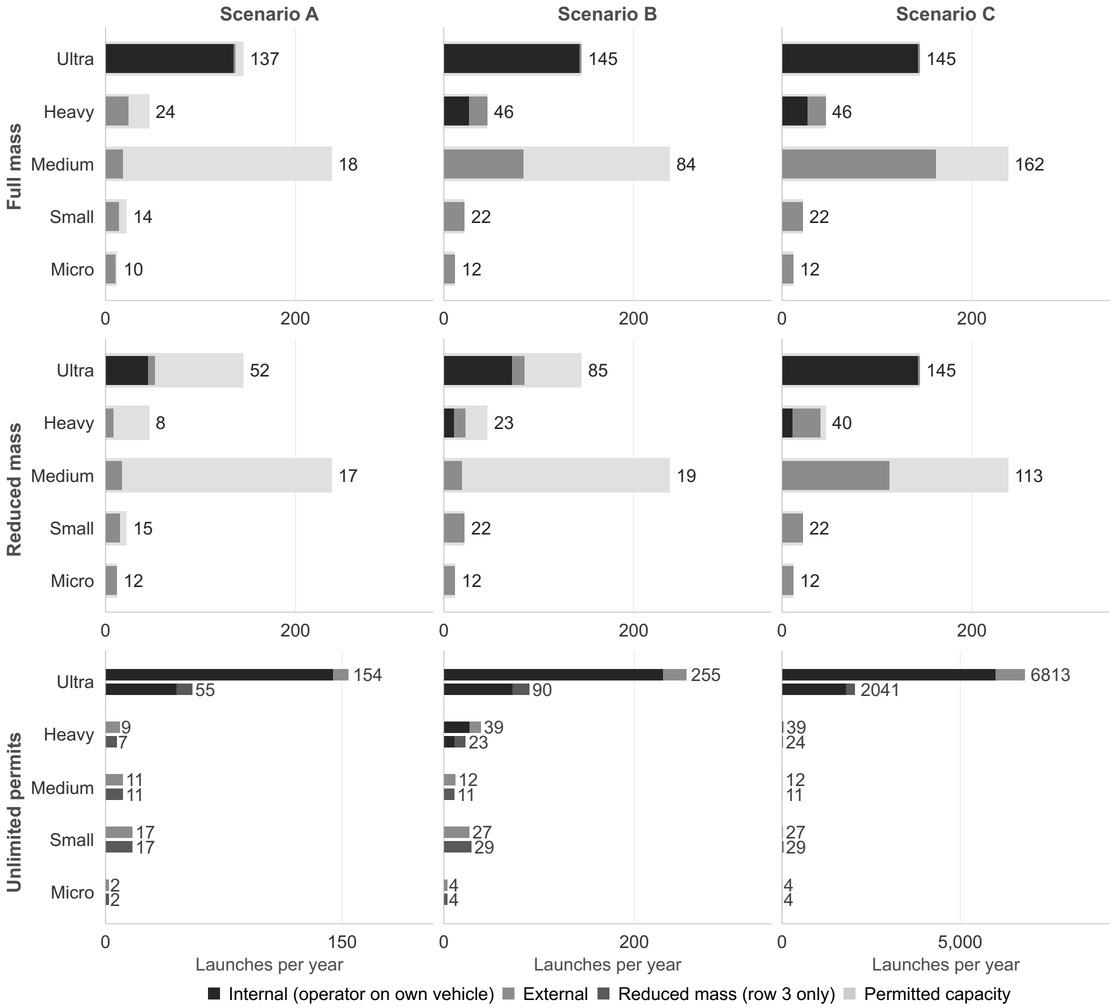


Figure ES.1. **Summary of launch capacity calculations across satellite demand scenarios.** The rows explore the capacity effects if the satellites are as massive as reported (top), if the satellites have reduced mass in line with historical anecdotes (middle), and when the launch supply is unconstrained (bottom). The bars indicate annual licensed capacity (light grey), launches of payloads from the market (medium grey), and launches of payloads owned by the launch provider (dark grey).

Finally, we estimate an annual launch manifest if there are no constraints on launch supply. Our algorithm shows that when larger vehicles come online, it may be technically feasible for them to satisfy the bulk of the satellites in all scenarios. Indeed, the largest launch vehicles may need to launch many thousands of times per year if space data centers materialize as proposed.

Potential Actions to Support Launch Capacity

We characterized the challenges facing traditional launch sites (primarily Cape Canaveral, Vandenberg, and Wallops) and non-traditional sites, defined as those neither federally operated nor reliant on a nearby federal site. We have drawn the following actions from our interviews and desk research. The actions are organized by whether they primarily benefit traditional sites, non-traditional sites, or both. These are presented not as recommendations, but as potential paths forward.

Actions that primarily support traditional sites:

- **Create a central authority to manage U.S. launch sites.** Operators are ambivalent about who gains this authority but noted that a single authority to manage operations may be necessary to coordinate activities and advocate for changes on sites that are shared by various Federal and commercial entities. This authority could also lead implementation for many of the following actions.
- **Create a zoning board function** to more strategically assign operators and infrastructure to locations on base.
- **Coordinate infrastructure upgrade investments** between the Department of Defense (DoD), NASA, local governments, and private companies to more effectively meet broader operator needs.
- **Create a centralized platform to coordinate shared resource scheduling**, including payload processing facilities, propellant access, heavy load transport, tanking and testing operations, and launch scheduling.
- **Reduce the size of evacuation zones** with improved explosive analysis for modern propellant combinations, such as methane and oxygen, to reduce disruptions on base.

Actions that support traditional and non-traditional sites equally:

- **Improve flight safety tools** by releasing USSF hazard area models to the community and having the Federal Aviation Administration (FAA) certify commercial alternatives, enabling operators to understand, refine, and run the tools themselves to optimize trajectories and reduce airspace disruptions.
- **Implement dynamic airspace management** using real-time launch vehicle monitoring to detect failures and rapidly reroute aircraft, eliminating the need for proactive airspace restrictions and potentially enabling inland launch sites.
- **Consider updating rocket overflight regulations** which may currently preclude launch and reentry operations that occur over land.
- **Pursue mobile payload processing facilities** that can flexibly support emerging spaceports, traditional launch sites, and responsive launch capabilities, rather than investing exclusively in fixed facilities tied to a single location.

Actions that primarily support non-traditional sites:

- **Create government-endorsed analyses of safe trajectory options, payload performance for those trajectories, and infrastructure costs to reach reasonable flight rates** for non-traditional launch sites to fill a critical literature gap and build credibility with state, congressional, and industry stakeholders.
- **Extend federal range services to non-traditional launch sites–**including radar, telemetry, tracking, and flight safety analysis–to reduce the capital requirements for new spaceports.
- **Provide Federal funding or anchor tenancy commitments to non-traditional launch sites** if they are deemed a national priority, as market forces alone are unlikely to create them.

Contents

Copyright Notice

Washington, DC

1. Introduction

A. Goal

This paper characterizes the conditions under which there may be gaps between the demand for launch from U.S. space operators and the capacity of U.S. launch sites to serve the demand. We provide qualitative considerations for using traditional, inland, and sea-based spaceports to address potential shortfalls. This paper does not make predictions about future levels of launch supply or demand; it quantifies the effects of various assumptions that readers may hold about the future.

B. Background

The commercial space industry's growth over the last decade has pushed U.S. orbital launch demand above an unprecedented 180 launches per year. Infrastructure forms the backbone of the launch industry, requiring forecasts of future launch demand to guide infrastructure that maintain and build launch capacity. However, existing forecasts rely on simple growth rates and fail to account for mission-specific parameters such as orbital destinations, launch azimuths, target inclinations, and payload masses. These limitations leave stakeholders unable to accurately understand whether current launch infrastructure can accommodate future demand.

Assessments of future demand must account for launch site and mission specific constraints that determine which launch sites, and which vehicles can serve which missions. Without this level of detail, industry and government stakeholders cannot rigorously assess whether new launch infrastructure is needed or where it should be located.

To address this knowledge gap, the Commercial Space Federation (CSF) commissioned this work to assess gaps between potential future demand for launch and existing capacity at U.S. launch sites. Further, we evaluate the potential for using traditional, inland, and sea-based spaceports to address any such gap. The analysis combines quantitative capacity modeling with qualitative stakeholder interviews to provide an assessment of U.S. launch infrastructure needs.

C. Outline of the report

The first chapter details how we used the Federal Communications Commission (FCC) application data to create a high-quality set of scenarios that characterize the potential satellites for which operators may demand launch services. Next, we discuss our method for allocating satellites to launch vehicles, assess the conditions under which annual launch capacity may be exceeded, and estimate a potential manifest for launch services if launch supply is unconstrained. The following two chapters discuss benefits and challenges faced by traditional and non-traditional launch sites. We conclude with a chapter on potential actions that may address the previously described challenges.

D. A note about our use of the word “demand”

Demand for satellites will drive demand for launch services. However, direct estimates of both quantities are beyond the scope of this report. Instead, we must rely on potential proxies for these quantities–proxies which lack the set of economic considerations that may drive market outcomes.

As a proxy of *potential* demand for satellites, we rely on statements made by satellite operators to their regulator, the FCC, about the quantities of satellites they may deploy. On one hand, this may be a reasonable indication of the number of satellites they will launch, because the operators should know the market in which they will compete and what that market will bear. On the other hand, operators are often optimistic about their markets and the share of those markets that they might capture or may wish to signal to their competitors or investors. For example, recall the low-Earth orbit (LEO) telecom bubble from the early 1990s; over one thousand satellites were initially proposed across multiple companies, but only Iridium launched their satellites. Clearly, not all proposed satellites become real satellites. We did not attempt to construct market estimates for satellite services that would allow us to estimate the numbers and types of satellites that would be needed to meet market demands for satellite services; thus, we have relied on the statements from the satellite operators to create scenarios of potential demand for satellites to launch.

As a proxy for launch demand, we construct launch manifests using a simple set of heuristics that primarily account for technical constraints on the vehicles, launch pads, and orbital mechanics. This means that many aspects of demand are not accounted for, such as launch price, schedule, and reliability. Likewise, some satellite operators may wish to support or avoid certain launch providers. We account for such preferences only if the satellite operator is the same company as the launch provider; otherwise, we assume any satellite will ride on any vehicle that can carry it to its destination. We assume that our five representative launch vehicles and ready and available for customers to use, including those vehicles that are not yet operational as of this writing.

Ultimately, we do not need to estimate launch demand to show the conditions under which there may be a gap in launch capacity. Instead, we can show feasible allocations of satellites to launch vehicles under various sets of assumptions. If certain assumptions lead to a capacity gap in our feasibility analysis, then a gap of similar severity is reasonable when real world market dynamics are in play. Our algorithm prefers to group payloads together onto larger vehicles, which reduces the total number of launches required compared to other methods that may prefer more launches on smaller vehicles. In the market, smaller launchers may be preferred if they are competitively priced or better suited to operational requirements. Thus, market outcomes may show a greater use of smaller launchers, leading to a greater number of overall launches and greater capacity gap than we have manifested. Assessing the conditions under which such demand dispersion may occur is an interesting question for future research.

2. Creating Scenarios for Assessing Launch Capacity

We created a set of scenarios that build to progressively larger demand for satellites that will require space launch services. Each scenario is a set of primarily U.S. satellites that may be launched on U.S. vehicles. Satellites are organized into scenarios based on the quality and coverage of data available about the number, mass, and orbital parameters of the satellites. The scenarios are snapshots at an unspecified moment in the near future, which is rotationally in the first few years of 2030. We have restricted our attention to U.S. satellites, except for commercial geosynchronous (GEO) satellites; the potential for international customers to drive gaps in U.S. launch capacity is out of scope for the current work.

These scenarios should not be misconstrued as predictions of future demand in the overall launch market or any submarkets, such as demand for small satellites or GEO satellites. The scenarios show varying levels of potential demand based on the best available data. Their purpose is to explore the implications for launch capacity of what has been proposed by U.S. space companies.

A. Summary of demand scenarios for satellites

We created three main demand scenarios, which we summarize here. We constructed and arranged the following scenarios sequentially, such that each scenario contains all the satellites associated with the previous scenarios. The building blocks that contribute to the scenarios are illustrated in Figure 2.1 and will be discussed in the following section

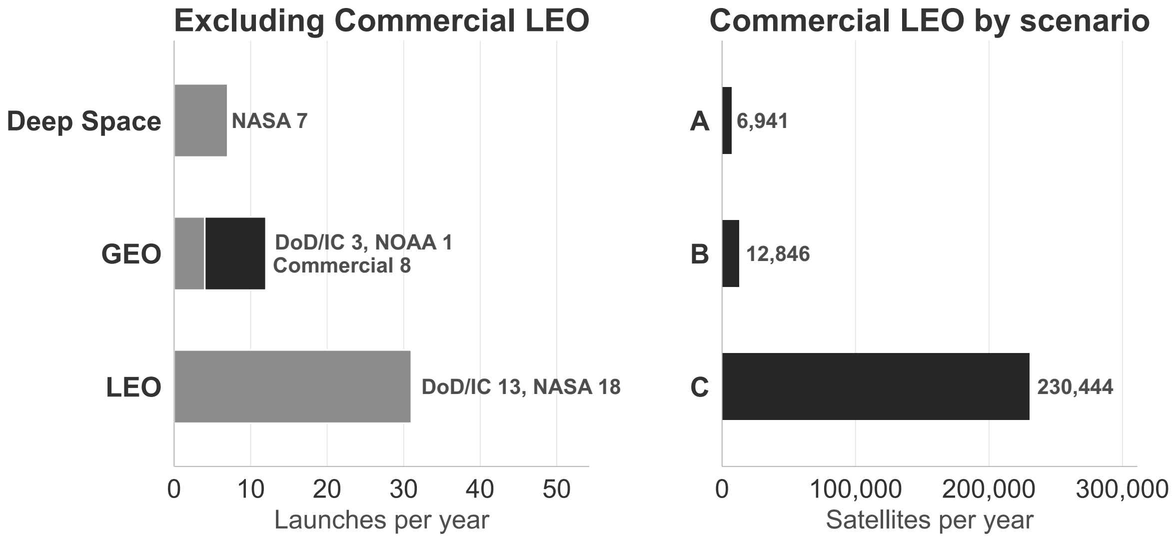


Figure 2.1. Summary of building blocks used to construct our launch manifests.

Scenario A: Part 25 approved. This scenario contains U.S. government demand for launches to any orbit and commercial GEO launches from U.S. and international clients, all shown on the left side of Figure 2.1. This scenario also includes nearly all spacecraft that are approved by the

FCC for operation under Part 25 of their licensing authority,[1] shown as building block A on the right side of Figure 2.1. Such spacecraft represent systems that are authorized to provide commercial service, as opposed to experimental or proof-of-concept systems that are authorized under FCC's Part 5 authority. The Part 25 application for an approved system generally has the technical data needed to conduct our analysis. Further, the operator is authorized to launch their systems at any time, if they have not already; thus, this is potentially the most immediate demand for launch services. For those constellations that are partially approved, we use the full constellation size. This is appropriate because we are trying to characterize potential demand in the early 2030s, by which time these systems may be fully deployed.

Scenario B: Part 25 not yet approved (excluding data centers). This scenario adds the satellites that have applied to the FCC Part 25 license but are not approved, building block B in Figure 2.1. We consider applications for space-based data centers in a separate scenario. We only considered applications submitted within the last five years. There are many reasons why an application may not be approved: the application may have been only recently submitted, it may have been explicitly denied, the operator may have withdrawn the application, or the proposed system may have been combined with another application that was approved. We have taken care to address applications that represent duplicative constellations but did not account for other reasons why an application is not approved.

Scenario C: Space-based data centers. In addition to all previously discussed satellites, this scenario adds applications for space data centers. With over one million data center satellites proposed, this represents a unique step change in the potential demand for space launch.

To assess launch capacity, it is important to account for the role of the demanded orbits. If there are few satellites going to a specific orbit, there may not be enough demand to justify launching a larger vehicle. Further, the inclination of the demanded orbits plays an important role, not just in determining which specific payloads can be launched together, but also the payload capacity of the launch vehicle that delivers them. All else equal, a rocket can deliver less mass to higher inclination orbits than to lower inclination orbits. Likewise, a rocket delivers less mass to higher altitude orbits than lower altitude orbits; however, with the increasing adoption of electric propulsion, the operational orbit of the satellites has reduced importance. Satellites may launch to low orbits then raise themselves many hundreds of kilometers in altitude with their onboard electric propulsion. For these reasons, we view inclination and mass as the key parameters to summarize our scenarios for the potential demand of satellites in the future. This is illustrated in Figure 2.2 for Scenarios A and B. The distribution for Scenario C is qualitatively similar in shape to Scenario B but is 20- to 40-times more massive at various inclinations.

---

[1] In some cases, we have removed approved systems that are no longer relevant.

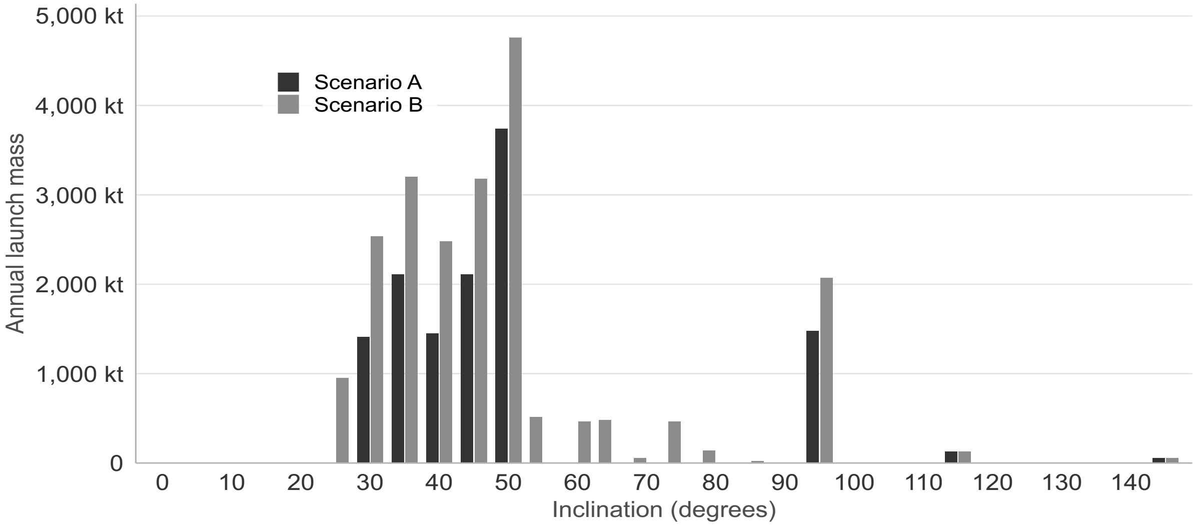


Figure 2.2. The distribution of satellite mass by inclination for Scenarios A and B. Scenario C appears similarly, but is an order of magnitude more mass than Scenario B.

B. Building blocks for creating demand scenarios

This section provides details regarding the sources, satellites, and methods we used to create our demand scenarios. The section is organized into *building blocks*, which are combined to create the scenarios previously summarized. Readers with limited time may choose to skip this section and proceed to the calculations of launch capacity.

1. Baseline government demand

We created a baseline amount of launch demand from government sources, shown in Table 2.1. The National Aeronautics and Space Administration (NASA) has 18 launches to LEO per year. This is mostly missions to private space stations and refueling flights to support crewed lunar flights. NASA also has seven deep space missions per year for the Moon and other destinations. The Department of Defense (DoD) and the Intelligence Community (IC) have 16 annual missions, with the majority being to LEO for deployment and replenishment of the Space Development Agency's (SDA) constellations. The National Oceanic and Atmospheric Administration (NOAA) is allotted one launch per year to GEO; this is an over-estimate of NOAA's annual demand, which is generally less than one such satellite per year.

Table 2.1. Government demand building block

Operator	System Name	Destination	Inclination [deg]	Launches Total	Launcher Size
NASA	HLS - Starship[a]	LEO	30	8	Ultra
NASA	HLS - Starship[a]	Deep	30	1	Ultra
NASA	HLS - Blue[b]	LEO	30	3	Heavy
NASA	HLS - Blue[b]	Deep	30	1	Heavy
NASA	CLD Missions[c]	LEO	51.6	3	Medium
NASA	CLD Missions[c]	LEO	51.6	2	Medium
NASA	NASA Science[d]	LEO	55	1	Micro
NASA	NASA Science[d]	LEO	97	1	Small
NASA	NASA Misc.[e]	Deep	30	4	Medium
NASA	NASA Misc.[e]	Deep	30	1	Heavy
DoD	DoD Misc.[f]	LEO	45	1	Micro
DoD	DoD Misc.[f]	LEO	45	1	Small
DoD	DoD Misc.[f]	GEO	2	1	Heavy
DoD	DoD Misc.[f]	LEO	70	5	Medium
DoD	DoD Misc.[f]	LEO	81	5	Medium
DoD	DoD Misc.[f]	MEO	55	1	Medium
DoD	DoD Misc.[f]	LEO	63	2	Medium
NOAA	NOAA Misc.[g]	GEO	30	1	Medium
Total				**42**	

a. Starship takes ~15 tanker launches for a mission according to GAO. With a mission every other year, trading off with Blue, that is 8 tanker launches per year on average after rounding up. Choosing 30° inclination because that can be reached from the Cape and Boca Chica. There would be half a launch of crewed HLS every year on average, rounded up to 1.

b. Blue Moon takes ~6 refueling launches for a mission, which averages out to 3 such launches per year. We round the crewed HLS variant up to 1 per year.

c. Three cargo missions and two crew missions per year to a future commercial LEO destination (CLD).

d. Based on the VADR missions.

e. This is two CLPS missions and three other miscellaneous things, such as gateway logistics or planetary science missions that historically would be slated for a medium rocket. A few things require a heavy launcher, like the PPE for Gateway, so we include one heavy launch in our profile.

f. Inclinations are chosen to be 45° for smaller launchers based on a DoD launch of Electron in 2025. Likewise, DoD launched a Vulcan to GEO in 2025. Starshields were launched to 70° in 2025. SDA satellites go to 81° to 97°. There was one launch to MEO for GPS III in 2025. Finally, there were 2 other launches on Medium launchers to 63° in 2025.

g. NOAA launches half a sat per year to LEO and half a sat per year to deep space. GOES launches rarely happen. We assign a single launch per year to NOAA.

2. Baseline commercial GEO demand

The greatest sensitivity to our results will be commercial launches to LEO; thus, we provide a simple background demand block for commercial GEO launches in Table 2.2. Based on actual launches in 2025, we assign eight total commercial launches to GEO, mostly from non-U.S. customers.

Table 2.2. Commercial GEO demand building block

Operator	System Name	Destination	Inclination [deg]	Launches Total	Launcher Size
Internationals	International Sats[a]	GEO	-	6	Medium
U.S. Commercial	U.S. Commercial Sats[b]	GEO	-	2	Medium
Total				**8**	

a. There were 6 such launches of international satellites on Falcon 9s in 2025.

b. There were 2 commercial launches in 2025, Sirius XM and Viasat.

3. Satellites approved by FCC under Part 25

For commercial satellites going to LEO and occasionally medium Earth orbit (MEO), we gathered data from all satellites that are approved by the FCC for operation under Part 25 of their licensing authority.[2] Such satellites represent systems that are authorized to provide commercial service, as opposed to experimental or proof-of-concept systems that are authorized under FCC's Part 5 authority. We determined approvals based on data from Dec 10, 2025, so systems approved after that date are not included in this category.

Space operators must submit an application to the FCC for Part 25 approval; these applications are publicly available through the International Communications Filing System (ICFS) and generally have the technical data needed to conduct our analysis. For a representative example, Table 2.3 shows the technical data for Starlink Gen 2 found in SpaceX's publicly available FCC filings. We gather data by orbital shell because, in general, each shell will contain satellites at different altitudes and inclinations. These parameters are important for estimating launch capacity because launch vehicles have reduced payload capacity to higher inclinations and higher altitudes. Satellites approved under Part 25 will list their operational altitude and many will also list their insertion altitude, which is where the launch vehicle actually separates from the satellite. The Starlink example shows that satellites may often be inserted at altitudes well below their operational altitudes, provided the satellites have electric propulsion systems to raise their orbit after insertion.

Table 2.3. Sample orbital data for SpaceX Starlink Gen 2 (call sign S2992/3069)

Shell (#)	Insertion (km)	Altitude (km)	Inclination (deg)	Total Sats (#)	Lifetime (yr)	Mass (kg)
1	300	614	115.7	324	5	-
2	300	604	148	144	5	-
3	300	535	33	3,360	5	-
4	300	530	43	3,360	5	-
5	300	525	53	3,360	5	-
6	300	360	96.9	3,600	5	-
7	300	350	38	5,280	5	-
8	300	345	46	5,280	5	-
9	300	340	53	5,280	5	-

Sources: Insertion altitude and satellite lifetime taken from SpaceX's 2020 filing SAT-LOA-20200526-00055. The insertion altitude was given as "an elliptical orbit of approximately 210 km by 370 km," which we smoothed out to 300 km. The remaining values are taken from a 2021 amendment SAT-AMD-20210818-00105. There have been subsequent amendments related to this callsign; however, the 2021 values are sufficient for our analysis. Mass is missing from the FCC documents and must be supplemented with information from other sources.

The data in these applications are often missing important parameters, such as satellite lifetime or per-satellite mass. In these cases, we rely on other open-source information to fill in the gaps. For example, to find the mass of satellites that have historically flown, we reference the American Enterprise Institute's (AEI) Global Space Data Navigator. In the Starlink Gen 2 example, we see

---

[2] In some cases, we have removed approved systems that are no longer being pursued by their operator.

the mass of a Starlink V2 Mini satellite launched in 2025 was approximately 575 kg (AEI n.d.). These values are injected into our scenario database for all missing values. For missing insertion altitudes, we assume that large constellations are likely to have electric propulsion and thus can be inserted at low orbits of 300 km, before orbit raising to their operational orbit. Any remaining satellites without insertion altitudes are assumed to be inserted at their operational altitude.

As of December 10, 2025, the FCC had approved 64 callsigns for non-geostationary orbit (NGSO) operations that are administered by the United States. Our database contains 58 unique and approved callsigns for LEO. The discrepancy is due to four lunar landers and two satellite servicers that the FCC considered as NGSO systems, but do not operate in LEO. Table 2.4 shows all of the operators and their associated number of satellites across all callsigns. We have shell-level data for these satellites, similar to Table 2.3.

Table 2.4. Operators approved under Part 25 and their associated satellites

Operator	Num Sats	Operator	Num Sats
Aethero Space Inc	1	Orbcomm[c]	0
Albedo Space[a]	24	Orbital Sidekick	6
Amazon Kuiper	3,236	Outpost Technologies	2
AST SpaceMobile	248	Pixxel	3
BlackSky	34	Planet Labs	778
Capella Space	5	PlanetiQ	2
HawkEye 360	60	Quantum Space	1
Helogen	1	R2 Space	8
Hubble Network	60	Sidus Space	4
Iceye	23	Spaceflight Inc	1
Impulse Space	1	SpaceX[d]	34,396
Iridium	78	Spire	8
Launcher Inc	1	Swarm Technologies	300
Ligado Networks[b]	0	Theia Holdings	120
Loft Orbital	15	Tomorrow.io	18
Lynk Global	10	Turion Space	2
Maxar	12	Umbra	10
Momentus Space	1	Vast	1
Muon Space	1	Xplore Inc.	1

Total U.S. Satellites Approved For LEO: 39,472

a. Albedo has publicly pivoted away from operating its own VLEO constellation; however, it still intends to sell its buses to other VLEO operators. Presumably the company must believe there is at least this much demand for future VLEO satellites.

b. Ligado's approval is to host instruments on AST SpaceMobile satellites; thus, it contributes no new satellites to the scenario.

c. Orbcomm's approval was to extend the license of a system that was originally granted in 1994; we assumed this constellation will not be refreshed when it has finally ended.

d. SpaceX has approvals for its Gen1 and Gen2 constellations. In our scenarios, we will disregard the Gen1 constellation.

The numbers given in the table are for full constellations. We annualize the demand to estimate the annual number of launches in the future. For sufficiently large constellations (i.e., more than 20 total satellites), we assume that the operators will launch their constellations steadily at whatever annual rate is required to keep the constellation fully stocked. This annual rate corresponds to the number of satellites in each shell divided by the average satellite lifetime. For example, to maintain a 30,000-satellite constellation where each satellite has a 5-year lifetime would require 6,000 satellites launched per year.

This approach does not work for the call signs with few satellites, because each shell may get rounded to zero. To annualize smaller constellations or one-off systems, we combined the call signs with fewer than 20 total satellites into a single new call sign (Fsub20) by aggregating the satellites into new shells with similar combinations of altitude, inclination, and mass. The resulting shells generally have enough satellites to allow effective annualization. Table 2.5 shows the resulting aggregation.

Table 2.5. Annualized demand for call signs with few satellites approved in Part 25

Shell (#)	Insertion (km)	Altitude (km)	Inclination (deg)	Total Sats (#)	Lifetime (yr)	Mass (kg)
1	450	450	96	2	Annualized	195
2	500	500	44	2	Annualized	515
3	500	500	52	1	Annualized	85
4	500	500	96	1	Annualized	84
5	500	500	96	1	Annualized	363
6	525	525	6	2	Annualized	5
7	525	525	96	5	Annualized	14
8	525	525	96	3	Annualized	88
9	525	525	96	1	Annualized	106
10	550	550	44	2	Annualized	12
11	550	550	96	2	Annualized	22
12	550	550	96	9	Annualized	88
13	550	550	96	2	Annualized	150
14	550	550	96	1	Annualized	216
15	575	575	96	2	Annualized	67
16	575	575	98	2	Annualized	9
17	600	600	48	1	Annualized	165
Total				**39**		**2,184**

Note: This annualization incorporates 148 satellites from 41 callsigns, with a further 3 callsigns skipped because they do not represent satellites that may be launched in the future.

To finalize this building block, we annualize the larger constellations, insert the new Fsub20 call sign, and remove the call signs that were used to create Fsub20. The resulting scenario contains the annualized number of satellites to be launched per year, including their masses, orbital altitudes, and inclinations. The systems with their resulting annualized satellites and masses are shown in Table 2.6. Insertion altitude, operational altitude, and inclination vary by shell within the systems.

As discussed in the footnotes of the table, the potential future mass of the Starlink satellites is a large departure from their currently flown mass. For example, SpaceX's V2 satellite was proposed to the FCC at 2,000 kg, later reduced to 730 kg as flown, and have reached 575 kg per satellite in 2025 (AEI n.d.). In our analyses of launch capacity, we will consider excursions from these scenarios, where the mass of satellites that get flown for all large constellations is less than what operators propose in their filings to the FCC. This is important to consider because manufacturing satellites at scale may present opportunities or incentives to reduce individual satellite masses.

Table 2.6. Summary of building block: satellites approved by the FCC under Part 25

Operator	Call Sign	System Name	Orbit	Annualized Sats (#)	Avg Mass (kg)
Albedo Space	S3208	Albedo SV-1	LEO	8	530
Amazon Kuiper[c]	S3051	Kuiper-Ka System	LEO	462	570
AST SpaceMobile	S3065	AST SpaceMobile System	LEO	35	6,100
BlackSky	S3032	BlackSky Gen-3	LEO	7	138
Composite	Fsub20	All Sub20 Grouped	LEO	39	105
HawkEye 360	S3042	HE360 Constellation	LEO	12	33
Hubble Network	S3212	Hubble Network Inc.	LEO	20	22
Iridium	S2110	Iridium NEXT	LEO	4	850
Planet Labs[a]	S2912	Pelican+Flock	LEO	253	12.3
SpaceX[b]	S2992/3069	Starlink Gen2	LEO	5,998	2,000
Swarm Technologies	S3041	Swarm NGSO constellation	LEO	60	0.6
Theia Holdings	S2986	Theia Satellite Network	LEO	24	270
Total				**6,922**	

a. While average masses are reported in this table, the launch capacity calculations will use the actual masses of the satellites; this is mainly relevant for Planet Labs constellation which mixes satellites ranging from 5 to 270 kg.

b. The current mass of a Starlink Gen2 satellite is about 575 kg. However, in the future, when Starship is active, SpaceX expects the mass of a Starlink satellite to increase. Public statements by Musk in May 2022 indicated that Starlink V2 satellites would be 1,250 kg (Ralph 2022). Subsequently in October 2022, SpaceX filed orbital debris analyses with the FCC indicating that Starlinks launched on a Starship would be 2,000 kg each (Goldman 2022). Similarly, promotional materials indicate that Starship will deliver 60 Starlink V3 satellites per launch; each V3 satellite adds 1 Tbps of capacity and each Starship launch adds 60 Tbps of capacity (SpaceX 2025). This implies a total mass of 120 metric tons per launch, which is within the commonly advertised payload capacity for Starship. For methodological consistency, we use the figures submitted to the FCC instead of public statements.

c. The mass of a Kuiper-Ka system is inferred from a public statement by ULA that gave the total payload mass for 27 Kuiper satellites (Smith 2025).

4. Satellites not approved under FCC Part 25 (except space data centers)

Many applications for Part 25 licensing are not currently approved. There are many potential reasons: the application may have been only recently submitted, it may have been explicitly denied, the operator may have withdrawn the application, or the proposed system may have been combined with another application that was approved. We use all applications submitted to the FCC under Part 25 since January 2020 but not approved as a source of potential demand for launch as shown in Table 2.7. We have taken care to address applications that represent duplicative constellations and to filter out large constellations that appear to be cancelled; however, we did not account for any other reasons why an application is not approved.

We have omitted from this building block all applications for space data centers. Due to their number and mass of satellites, they would overwhelm the demand shown in Table 2.7. Data centers will be considered in a subsequent section. To finalize this building block, we annualize the constellations in the same manner as before. The resulting annualized demand for satellites is shown in Table 2.8.

Table 2.7. Satellites not approved under FCC Part 25 (except space data centers)

Operator	Num Sats	Operator	Num Sats
Albedo Space[a]	0	Momentus Space	2
Amazon Kuiper[b]	4,538	Muon Space	3
Anduril	1	NOVI Space Inc	2
Argo Space Corp	1	Orbital Sidekick[f]	0
Astra Space[c]	~~15,412~~	Pixxel	1
Astro Digital	25	Planet Labs[g]	0
Basalt Technologies Corp	3	Reflect Orbital	1
Blue Origin[d]	5,408	Satellogic S.A.	120
Capella Space	7	Sierra Space	3
Firefly Aerospace	1	SN Space Systems[h]	1,190
Iceye	1	SpaceLink Corporation	4
Impulse Space	1	SpaceQuest Ltd	2
JSAT Beyond Innovation	10	SpaceX [i]	15,000
Katalyst Space	1	Spire	175
Loft Orbital	2	The Boeing Company[j]	~~8,892~~
Logos Space Services[e]	3,960	Umbra	4
Lunasonde	1	Xona Space Systems	258

Total U.S. Satellites Not Approved for LEO/MEO: 55,029

Total Satellites After Removals: 30,725

a. This is a supplemental application that applies to one of their previously approved satellites.
b. This is the Kuiper-V system, as opposed to the already approved Kuiper-Ka system.
c. This constellation appears to be on hold; its satellites will be removed from the total.
d. This is Terawave.
e. This constellation was approved by the FCC in February 2026; however, we determined approvals based on data from Dec 10, 2025, so this constellation remains in the not-approved portion for the analysis.
f. This is a duplicate submission of a previously approved satellite.
g. This application was a modification of the SkySat constellation that was already included in the Part 25 approvals.
h. This is a wholly owned subsidiary of SpinLaunch and the satellites are designed for launch on their platform. Regardless of whether SpinLaunch succeeds at developing its launch segment, the satellite broadband market is larger than the launch market, so the company has an incentive to launch these satellites. We note that compared to their FCC filing for 1,190 satellites each with a mass of 200 kg, the SpinLaunch website suggests a more modest constellation of 250 satellites at 70 kg each (SpinLaunch n.d.).
i. SpaceX has proposed a new mobile satellite system (MSS) for direct-to-cell communications. For now, we assume this to be separate from Starlink because 1) it has its own FCC callsign that has not yet been merged with an existing Starlink callsign and 2) SpaceX materials speak of this constellation as a separate constellation from Starlink. However, FCC data shows many applications for Starlink-like constellations that eventually got merged into a single Starlink system. Indeed, SpaceX has already begun adding MSS satellites to its currently approved Gen2 Starlink constellation.
j. In 2017, Boeing filed an application requesting to operate 147 satellites in the V-band. The FCC eventually approved this constellation, but Boeing relinquished its spectrum in 2023 (Kan 2023). Despite the modest request for 147 satellites, Boeing had quickly amended its application to request 5,936 satellites total. Further, Boeing had previously requested authority to operate 2,956 satellites. All these constellations are assumed to be cancelled and their satellites removed from our scenarios.

Table 2.8. Summary of building block: satellites not approved under FCC Part 25 (except space data centers)

Operator	Call Sign	System Name	Orbit	Annualized Sats (#)	Avg Mass (kg)
Amazon Kuiper	S3105	Kuiper-V System	LEO	648	570
Astro Digital	S3014	Mission-as-a-service	LEO	5	48.5
Blue Origin	S00788	TeraWave	LEO, MEO	1,070	601.63
Composite[a]	Fsub20NA	All Sub20 NA Grouped	LEO, MEO	20	210.7
Logos Space	S3210	Logos Network	LEO	792	575
Orbital Sidekick	S3129	GHOSt	LEO	4	91.4
SN Space Systems	S3107	SN Space Systems Limited	LEO	238	200
Satellogic S.A.	S3188	Satellogic	LEO	40	48.5
SpaceX	S00735	SpaceX MSS	LEO	3,000	2,500
Spire	S3213	LEMUR-4 Constellation	LEO	36	20
Xona	S3177	Xona System	LEO	52	149
Total				**5,905**	

a. We annualize the callsigns with fewer than 20 satellites in the same manner as previously discussed. This combined 68 satellites across 26 callsigns into a new callsign Fsub20NA.

5. Space data centers

At the time we gathered the FCC applications, there was only a single space data center proposed. Regardless, data centers likely justify their own building block because they represent a fundamentally new business model and the proposals seen in the trade press tend to be much larger than traditional satellite systems. We make no claims or predictions about whether space data centers will lead to viable business models; we merely recognize their novelty and potential scale as justifying a separate category.[3] Details for the space data centers that have applied to the FCC for licensing under Part 25 are shown in Table 2.9.

Table 2.9. Summary of building block: space data centers

Operator	Call Sign	System Name	Orbit	Annualized Sats (#)	Avg Mass (kg)
SpaceX[a]	S00798	SpaceX Orbital Data Center	LEO	199,998	2,500
Starcloud[b]	S00803	Starcloud Orbital Datacenter	LEO	17,600	3,000

a. The application only appears to request a license for 3 satellites; however, the narrative of the application lists the aspirational size of the constellation as 1 million satellites. For the purposes of analysis, we investigate the effect of the aspirational constellation. The application did not contain key technical specifications; thus, we assign each data center the same mass (2,500 kg) and operational lifetime (5 years) as the satellites in SpaceX's Mobile Satellite Service (MSS) application, which was submitted a few months prior. A five-year lifetime implies the annualized number of satellites is approximately 200,000. The altitudes for the data center were given as a range extending as high as 2,000 km; however, for satellites with electric propulsion, the operational altitude is less important than the insertion altitude. We assume all data centers will be inserted at 300 km altitude. Finally, we distribute the data centers across the same inclinations used by the Starlink constellation.

b. As with SpaceX, the application only appears to request a license for 2 satellites; however, the narrative indicates an aspirational size of 88,000 satellites. The application indicates that the full constellation would all be deployed in sun-synchronous orbits from 600 to 850 km in altitude. TechCrunch reports that each satellite will have a mass of 3 tons and be designed for deployment from Starship (Fernholz 2026). Since Starship is optimized for launching to low orbits, like 300 km, we assume that Starcloud's satellites will be injected at that altitude and use electric propulsion to reach their operational altitude. Despite being designed for Starship, we will assume that Starcloud is willing to ride on any launch vehicle.

---

[3] This same argument may also apply to space-based solar power systems.

C. Assembling the building blocks

As previously described, the scenarios build on each other, with each new scenario containing all satellites from the previous. In terms of the building blocks, the scenarios are defined as shown in Table 2.10.

Table 2.10. Scenarios and their constituent building blocks

	Scenario A	**Scenario B**	**Scenario C**
Baseline Government Demand	Included	Included	Included
Baseline Commercial GEO Demand	Included	Included	Included
Approved by the FCC under Part 25	Included	Included	Included
Not Approved by the FCC under Part 25 (Excl. Data Centers)		Included	Included
Space Data Centers			Included

3. Launch Capacity to Serve Satellite Demand

A. Method

1. Representative launch vehicles to service demand

To deliver the satellites defined in the scenarios, we have created five generalized categories of vehicles. These vehicles approximately cover the breadth of launch capabilities that may be available in the near future. Their approximate payload capacities are shown in Table 3.1.

Table 3.1. Launch vehicle categories and payload capacity

	Payload Capacity [kg]		
Category	**LEO [a]**	**GTO**	**Equatorial LEO**
Micro	300	-	-
Small	1,000	-	-
Medium	18,000	8,000	4,000
Heavy	32,000	12,000	6,800
Ultra	100,000	-	-

a. Defined as a circular orbit at 200 km altitude and 30° inclination

For non-equatorial deliveries within LEO, we use the Launcher Calculator (Launcher n.d.) to model the variation in payload capacity as a function of altitude and inclination. For example, Figure 3.1 shows how payload performance varies for our Heavy launch vehicle. We also use the calculator to estimate payload capacity to geosynchronous transfer orbit (GTO). Our estimates of payload capacity to equatorial LEO are based on rough estimates from historical launches to this destination. Destinations that are missing a payload capacity are not modeled in this analysis.

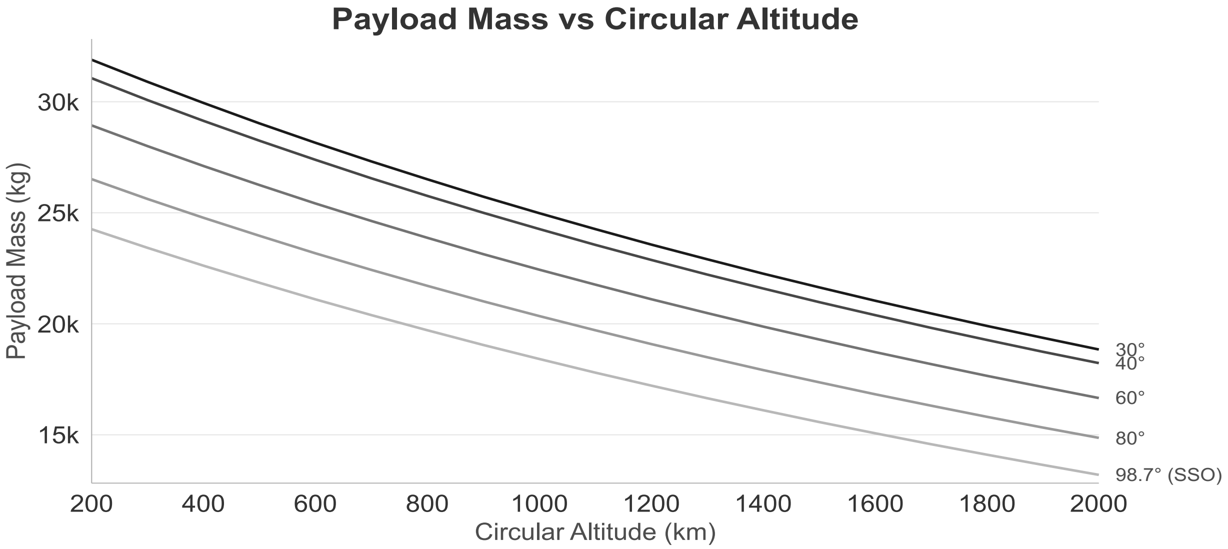


Figure 3.1. Payload mass by circular altitude and inclination for a Heavy launch vehicle.
Source: Rational Futures calculations using Launcher Calculator (Launcher n.d.).

2. Spaceports that are permitted to host the launch vehicles

We collected the maximum allowed annual launches for each launch pad licensed by the Federal Aviation Administration (FAA) (FAA 2026b). We also inferred the maximum annual launches associated with potential future launch licenses that have not yet been approved. In both cases, we extracted the maximum allowed annual launches at each pad from environmental assessment reports used to support the licensing process. Finally, we correlated the licenses with categories of vehicles to assign each a maximum number of annual launches allowed at each site.

Table 3.2. Launch sites and number of permitted launches

Launch Site	Inclinations	Heavy	Medium	Micro	Small	Ultra	Total
Cape/KSC	28 to 60	32	132		5	120	213
Vandenberg	58 to 145	14	100		17		207
Starbase	26 to 34					25	25
Wallops	38 to 60		6	12			18
Total		**46**	**238**	**12**	**22**	**145**	**463**

The location of the launch site influences the orbits that can be reached. For example, it is difficult to launch into orbits with inclinations that are lower than the latitude of the launch site. Further, only certain launch directions are allowed from each site to protect the safety of people and property downrange. Taken together, the allowed launch directions and the latitude of the launch site constrain the orbital inclinations accessible from each launch site. It is possible to reach a wider set of inclinations than shown in the table; however, it would require complex maneuvering that also reduces the payload-to-orbit of the launch in ways that we are not able to calculate.

3. Matching launch supply with operator demand to create launch manifests

We assign satellites to launch vehicles and launch sites based on a set of simple technical rules, illustrated in Figure 3.2 and described below. These rules do not explicitly account for competition and the price each satellite operator would pay for a launch. We sought to avoid competitive pricing considerations as this would introduce a dynamic that would be more speculative and closely tied to the operations of specific launchers and satellite operators. Instead, we have focused on assigning payloads based on the orbits demanded and the payload capacity of vehicles to reach those orbits from available launch sites. Our estimates show manifests that reflect one version of what is technically possible, not necessarily what the market will do.

To assist in the assignment, we marked some satellites as requiring a dedicated launch. For example, we do not know the number nor the masses of payloads that NASA will send to the Moon as part of the Commercial Lunar Payload Services (CLPS) program; however, we know that NASA plans for two such launches annually (NASA n.d.). Therefore, we have two CLPS payloads, each getting a dedicated launch aboard a Medium vehicle. Similarly, we use dedicated launches for all government payloads, because we can make more reliable estimates regarding the number of launches than the masses and orbits of the payloads. Further, all commercial GEO payloads are given their own dedicated launches, reflecting a common practice that we have seen in the historical data.

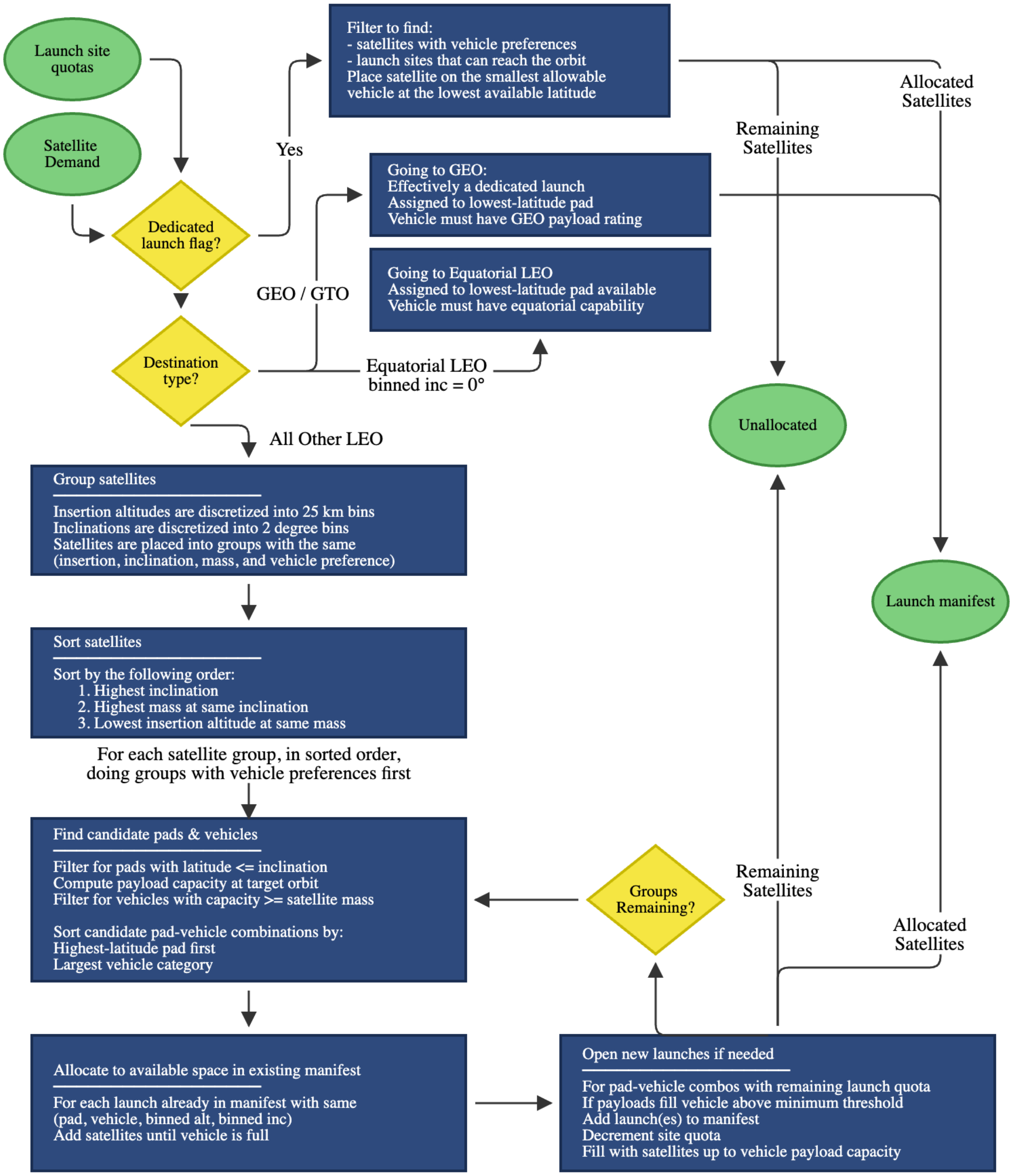


Figure 3.2. Illustration of algorithm for allocating satellites to launch vehicles and pads.

Most commercial satellites can share a launch vehicle with other payloads; however, some satellites may have a strong preference for the type of vehicle that they are placed on. Specifically, if a satellite operator is also a launch provider, we assign those satellites to the category of launch vehicle that is closest to the vehicle they operate.

The assignment of satellites to launch vehicles happens in two phases. In the first phase, any satellite that requires a dedicated launch is assigned. The vehicle category is specified in the scenario; thus, the only remaining choice is the launch site. For launches to LEO, the launch site is assigned to the highest latitude site that can access the inclination of the demanded orbit. For launches to GEO or deep space, the site assignment is based on the lowest latitude site that can reach the satellite's inclination.

The second phase assigns the rest of the satellites. This phase begins by grouping satellites together based on their injection altitude, inclination, mass, and vehicle preference. Satellites with a vehicle preference have priority, ensuring that they will not be bumped from a launch because other satellites were placed before them. We assigned the remaining satellites starting with the highest orbital inclinations, then working down to progressively lower inclinations. Likewise, at any given inclination, we process more massive satellites and lower insertion altitude satellites first.

The assignment process only places payloads into a vehicle if 1) the vehicle is going to the relevant orbit and 2) the added payloads would not exceed the payload capacity of the vehicle to that orbit. If no vehicles exist with sufficient space and desired orbit, a new vehicle is added to the manifest if 1) doing so would not exceed the number of permitted launches for the launch-site-and-vehicle combination and 2) the launcher would be acceptably full. As with the first phase, new launches to LEO in the manifest are preferentially placed at the highest latitude site possible for the inclination of the payload.

For this analysis, we have specified that all launch vehicles must carry at least 20 percent of their payload capacity, calculated based on the specific orbital destination, to be acceptably full. Empirically we appear to see launches to LEO that are less than half full for some types of vehicles; however, we did not attempt to assess empirical fill fractions when selecting 20 percent. Instead, we made a simple argument that is roughly based on launch vehicle prices. Assume that a Small vehicle has a price of $20 million and delivers 1 metric ton, while a Medium vehicle has a price of $70 million and delivers 18 metric tons. At these prices, a satellite operator would be ambivalent between launching on 3.5 Small vehicles or one Medium vehicle, since both options would have equal price. Taking the ratio of the masses delivered for each option yields approximately 20 percent.[4] Thus, if the amount of payload to be delivered on a larger vehicle were less than this threshold, the payload owners would have an incentive to drop down to multiple smaller launch vehicles.

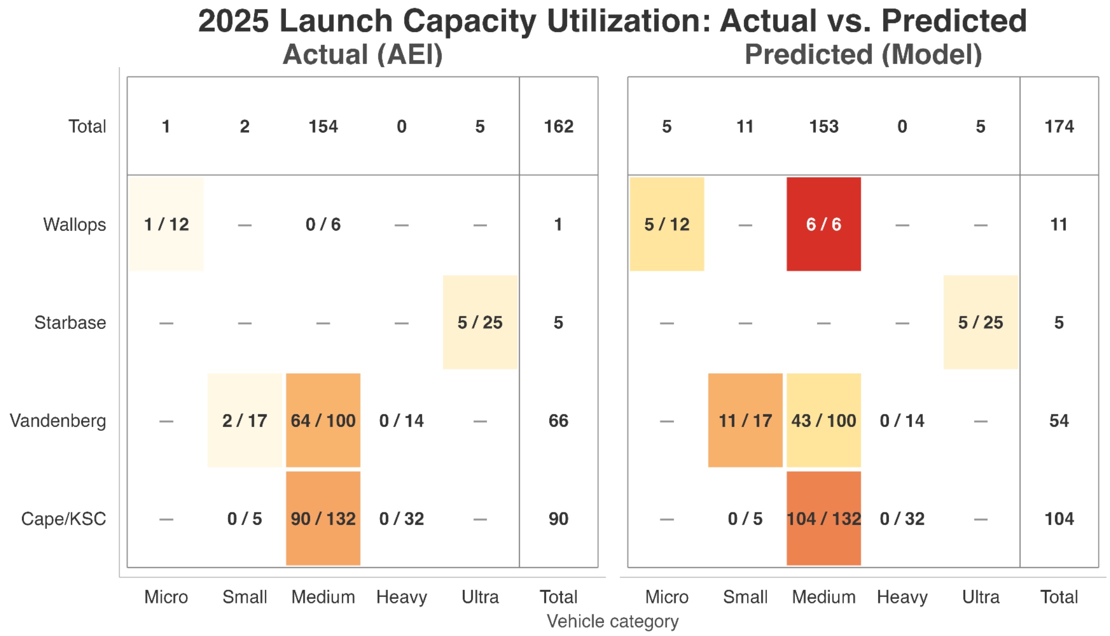
B. Validation case

We use the data compiled by the American Enterprise Institute's (AEI) Global Space Data Navigator (AEI n.d.) to demonstrate that our launch vehicle allocation method produces reasonable results when applied to historical launch traffic. We also use this as an opportunity to discuss how our results may differ from the actual launch behavior that may be seen in the future.

---

[4] 3.5 tons divided by 18 tons is 19.4 percent, which we round up to 20 percent.

We expect the greatest variation in launch capacity to be for deliveries in LEO; thus, we focus validation of our launch manifest algorithm on the demand for launches to LEO in 2025. In the AEI data, there are 3,835 payloads launched from the United States to LEO[5] aboard 162 launches. The distribution of the launches by category and launch site are shown in Figure 3.3. The same table also shows the results of our placement algorithm for comparison.



Actual (AEI)

	Micro	Small	Medium	Heavy	Ultra	Total
Total	1	2	154	0	5	162
Wallops	1 / 12	—	0 / 6	—	—	1
Starbase	—	—	—	—	5 / 25	5
Vandenberg	—	2 / 17	64 / 100	0 / 14	—	66
Cape/KSC	—	0 / 5	90 / 132	0 / 32	—	90

Predicted (Model)

	Micro	Small	Medium	Heavy	Ultra	Total
Total	5	11	153	0	5	174
Wallops	5 / 12	—	6 / 6	—	—	11
Starbase	—	—	—	—	5 / 25	5
Vandenberg	—	11 / 17	43 / 100	0 / 14	—	54
Cape/KSC	—	0 / 5	104 / 132	0 / 32	—	104

Figure 3.3. Launch vehicle allocation algorithm validation results. Source: Rational Futures calculations using AEI (n.d.) data.

There are three main points to draw from this comparison. First, our algorithm did a good job of predicting the number of Medium launches; we differed only by one launch from the historical data. Second, we overpredicted launches on Small and Micro category vehicles. This is likely because there are unmodelled factors, such as launch price, that may prevent some satellites from choosing to ride on such vehicles.

Third, while we have effectively the same number of Medium launches as the historical data, our algorithm assigned these launches to the eastern spaceports (Cape and Wallops) more than historically observed. This is because launches from the Vandenberg Space Force Base (VSFB) have an azimuth constraint, likely to prevent overflights of Mexico, that would not allow a launch vehicle to reach orbital inclinations of less than 58°, as shown in Figure 3.4. However, the historical data shows that SpaceX has performed many Starlink launches from VSFB that went to orbits at 53° latitude. This could be achieved by a “dogleg” maneuver that launches at the allowed azimuth limit, then changes course once the rocket is sufficiently downrange that it would not pose an overflight risk. We do not model dogleg maneuvers; thus, we cannot assign

---

[5] Satellites marked with Lower LEO and Upper LEO as their orbit category. There are a few more launches to LEO are marked as ‘Other’, which we disregard for the purposes of this validation.

satellites going to orbits below 58° to VSFB in the validation case. This explains why we assign more launches from the Cape than is seen in the historical data.

For the future scenarios, we will explore the effect that allowing dogleg maneuver to occur "for free" may have on launch capacity, especially for launches from The Cape. Of course, these maneuvers should substantially reduce the amount of mass that can be delivered to orbit; however, we did not attempt to model this reduction, merely to bound it.

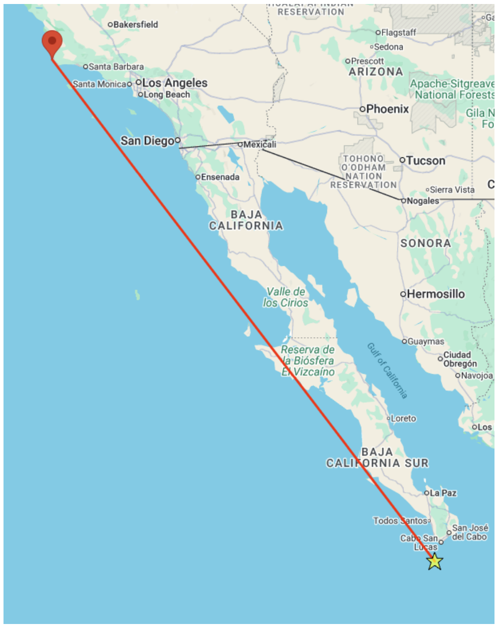


Figure 3.4. Flight path to reach 58° inclination orbit.

C. Results

In this section, we present some conditions under which there may be gaps between the launch supply and launch manifests that satisfy the potential demand scenarios for satellites. Before getting to the numbers, we must emphasize a few important points. First and foremost, the resulting gaps are not predictions of the future. They are the consequences of specific assumptions about the future that, if true, would create a gap. We have chosen assumptions about the future that appear interesting and important; however, the assumptions we have assessed are not comprehensive. For example, in all of our assessments, we have assumed that an Ultra vehicle is available and that it has a 100 metric tons payload capacity. Some readers will find our assumptions about this vehicle too optimistic, while others will find us too pessimistic. Improving the breadth and fidelity of assumptions may be the subject of future work.

Our assessment of capacity gaps here is focused mainly on available licenses for launch. There are many unmodeled factors that may preclude launch vehicles from being able to launch at their licensed amounts. We discuss these unmodeled factors qualitatively in a subsequent section of this report. Further, operators are able to secure new licenses or higher licensed amounts of annual launches. This is likely easier as the launch vehicle gets smaller; thus, licensed annual launches are not a hard constraint on supply.

In discussing the gaps, there are subtleties that are difficult to convey without going into the specifics of the satellites and launch vehicles involved. We strive to retain generality while avoiding the risk of mischaracterizing any specific operator of satellites, launch vehicles, or spaceports.

Finally, we make no claims about the probability that the various satellite demand scenarios materialize, that permits remain at the level we have estimated, that there will be launch vehicles with the specific performance parameters we have used, or that any other assumption about the future will be realized. Everything that follows should be treated as possibilities, not predictions. The reader should keep these caveats firmly in mind.

1. Future launch manifests if satellites are as massive as reported

The number of launches needed to satisfy the satellite demand from Scenarios A, B, and C are shown in Figure 3.5. The numbers of allocated and unallocated satellites for the launch scenarios are shown in Table 3.3. For each scenario, we have investigated launches where dogleg maneuvers are not allowed and where Ultra vehicles can perform dogleg maneuvers from the Cape without any reduction in payload capacity. This latter assumption is physically impossible but used to assess an upper bound for launches of an Ultra vehicle.

Use of a dogleg appears necessary because we have not found any licenses or applications for an Ultra vehicle to fly from VSFB. This suggests Ultra vehicles cannot launch to orbital inclinations above 60° without performing a dogleg maneuver from the Cape, leaving many of the internally demanded satellites unable to reach these higher inclination orbits. Dogleg maneuvers require launching in the "wrong" direction for safety reasons, then revectoring the vehicle to the desired azimuth. This can substantially reduce the amount of payload the vehicle can deliver.[6] We show results where dogleg maneuvers from the Cape are "free" (i.e., they incur no reduced payload capacity), because simulating such a maneuver at high-enough fidelity to estimate the payload capacity reduction is beyond the scope of this work. The cases with penalty-free dogleg maneuvers allow for more of the internally demanded constellations to be deployed in our model.

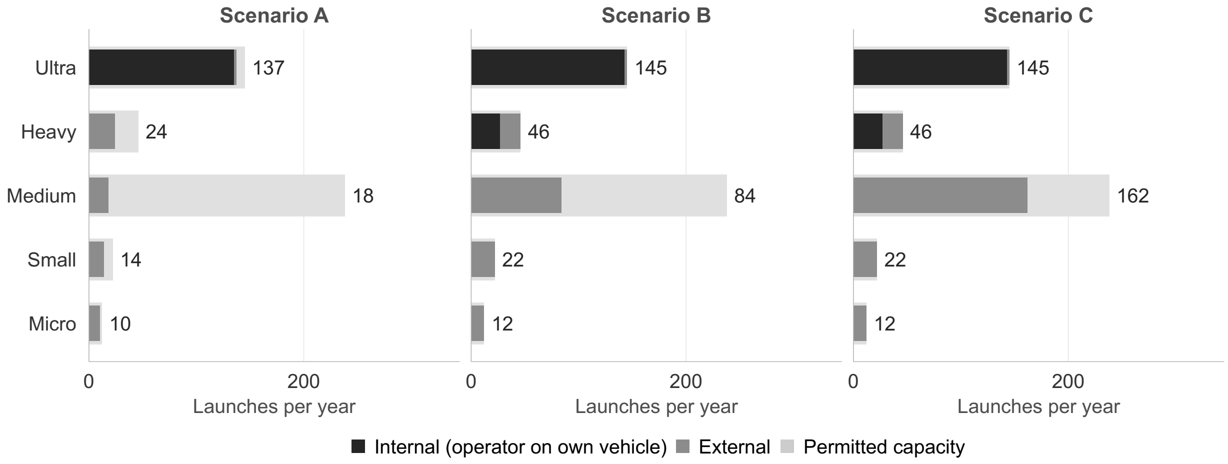


Figure 3.5. Annual launch capacity by vehicle category for reported satellite masses and penalty-free dogleg maneuvers.

Assuming that licenses define launch capacity, our results illustrate that potential capacity gaps exist even in Scenario A. Without doglegs, we see that micro and small vehicles are effectively at capacity (not shown). The Ultra vehicle appears to have excess capacity, yet there remain many satellites not allocated to launch vehicles. These are mostly satellites with a preference to ride on an Ultra. They remain unallocated because the Ultra does not have licenses from a west coast

---

[6] Estimates for the Space Shuttle to launch into a highly inclined orbit using a 20° dogleg showed a roughly 50 percent drop in payload capacity (GAO 1978).

site that could send these satellites to the highly inclined orbits they demand.

Table 3.3. Total launches and satellites allocated or not for various scenarios.

Scenario	A		B		C	
Dogleg	None	Free	None	Free	None	Free
Total Launches	179	203	309	309	387	387
Allocated Sats						
Number	6,112	6,528	9,693	8,688	8,688	6,905
Mass [MT]	10,867	11,699	14,695	15,578	15,578	11,106
Unallocated Sats						
Number	829	413	3,153	3,713	221,756	223,539
Mass [MT]	1,628	796	6,819	7,897	558,731	563,203

Note: In all cases, the vast majority of unallocated satellites are owned by launch vehicle providers.

Penalty-free doglegs allow our model to use an Ultra to hit highly inclined orbits from the Cape until the licensed capacity of 120 annual launches is reached at that site. The remaining unallocated mass is still mostly due to satellites with a preference to ride on an Ultra. There is some seemingly excess capacity to launch from Boca Chica. However, launches from that site cannot reach the orbital inclinations demanded by the remaining unallocated satellites.

In Scenario A, allowing Ultra doglegs from the Cape has increased the number of Heavy launches. This is because satellites with vehicle preferences get allocated first; the newly allocated satellites to the Ultra have displaced satellites without vehicle preferences that had previously been allocated to it. With no remaining capacity from the Cape for an Ultra, the payloads have moved to the next smaller vehicle class.

The Heavy and Ultra vehicles have reached their licensed capacity by Scenario B. Adding more payloads or allowing doglegs do not change the situation. The overwhelming majority of unallocated satellites belong to operators with a launch vehicle preference. There is no operator with a preference for Medium launch vehicles, which is why this category of vehicle remains below its licensed capacity.

In Scenario C, the number of delivered satellites has decreased compared to Scenario B. As previously discussed, our assignment algorithm assigns the highest inclination and most massive groups of spacecraft first. Adding in the heavy data centers means they get preferential placement. Because they are larger, fewer can be launched at a time. Further, the highest inclination satellites get launched first and such high inclinations incur large losses in payload capacity of the rocket. Thus, these highly inclined and massive satellites consume a substantial portion of the available launch capacity.

In our results across all three scenarios, the unallocated satellites mainly belong to companies that operate both satellites and a launch vehicle. For other satellites, there may be excess capacity in Medium, Heavy, and Ultra vehicles, depending on the scenario. However, aggregating these unallocated satellites into missions that could use the excess capacity would cause the vehicles to not meet the minimum fill fraction. In our model, the most expedient way to address the needs of these unallocated satellites is to increase the supply of Small launchers.

While beyond the scope of this analysis, reaching capacity at these launch sites may have a strong effect on the market price of these vehicles. Using the numbers shown for Scenario B, four out of five categories of launcher have no excess capacity. Scarcity of launch capacity may drive prices upward (Rao and Colvin 2025). In other words, the price to launch on these vehicles could increase beyond 2026 levels if the capacity issues are not resolved.

2. Future launch manifests if large constellations have reduced masses

Where possible we have used masses that have been reported to the FCC. For some large constellations, FCC data does not appear to contain mass information. In these cases, we have looked to other sources of data or reasoned by analogy to estimate what the masses may be. However, historical examples for large constellations indicate that satellite operators may ultimately develop satellites that are substantially smaller than initially proposed. Table 3.4 illustrates three such data points. Based on these data points, it appears that final masses could be as low as 30 percent of initially proposed masses. A substantial portion of this mass reduction may come from reducing the scope, complexity, or capability of each individual satellite. Likewise, there is room for optimization and miniaturization to bring the per-satellite mass down as well.

Table 3.4. Examples of reduced mass satellites.

Operator	Callsign	System Name	Total Satellites	FCC Mass (kg)	Real-World Mass (kg)	Ratio
SpaceX	S2992/3069	Starlink Gen2	29,988	2,000	575 [a]	0.29
SN Space	S3107	SN Space	1,190	200	70 [b]	0.35
SpaceX	S00735	SpaceX MSS	15,000	2,500	960 [c]	0.38

a. (AEI n.d.)
b. (SpinLaunch n.d.)
c. This is the mass of the direct-to-cell satellites currently being flown in Starlink Gen2 (AEI n.d.). While surely not as capable as the larger MSS satellites proposed to the FCC, this shows that an MSS satellite at this mass level produces viable market offerings.

While the resulting constellations are surely not as ambitiously capable as their initial proposals, satellite operators have many incentives to reduce the mass of their satellites. Such reductions may lead to lower capital costs and reduced launches for deployment, both of which yield cost savings that could be passed on to customers in a competitive market or captured by the company as profit. Further, for satellites that serve emerging markets, starting small may mitigate risk for the company if the market does not materialize at the desired level.

For all constellations with greater than 1,000 total satellites, we have reduced the mass of each satellite by a factor of 0.3; the affected satellites and changes in masses are shown in Table 3.5. The effect of this mass reduction is shown in Figure 3.6. Compared to the previous full-mass results, we see that launch capacity may not be meaningfully constrained in Scenarios A and B. The Ultra reaches its licensed capacity only in Scenario C.

Table 3.5. Large constellations with full mass reduced by a factor of 0.3 in the scenarios.

Scenario	Operator	Call Sign	System Name	Orbit	Total Satellites	Full Mass (kg)	Reduced Mass (kg)
A	SpaceX	S2992/3069	Starlink Gen 2 (v3)	LEO	29,988	2,000	600
A	Amazon Kuiper	S3051	Kuiper-Ka System	LEO	3,236	570	170 [a]
B	SpaceX	S00735	SpaceX MSS	LEO	15,000	2,500	750
B	Blue Origin	S00788	TeraWave	LEO	5,280	575	170 [a]
B	Blue Origin	S00788	TeraWave	MEO	128	1,700	510
B	Amazon Kuiper	S3105	Kuiper-V System	LEO	4,538	570	170 [a]
B	SN Space	S3107	SN Space	LEO	1,190	200	60
B	Logos Space	S3210	Logos Network	LEO	3,960	575	170 [a]
C	SpaceX	S00798	Orbital Data Center	LEO	1,000,000	2,500	750
C	Starcloud	S00803	Starcloud	LEO	88,000	3,000	900

a. This is comparable to the mass of a OneWeb satellite.

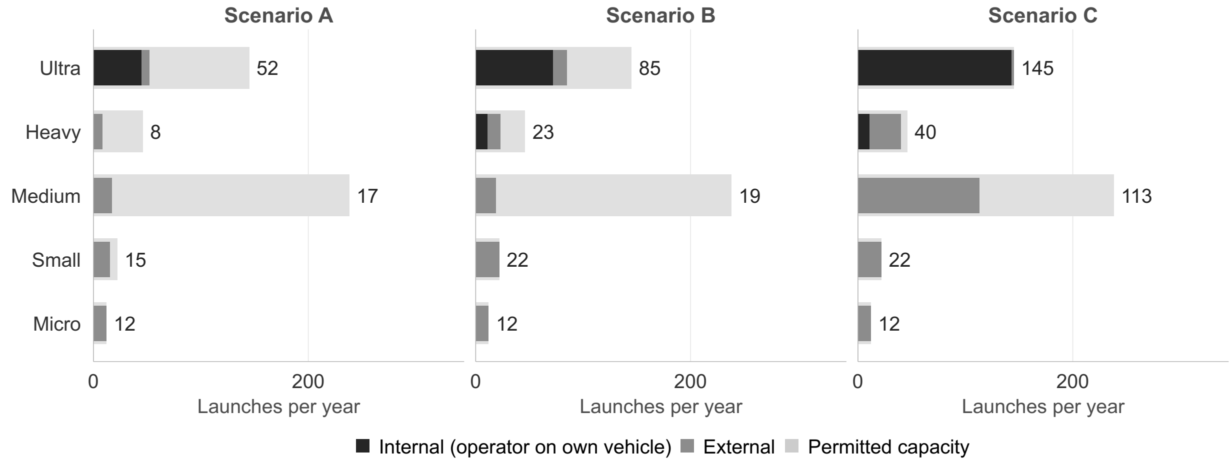


Figure 3.6. Annual launches by vehicle category for scenarios using reduced-mass satellite constellations and penalty-free dogleg maneuvers.

These results can be interpreted in at least two ways. First, these are plausible scenarios where launch capacity may not be especially constrained in the near future. This would be the right interpretation in the case where there are technical or business reasons for large constellation providers to scale back the size of their constellations. Second, these scenarios show how potential launch constraints may exist but be hidden from view in the future. This interpretation corresponds to satellite operators predicting that launch constraints will hamper their operations, then changing their constellation designs to avoid the perceived risk of having satellites that are too large to be fully deployed. These interpretations are not mutually exclusive.

3. Future manifests where launch quotas are unlimited

Permits are not a fixed constraint and each launch site may be able to get the permits needed to meet demand from satellite operators. If this were the case, launch manifests may look like the scenarios shown in Figure 3.7. Each scenario assumes that there are launch vehicle preferences, that Ultra vehicles can launch up to 100 metric tons, and that the satellites are full mass without any reductions. The results from the previous full-mass scenarios are also shown for comparison. This gives a sense for potential launch manifests by vehicle type based solely on payload characteristics and orbital mechanics and how that may inform the added number of launches to satisfy satellite operator demand for launch.

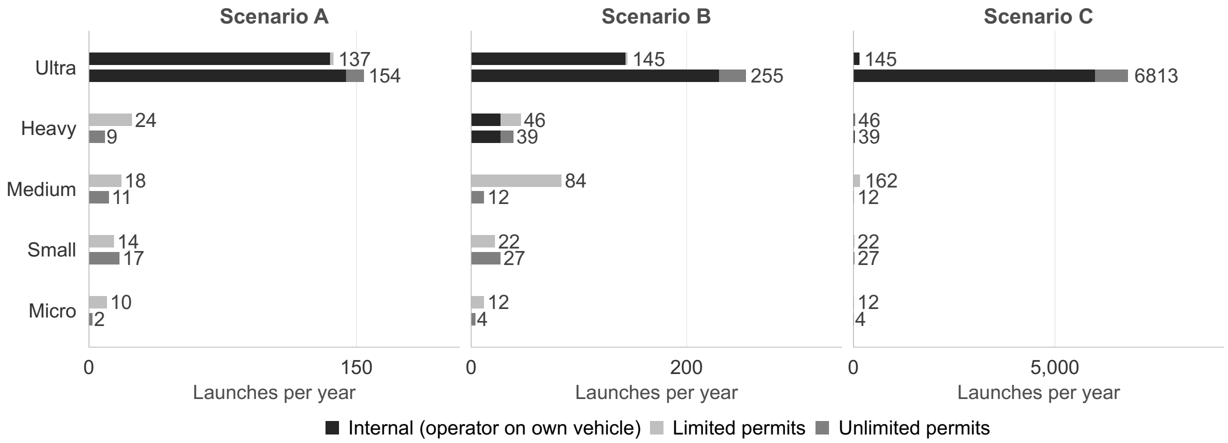


Figure 3.7. Full-mass scenarios for launch manifests, where launch licenses are constrained (higher bars) and unconstrained (lower bars). Internal demand is illustrated by the darker-shaded bars.

These results show launches manifested for Medium launch vehicles have decreased; most satellites that would have previously launched on a Medium vehicle can be assigned to a larger class of vehicle. Remaining payloads might be more appropriately allocated to smaller launch vehicles. However, recall that this assessment is based on purely technical constraints; when factors such as launch price are factored in, demand for Medium vehicles could remain robust.

Figure 3.8 shows analogous results when large constellations have reduced satellite masses. We see that if Scenario C materializes, it would still take around 2,000 launches annually to alleviate the capacity gap, compared to the approximately 7,000 annual launches from the full-mass scenarios.

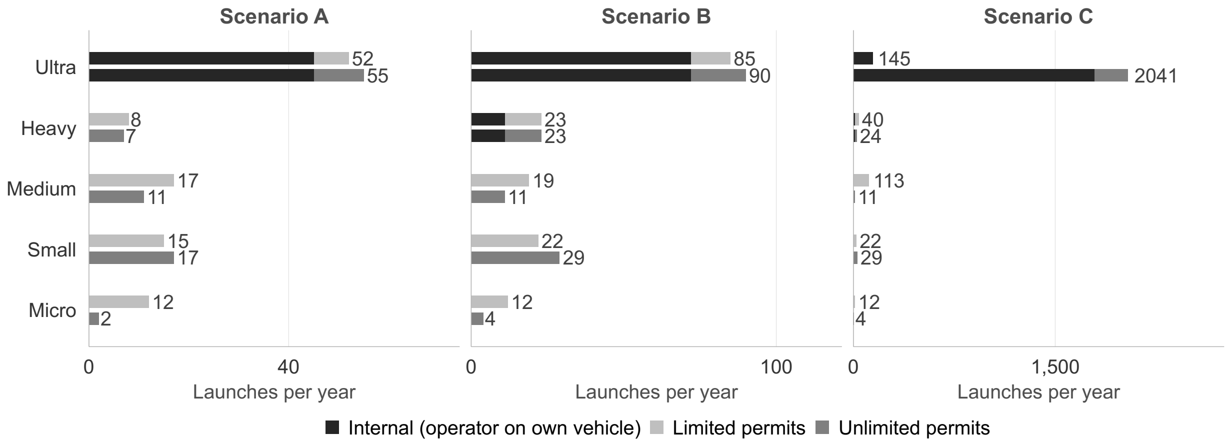


Figure 3.8. Reduced-mass scenarios for launch manifests, where launch licenses are constrained (higher bars) and unconstrained (lower bars). Internal demand is illustrated by the darker-shaded bars.

4. Supply-side considerations

There are two main interpretations of these results. Given launch vehicle preferences, the launch capacity gaps mainly exist for companies that operate satellites which they intend to launch on the vehicles that they own. If the supply of Medium launches does not decrease, there will be sufficient supply of Medium and occasionally Heavy vehicles with desired orbit access to meet the potential demands of all other satellite operators. There is a bit of a gap associated with smaller payloads trying to reach higher orbits, but a few extra smaller launches per year can mitigate this gap.

Since the Ultra and Heavy vehicles will primarily serve launch vehicle providers' internal demand for satellites, there is a risk that these providers hit their launch capacity launching their own satellites. In this case, where there is little-to-no excess capacity, it would be unlikely that such launchers would be offered in the market at a meaningful quantity. More precisely, the market price of such launch vehicles may be too high for the market to afford, as discussed in Rao and Colvin (2025).

The second interpretation is that if satellite demand reaches the level of Scenario B, there may be little excess supply of licensed launches. Specifically, even with free doglegs from the Cape, we still observe over 4,000 unallocated satellites; though, they are overwhelmingly from the largest constellations. This is despite the Cape hosting around 200 launches annually.

It is worth repeating that the results we have shown are meant only to illustrate possible futures and tradeoffs among assumptions. The future will surely be different from what we have sketched out here. We have aimed to improve the rigor with which launch capacity is analyzed and provide some potential conditions under which launch capacity gaps may exist.

Finally, the gaps assessed thus far have been based solely on available launch licenses. However, as we explore in the next chapter, there may be many factors not quantitatively modeled that could preclude launch providers from being able to supply launches at their licensed levels.

5. Demand-side considerations

The satellite demand scenarios we have investigated are closely tied to data provided by the satellite operators. However, there are many technical and market incentives that may cause satellite operators to change their plans in ways that reduce demand for launch services. Specifically, if demand for satellite services is weaker than desired or if launch constraints make full deployment challenging, these forces may reduce the number or size of satellites that an operator ultimately launches.

Accordingly, demand for the services provided by many of these future satellites is highly uncertain. We have used FCC applications as a proxy for satellite demand, but it is an unreliable proxy. This is because the satellite operators who have submitted these applications do not *demand* satellites or their services; they *supply* satellites to meet the demands of downstream customers that pay for satellite services. Consider the LEO telecom bubble from the early 1990s, when many satellite operators submitted applications to the FCC for large constellations. Only Motorola's subsidiary (i.e., Iridium) successfully launched their constellation, which promptly went bankrupt. Clearly, the satellite operators had misjudged the market. The reader must decide whether they believe the satellite demand scenarios we analyzed in this report are credible expectations for market demand or not.

Operators may also reduce the size of their own constellations for a variety of reasons. We have shown that if operators reduce the per-satellite mass of large constellations, the launch capacity gaps are mostly alleviated. As always, it is up to the reader to determine which potential future they believe is more reasonable.

4. Traditional Launch Sites

We define traditional launch sites as those currently used for orbital launches, mainly the Cape, VSFB, and the Wallops Flight Facility. In this section, we provide a brief background on each site, including key operational challenges. Some of these challenges may preclude launch providers from launching at their permitted rates. One or more of these challenges may need to be addressed for these sites to increase their annual launch capacity beyond what they have demonstrated to date.

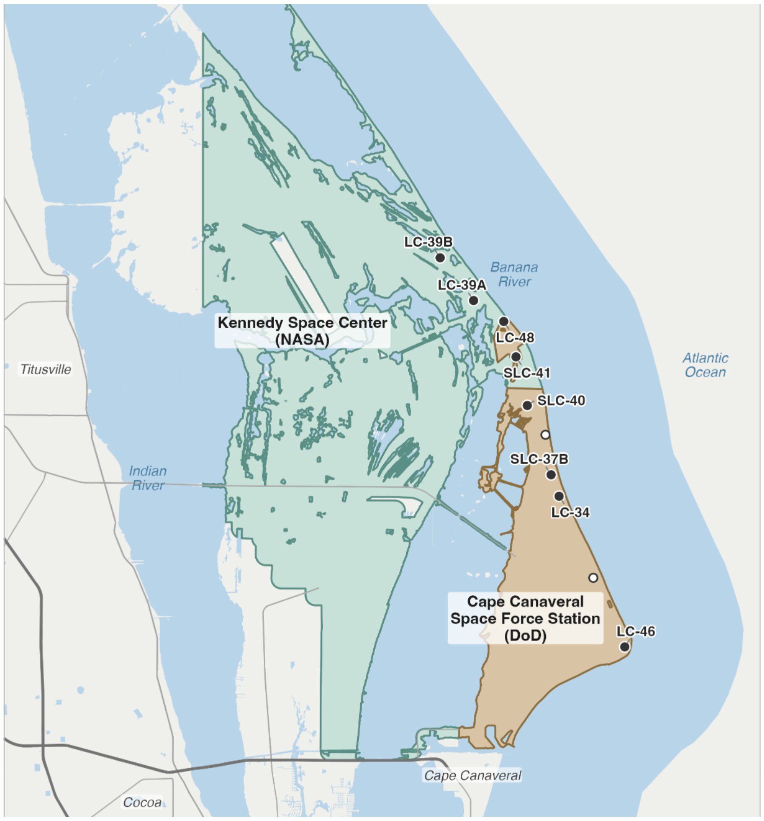


Figure 4.1. Kennedy Space Center manages the facilities to the north and west of Cape Canaveral Space Force Station. Source: Rational Futures compilation from OpenStreetMap boundary data, FAA/NASA/USAF pad records, and U.S. Census Bureau TIGER/Line (2023).

The Cape. The launch site colloquially referred to as the Cape is composed of two separately managed launch sites, shown in Figure 4.1. Kennedy Space Center (KSC), managed by NASA, operates two pads located at the northern tip of the area; one pad for the Space Launch System (SLS) and another for SpaceX Falcon 9 and Starship. Cape Canaveral Space Force Station (CCSFS), managed by DoD, consists of the remaining pads to the south of the Cape. These pads include those actively licensed for use by the United Launch Alliance (ULA) Atlas and Vulcan, SpaceX Falcon 9 and Starship, Relativity Terran R, and Blue Origin New Glenn. Private companies hold leases for some of the smaller pads. However, they are not yet licensed by the FAA for launch. These companies are Firefly Aerospace, Long Wall (previously known as ABL Space Systems), Stoke Space, Phantom Space, and Vaya Space. The majority of the pads in the

DoD property appear to be unused for launch purposes, with some serving as memorial sites, storage and museums. Figure 4.2 provides a brief graphical summary. With the exception of LC-48, which was built for small launchers in 2020 to host 52 launches per year, the unused pads are not currently suitable for use without substantial capital improvements. Despite the majority of the launch pads being located on DoD property, much of the pre-flight infrastructure needed for commercial launches is located on NASA property. This includes things like payload processing facilities and access roads to CCSFS that can handle heavy loads.

Figure 4.2. Summary of the pads located at the Cape. Map based on Copernicus Sentinel data. Pad locations approximate. Source: Rational Futures compilation from Copernicus Sentinel-2 imagery (2026-03-10), FAA licenses, OpenStreetMap (ODbL), CCSFS/KSC lease records, and public reporting.

VSFB. This facility is managed by U.S. Space Force (USSF) and hosts twenty pads along the Pacific coast, shown in Figure 4.3. Four pads are actively operational: Firefly Aerospace operates SLC-2W, SpaceX operates SLC-4E with booster recoveries at SLC-4W, and Northrop Grumman operates SLC-8. Three pads are leased but not yet operational: ULA has leased SLC-3E, Phantom Space has leased SLC-5, and SpaceX has leased SLC-6. Blue Origin has been selected for lease negotiations at SLC-14. Long Wall, formerly known as ABL Space Systems, holds an FAA Vehicle Operator License at LC-576E. SLC-10E and SLC-10W are National Historic Landmarks. The remaining pads are inactive or undeveloped.

Figure 4.3. Summary of the pads located at VSFB. Map based on Copernicus Sentinel data. Pad locations approximate. Source: Rational Futures compilation from Copernicus Sentinel-2 imagery (2026-02-04), FAA licenses, USGS PAD-US 4.1 boundary data, USSF lease records, CEQA filings, and public reporting.

Wallops. The Mid-Atlantic Regional Spaceport (MARS) at NASA Wallops Flight Facility (WFF), on Wallops Island, hosts four launch pads, shown in Figure 4.4. The Virginia Spaceport Authority holds the FAA Site Operator License for the spaceport and grants pad use rights to commercial tenants under a use agreement with NASA. Northrop Grumman operates Pad 0A and Pad 0B. Pad 0A is being prepared for Northrop Grumman’s Antares 330 and will also host Firefly’s Alpha and Eclipse vehicles. Rocket Lab operates Pad 0C and Pad 0D. MARS has no unused pads.

Figure 4.4. Summary of the pads located at the Mid-Atlantic Regional Spaceport at NASA Wallops Flight Facility. Map based on Copernicus Sentinel data. Pad locations approximate. Source: Rational Futures Compilation from Copernicus Sentinel-2 imagery (2025-07-25), FAA licenses, OpenStreetMap (ODbL), NASA WFF and USACE records, and public reporting.

A. Benefits at traditional sites

We do not spend much time discussing the benefits of traditional sites because the benefits are obvious to all stakeholders. As one interviewee stated, the Cape "is the gem of launch property. It is an irreplicable launch asset, and we need to find a way to operate it as such." Similarly, another interviewee said: "the Cape, Wallops, VSFB–there's a reason why they are there."

Indeed, there are many reasons. These traditional sites contain all the infrastructure needed to host orbital launches from many providers at reasonable cadences. These sites also have coastal locations, which allows them to offer flight paths that cover a very wide range of orbits while simultaneously preserving the safety of people on the ground, ships at sea, and aircraft in flight. While the DoD recovers a large portion of its costs to support industry,[7] commercial operators

---

[7] The DoD is required to charge companies for direct costs associated with the use of DoD launch facilities and may recover a portion of the indirect costs as well (10 USC § 2276a). The Congressional Research Service reported that USSF is likely to collect about $89 million in direct cost recovery and $16 million in indirect costs reimbursements (DiMascio, Lindbergh, and Dennis 2026). Despite these mechanisms, it appears that USSF still offers some amount of goods and services to launch operators for free or at reduced cost.

indicated that they do receive a number of goods and services for free or reduced price. For example, some operators using these sites indicated that they can get commodities, such as fuel, oxidizer, and pneumatics for free or for a small fee. Further, USSF handles the calculation of appropriate hazard areas for ensuring that people, ships, and aircraft downrange are safe. This feature assures compliance with FAA regulations for range safety with relatively little input needed from the launch operator. Operators at traditional spaceports clearly benefit from pre-existing Federal range infrastructure, which may differentially improve the economics of traditional sites compared to non-traditional sites.

Thanks to billions of dollars of prior investment, interviewees indicated that infrastructure is not the major constraint. Instead, launch capacity is stressed by operational concerns, such as the inefficiencies with how operators share access to common resources like payload processing facilities, road, fuel vendors, etc. This means that operational changes can lead to large increases in capacity. For example, two interviewees credited the Eastern Range moving to an automated flight safety system (AFSS) with allowing the Cape to scale up from about 20 annual launches in 2017 to nearly 100 annual launches by 2024. Speaking in 2017 about use of the AFSS at VSFB, the commander of the 45th Space Wing stated, “We have been able to reduce our main launch footprint by 60 percent and reduce the cost of a single launch by over 50 percent” (Fabey 2017). In our interviews, users of the traditional sites expressed that operational improvements were the easiest ways to increase national launch capacity.

B. Challenges at traditional sites

In this section, we describe challenges that have been brought to our attention through the interviews. We do not vouch for the veracity of these claims, though we try to provide some analysis, where possible. Further, we do not believe that any operator or government agency is at fault for these challenges and it is not our intention to suggest blame. Instead, these challenges should be viewed as the growing pains of an expanding launch industry. By discussing these challenges, we hope to raise awareness of the issues and to suggest possible paths forward.

1. Safety on base

Evacuation areas during tanking, testing, and launch

There is risk of explosion during the tanking (i.e. loading of propellant), testing, or launching of a liquid rocket. To mitigate these risks, the public are evacuated from areas where they may face intolerable danger. For the purposes of an evacuation, anyone who is not personnel of the rocket’s operator are considered ‘the public’. Thus, when one operator is tanking, testing, or in the process of their launch, all other operators may be required to stop their work to vacate their areas. The effects of these evacuations are difficult to quantify. In a subsequent section on shared infrastructure, we briefly explore the non-linear delays to operator schedules that road closures (such as those caused by evacuations) may create.

This challenge is not simply about inherent risks of spaceflight, but about the analytic tools and safety procedures that have created evacuation zones of this size. Several interviewees indicated that modernizing such tools and procedures is needed. For example, Section 1601 of the National Defense Authorization Act for Fiscal Year 2024 has directed DoD, the Department of Transportation (DOT), and NASA to establish a process through which scientifically valid TNT equivalency determinations can be assessed for launch vehicles.

Critical asset protection

In addition to risks to the public, there are also risks to physical property. To receive protection, such property must be “items that if damaged, present a risk to surrounding population centers or items needed to successfully accomplish the range’s mission” (RCC 2020). When the FAA approved its update of 14 CFR 450 in 2020, which includes such a rule to protect critical assets, the Agency stated that risks to critical assets at the Cape rarely exceeded the FAA’s adopted thresholds; further, such protections have not “imposed significant restrictions on launch activity” (FAA 2020b).

Despite the FAA’s statement, our interviews indicated that such rules can be a problem for launches from VSFB. Operators launch in the southern direction to reach polar orbits; however, this may require them to fly over much of the infrastructure on the base and the launch pads of other operators. To mitigate the risks, operators may need to fly on dogleg trajectories to avoid overflying critical assets. These suboptimal trajectories reduce the amount of payload that can be delivered to orbit–an effect that may be particularly acute for small launchers that do not have much margin to spare. We were told that the USSF is actively working with multiple operators on base to revise their resource protection policy based on these concerns.

2. Shared infrastructure

Payload processing

Interviewees noted that payload processing facilities can be a bottleneck on launch capacity, and that U.S. government customers expressed interest in seeing payload processing infrastructure expanded. These comments are echoed in public statements by Brig. Gen. Panzenhagen (Erwin 2025a), and in a recent Government Accountability Office (GAO) report (GAO 2025). The GAO noted that DoD lacked sufficient insight into commercial scheduling to manage payload processing, creating additional coordination challenges.

While some launchers have their own payload processing facilities, not all do. Interviewees noted that smaller firms share facilities that can get congested as more launchers use them. Classified payloads may also displace users of shared facilities and create launch capacity constraints. The basic economic challenge interviewees highlighted was that payload processing infrastructure, like roads and wastewater treatment plants, is an expensive fixed cost. A firm planning to invest in this infrastructure needs to anticipate sufficient demand for orbits reachable from that location to justify the fixed cost. However, some interviewees observed that the demand signals necessary to justify private investment in payload processing capabilities had not yet appeared.

While private investment in shared spaceport infrastructure may not be forthcoming, the USSF has recently issued contracts to expand payload processing facilities at the Cape (Erwin 2025b) and VSFB (Erwin 2025c). The Blue Origin facility at the Cape is intended to support up to 16 more missions per year (Albon 2025). While a positive development, it is unclear whether these investments will solve the payload processing capacity issues and—if so—for how long.

Fueling

Some operators have reported difficulty getting access to propellant. Interviews indicated that there are only two propellant vendors at the Cape, one of which is the Defense Logistics Agency (DLA). For hydrazine, a highly dangerous propellant, DLA is the only vendor. Commercial and government operators compete for access to propellant providers. Development of a new methane (liquid natural gas) facility at Port Canaveral had been proposed, which could have helped supply some of the larger vehicles on base. However, the Canaveral Port Authority Board of Commissioners rejected the proposal due to its proximity to homes and an elementary school.

Roads and bridges

Another important shared resource is roads and bridges. Launch operators need to transport large and heavy loads, such as entire rocket stages; however, there are limited roads that may be available for such loads. During the day, normal vehicle traffic may make it difficult to move large loads and large loads may have to move slowly, backing up traffic. Operators are recommended to transport large loads at off-peak hours to ease congestion. In addition, some existing bridges cannot withstand the loads required to transport modern launch vehicles. One stakeholder indicated that funding for infrastructure upgrades is tight, particularly for NASA.

Roads can often be closed due operator activities, such as tanking, testing, or launching. For example, there are limited roads at the Cape capable of handling heavy loads. The average speed of a truck carrying such a heavy load may be below five miles per hour.[8] The distance from the hangar where the vehicle is integrated to the launch pad may be 5 to 20 miles. At these speeds and distances, transport of a rocket may take up to four hours. A three-hour road closure due to pad activities can preclude other operators from beginning some of their own pre-launch preparations, putting them further behind than the duration of the evacuation zone would suggest.

3. Deconfliction on base

As previously discussed, the site commonly known as the Cape is composed of NASA KSC and CCSFS. Launch operators use infrastructure that is distributed across both sites. For example, an operator may use payload processing facilities located on KSC property before moving to CCSFS for vehicle integration and launch. As discussed, when a single operator has a tanking, test, or launch event, this may affect uses of buildings and roads on both properties.

The procedures for coordinating the use of these assets appear to be relatively ad hoc. Interviewees reported frequent issues with badge access to needed facilities, where badges of employees or temporary technicians and construction workers are accepted on one piece of government property but not another. Multiple interviewees described the coordination and

---

[8] As an extreme case, the crawler used for SLS travels at 1 mph when loaded. Commercial vehicles can travel faster by truck when they are in sections (see videos of Blue Origin and SpaceX moving their vehicles); however, we are unsure of the average speed for an integrated vehicle.

deconfliction process as happening over email between operators. This aligns with a recent GAO report that found DoD lacked sufficient insight into commercial scheduling to manage payload processing, creating additional coordination challenges (GAO 2025). There does not appear to be any centralized mechanism by which movements on base and use of shared resources can be scheduled, leaving coordination processes inefficient and opaque.

A similar issue is that national security launches take priority over other launches. This is understandable, since most of the launch pads are within USSF property and ranges. However, this national security priority also leads to delays for the other operators. As demand for commercial launches increases, the penalty imposed on commercial operators by defense-induced delays may also increase. Efforts to increase efficiency on base should consider ways to lessen effects that national security payloads have on the schedule of other operators.

4. Outdated tools and procedures for launch safety and availability

Interviewees expressed concerns with a variety of analytical tools used to manage operations. One example is weather models that were deemed outdated. The ranges use these models to determine launch availability windows based on modeled weather conditions. More accurate models could lead to less unnecessary restrictions to launch availability. Likewise, different launch vehicles and payloads may have different tolerances for weather conditions. Incorporating these differences could improve determinations of launch availability.

Interviewees also shared that the Ranges handle calculation of aircraft hazard areas, which are no-fly zones enforced during launch (see Figure 4.5), but do not allow operators access to the models. Without an understanding of the specific model used to calculate hazard areas, it is difficult for operators to work with the Range to shrink the size of the hazard areas while maintaining safety. It is possible for operators to use privately developed methods to calculate hazard areas; however, there appears to only be a single provider of such models and we are told that it can take three to five years for the FAA to certify the use of these privately generated hazard areas.

To avoid the time and expense of getting privately generated hazard areas to be approved by the FAA, operators use the hazard areas generated by the Range because they are provided and approved by the FAA. This is a boon for some launch operators; however, we have heard that the USSF lacks sufficient resources to produce hazard areas at the same rate they are being requested. Multiple interviewees indicated that they have been forced to wait to receive their hazard areas because there is a queue ahead of them. It is not clear to us what effect these delays may have on an operator’s launch cadence, but it reinforces the point that it is difficult for operators to work with the Range to reduce their risk profile because black-box models and slow turn-around times make design iterations challenging.

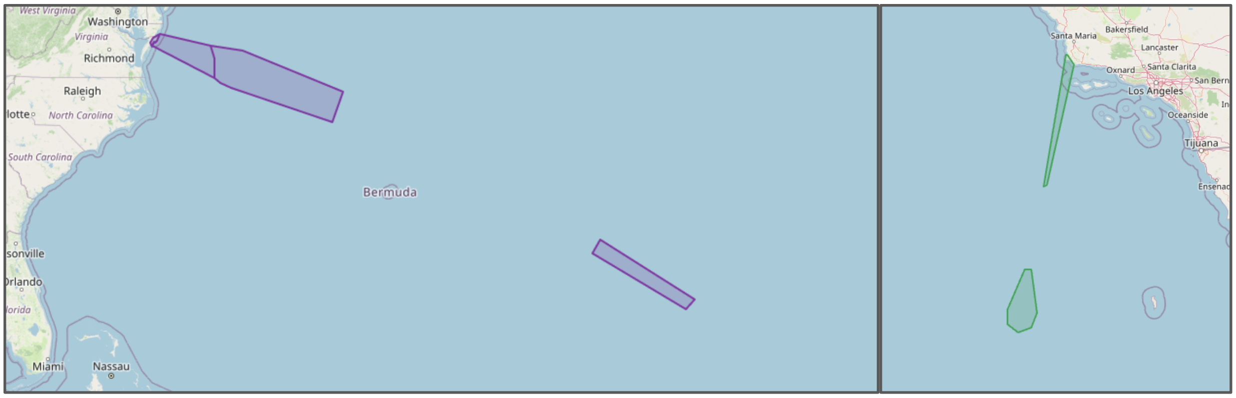


Figure 4.5. Representative aircraft hazard areas, Electron out of Wallops (left) and Falcon 9 out of VAFB (right). Source: Rational Futures rendition from publicly available sources (FAA 2023a; USCG 2026).

Range surveillance capabilities also influence launch availability. Ships at sea or aircraft in flight must be clear from the hazards posed by launch operation and the size of areas to be evacuated can depend on the level of range surveillance available. An interviewee noted that the ranges may not have sufficient surveillance capabilities to support more efficient launch operations and airspace integration. However, we were not provided information regarding the effect this may have on operators now or in the future.

5. Airspace management

For the past 25 years, the FAA has consistently communicated their effort to modernize the airspace, allowing for more dynamic and efficient integration of air and space traffic in the national airspace (FAA 2001; FAA 2020a). Interviewees stated they have not yet seen sufficient improvements related to airspace management during space vehicle operations; however, they believe that a more dynamic air traffic control system is possible. As one interviewee stated, “they’re not evolving the airspace system itself, just the equipment used in it.” While we believe the FAA deserves credit for their substantial improvements to date, the sentiment of our interviewees was that there remains much room to improve.

One example of successful airspace modernization is the FAA’s recent reshaping of a special use airspace (SUA) at the Cape that has historically blocked a high-traffic flight corridor into central Florida. Approximately 80 percent of launches from the Cape are to the southeast; removing the northern half of the SUA allows an apparent elimination of air traffic disruptions *on this corridor into central Florida* for most launches. The old and new SUAs are shown in Figure 4.6. It is important to note that this SUA is one of potentially many hazard areas that may be activated during a launch and which would generally extend beyond the border of the illustrated SUA. The size of such hazard areas can be inferred from Figure 4.5. Such hazard areas may still affect flights that are traveling north-south on offshore and oceanic routes.

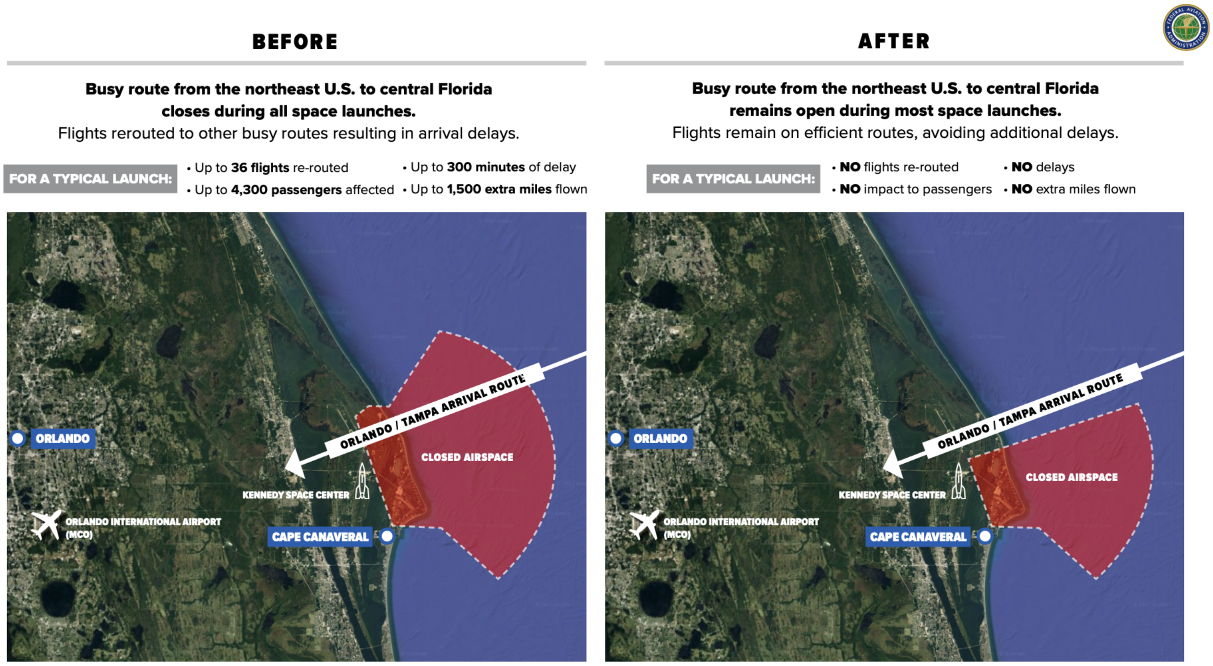


Figure 4.6. FAA improvements to a special use airspace at the Cape. Source: FAA 2023b.

Another example of successful airspace modernization is the use of a space operations hotline to ensure stakeholders are up to date on the status of a launch. Specifically, if a launch is successful and is confirmed to no longer pose a risk to the range, the operator can relay this information through the hotline to air traffic control (ATC), who then removes the aircraft hazard areas as soon as possible. Historically these hazard areas would close the airspace for three-to-four hours; however, the FAA reports that using the hotline and similar methods has reduced airspace closures by 1.5 hours per mission (Coleman et al. 2023). If a debris-generating event occurs, the hotline can also be used to convey relevant information, at which time ATC will generate and activate debris response areas that cover the volume of airspace where debris is likely to fall. In this manner, air traffic controllers can reroute aircraft around hazardous airspace more quickly than was possible before NextGen.

The FAA has been prototyping a new capability called the Space Data Integrator (SDI). The SDI allows the FAA to track the trajectory and status of the space vehicle in real-time (FAA 2025). Data from the SDI can be used to supplement or eventually replace some uses of the hotline for more dynamically managing hazard areas. However, until that transition occurs, it appears that the FAA may still be relying on outdated and disconnected networks for conveying digital information from launch providers to air traffic control to pilots.

A more digitally connected ATC system could enable hazard areas to become more dynamic than current practice, potentially eliminating the majority of disruptions to air traffic from launch vehicle operations. Specifically, if a rocket fragments during its ascent, the resulting debris may take some time before it reenters the national airspace. If the time to reentry is long enough, ATC and pilots may be able to safely evacuate the area. This would allow hazard areas to shrink as the airspace is protected reactively, only after an off-nominal event, instead of proactively. In 2014, the FAA conducted a human-in-the-loop simulation with real pilots and air traffic controllers (Larson et al.

2018); conversation with leaders of the study indicated that pilots and ATC can clear debris hazard areas with approximately three minutes notice. To achieve this level of performance requires NextGen capabilities to be digitally connected: automated monitoring of the launch vehicle's status and state vector must be digitally passed to ATC the moment an anomaly occurs, allowing automatic creation of new hazard areas and rerouted flight plans that are digitally uploaded to pilots at the touch of a button. These capabilities appear to exist already in NextGen, but they have not been connected in this way.

Taken further, an ATC system that provides the ability to react to off-nominal events with three-minute notice may allow the shapes of aircraft hazard areas to be contoured by altitude and updated minute-by-minute. This effectively breaks large static hazard areas into a collection of smaller, fully predictable hazard areas, that sweep across the airspace and do not need to be activated until the rocket is known to be within three minutes of lift-off. FAA-funded simulation studies have shown that hazard areas contoured in space and dynamic in time can nearly eliminate disruptions at traditional and non-traditional launch sites (Colvin 2016; Young et al. 2017). We do not mean to suggest that making such changes to airspace operations would be easy, but to highlight that it is possible with existing technology and may produce enormous benefits.

Despite indications that air-traffic controllers could use NextGen capabilities to respond to dangerous events within minutes, an interviewee noted that launch providers must still provide 14-days notice prior to a launch. This lead time limits the flexibility available to launch operators for optimizing use of the shared launch infrastructure.

6. High-level management

Traditional launch sites are making strides to modernize their infrastructure and DoD has been executing on its strategic intent from *Range of the Future 2028*. The benefits of DoD leadership to U.S. commercial launch have been enormous. Recently, this included transitioning to a highly efficient automated flight safety system, moving building and infrastructure away from pads, and funding the creation of new payload processing facilities. More broadly, the DoD provides innumerable services to commercial launchers, such as access to most of the launch pads in America, access to propellants that are difficult to procure (e.g., hydrazine), handles regulatory hurdles for commercial companies, and operates the ranges to ensure launches are safe and successful.

All interviewees applauded the DoD and NASA for their support. They also noted that there does not appear to be a long-term vision for the design and operation of traditional spaceports, nor a central authority to coordinate and implement such a vision. This appears to have created a relatively ad hoc design of each site, where operators are assigned locations based on availability, rather than long-term facility optimization.

For example, small launchers at the Cape have been given leases to pads that are clustered between pads for very large launch vehicles. If evacuation areas remain unchanged in size, these launchers will frequently be unable to access key infrastructure because they are affected by multiple large vehicles with relatively high launch cadences. The pain goes both ways. Because of their location, the operations of one small launcher may affect the operations of multiple large launchers simultaneously. Further, we see a lease intended for a heavy launch vehicle in the middle of missile row (see Figure 4.2), which itself is likely to affect all small launchers and multiple large launchers simultaneously.

We have already seen two launch operators, Rocket Lab and Firefly Aerospace, hold leases at the Cape but decide to operate at Wallops instead. This may represent a unique opportunity for smaller launchers to cluster at Wallops, leaving the Cape to larger vehicles. However, it is likely efficient for a company with rockets of multiple sizes to operate them all from a single site. Rocket Lab plans to launch their Neutron rocket from Wallops in the future (Rocket Lab n.d.). Firefly is developing a new vehicle called Eclipse and also plans to launch from Wallops (Firefly 2025). As these larger rockets begin to operate from Wallops, strategically locating the launch operators to minimize disruptions to other launcher operations would be beneficial.

Each commercial launcher spends large amounts of capital on infrastructure improvements and shared commodities. Interviewees expressed a desire for some entity to coordinate these investments to achieve broader benefits. This type of coordination may be increasingly important in the future, as some interviewees highlighted that constraints at the Cape are not related to real estate, but providing enough shared commodities (e.g., roads, power, bridges, wetlands mitigation, and propellant) to service the demand. Operators also stated that counting the number of launches from a site is a poor proxy for measuring capacity, since larger rockets may launch less frequently while requiring a greater level of commodity usage.

There are also concerns about neighbors off base. Interviewees mentioned that activities unrelated to space or missiles are also allowed to use the range, generating delays for launchers. If there is a desire to remove as many barriers to launch capacity as possible, a central authority could encourage non-space activities to leave the range, allocate and protect space for launch operators among launch sites based on their needs, and potentially organize the development of new, non-traditional sites as necessary.

5. Non-Traditional Sites

There are a number of non-traditional sites licensed by the FAA, shown in Figure 5.1. We consider a site non-traditional if it is not a Federal site or reliant on a nearby Federal site. Only two of non-traditional sites have hosted orbital launches: Pacific Spaceport Complex - Alaska (PSCA) and Mojave Spaceport. In both cases, we were unable to find any launch permits for currently active vehicles from these sites. SpaceX operates out of Boca Chica, which is permitted for 25 orbital flights of Starship; however, all launches to date have been test flights on suborbital trajectories. The remainder of these sites are in various stages of development and tend to focus on suborbital and horizontal launch.

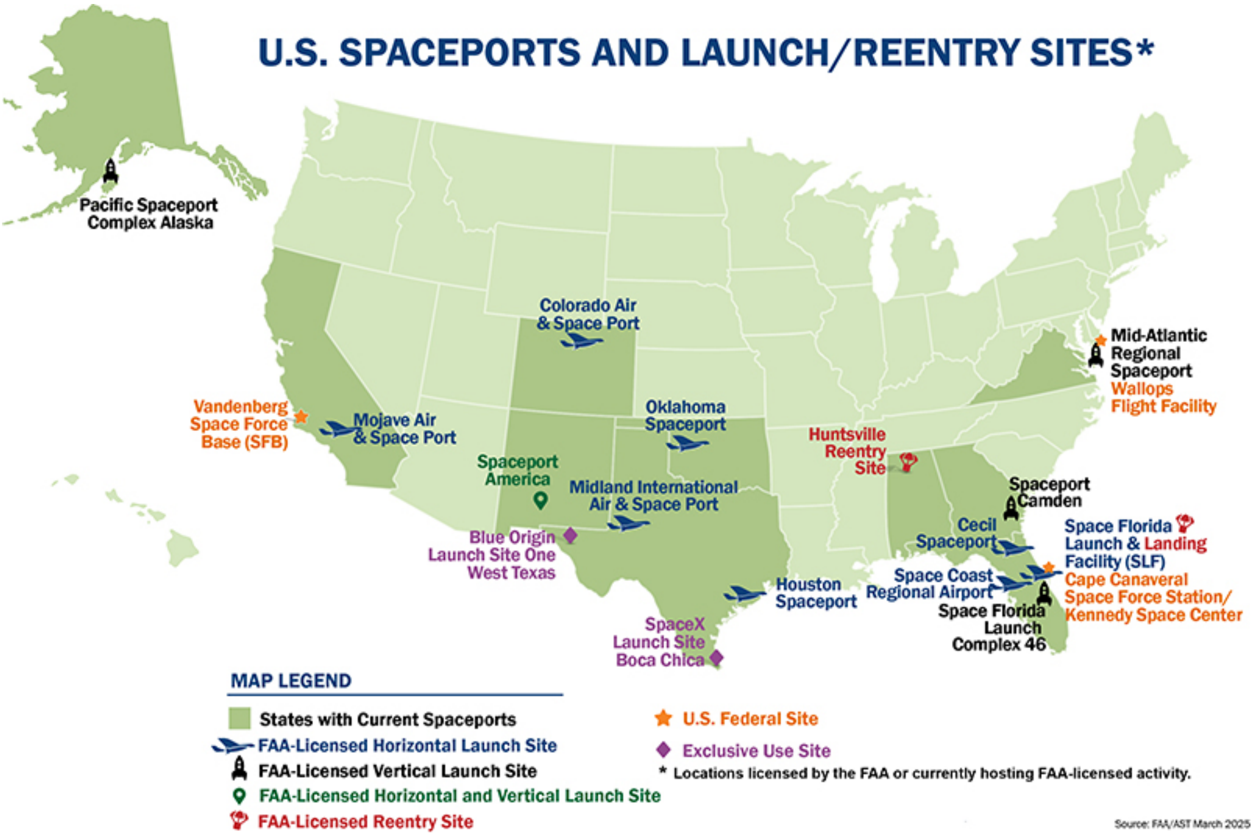


Figure 5.1. Map of U.S. Spaceports. Source: FAA 2026b.

A. Benefits

Clear benefit: reduced uncertainty regarding disruptions to launch vehicle operations

While the interviewees generally indicated that making improvements to the traditional sites is the most efficient path forward, the timeline required for such improvements is unclear. The efficiencies that result from such improvements are also uncertain. Interviewees did not know what the current launch capacity at Traditional sites is, whether new efficiencies may produce a 1 percent or 100 percent improvement in capacity to launch, nor whether changes may happen quickly or may take many years of analysis and regulatory processes.

A launch operator may see value in moving to a non-traditional site if it lowers their operational uncertainty, particularly when the timing and impact of improvements at traditional sites are unclear. For example, Rocket Lab and Firefly Aerospace are developing infrastructure at Wallops despite holding leases at the Cape. While these are movements from one traditional site to another, it illustrates the behavior of actively launching operators to move away from the congested Cape. Further, the development of non-traditional launch sites in Texas (e.g., Corn Ranch for New Shepard suborbital flights and Starbase for Starship) also appear to demonstrate the point. These operators could have chosen to perform their test and operational flights from a traditional site, but the constraints imposed by those sites would not have met their needs. In these cases, the launch providers built the non-traditional launch sites to serve the needs of their specific operations. This illustrates the value of having a strong anchor tenant around which infrastructure can be tailored, rather than an “if-you-build-it-they-will-come” approach.

Clear benefit: supports local economic development

Interviewees noted that economic development is often a motivation behind regional interest in spaceports. However, interviewees also noted that existing traditional launch sites have benefited from decades of investment into infrastructure, and that a new launch site may need similar investment to generate comparable levels of economic activity. Federal mechanisms may support investment into non-traditional spaceports, such as the Space Transportation Infrastructure Matching (STIM) program.[9] There may also be state, county, or other local funding mechanisms available to encourage the necessary investments. For example, private activity bonds for spaceport bonds for spaceports have recently become eligible for tax-exempt status, similar to bonds for airports.

A 2024 economic impact analysis of Spaceport America, prepared by New Mexico State University for the state spaceport authority, offers some insight into how economic activity from a non-traditional launch site may materialize. Over the 2019 to 2024 study period, the report attributed roughly 400 to 1,000 total jobs in New Mexico to the spaceport annually, with tenant operations driving the majority of output and employment in 2024 (Winingham, Erickson, and Vargas 2025). Privately funded construction activity contributed meaningfully in earlier years, accounting for roughly 27 percent of total jobs in 2020. The contribution from construction was lumpy and trending downward over the study period, while the contribution from tenant employment was less lumpy and trended upward.

In 2024, the spaceport was estimated to contribute roughly $240 million in economic output to the state of New Mexico. Though the spaceport is in Sierra County, roughly three-quarters of the jobs and economic output accrued in neighboring Doña Ana County, the nearest regional population center. Total tax revenue from spaceport-related activity was $24.4 million in 2024, most of which

---

[9] This program was initially created in 1994 (Public Law 103-272) to provide matching grant to public spaceports but only made $1.5 million in total awards over the period of 2010 to 2012 (GAO 2020). The SPACEPORT Act, introduced in the current Congress, would modernize this program. For an in-depth analysis of broader Federal mechanisms available to support U.S. launch infrastructure, we recommend the previously referenced GAO study.

also accrued in Doña Ana County. Around two-thirds of the total tax revenue was federal. The report estimates local taxes to Sierra County in 2024 to be roughly $281,000, while state and federal revenues in the same county and year were roughly $1.2 million and $2.2 million. Local tax revenues were constrained in part by a New Mexico statute that exempts space operations from the state's Gross Receipts Tax. This experience suggests that, with a sufficient cadence of tenant operations, new launch sites may generate appreciable local economic benefits. However, benefits may concentrate in nearby population centers rather than the host county.

Clear benefit: investments can also support other aerospace activities

The value of an investment into non-traditional spaceports may be far broader than for traditional spaceports, which are generally focused on vertical launches to orbit. Non-traditional spaceports are designed as flexible aerospace test environments supporting a wide range of activities. For example, Spaceport America has hosted suborbital flights, High Altitude Platform Station (HAPS) tests, and experimental unmanned aerial vehicle operations. Similarly, supersonic flight testing is an emerging use case, with Hermeus conducting tests at Spaceport America and Starfighters Space ramping up its operations at Midland. An investment in non-traditional spaceports can build a broader aerospace ecosystem that is not solely tied to the economics of orbital launch.

Potential benefit: can increase launch capacity

Building more infrastructure to support launch operations from non-traditional sites technically represents an increase in U.S. launch capacity. However, many assumptions must be true to reap these benefits. There are clear benefits to non-traditional sites if some launch providers are unable to launch from traditional sites at the rates demanded by their customers. This could occur if the disruptions at traditional launch sites, as discussed in the previous section, make it sufficiently difficult for launchers to reach their permitted number of annual launches. In such cases, the supply of launch is constrained and being able to launch from a non-traditional site could represent a meaningful increase in supply. For example, if a small launcher is permitted to launch 20 times per year from the Cape but only able to launch five times per year due to operational disruptions, moving to a non-traditional site where they can launch 20 times per year increases the launch supply. This scenario represents a clear increase in launch capacity.

On the other hand, if launchers can meet their projected launch demand from traditional sites, then supply is not constrained. Moving one or more of them to a new launch site would not change U.S. launch rates. More generally, non-traditional spaceports appear to be targeting smaller launch vehicles; however, the large increase in launch demand is primarily due to large numbers of spacecraft that are not appropriate for smaller launchers. For example, Starlink V2 Minis currently have a mass of 575 kg and a small launcher could only launch perhaps two of these at a time. Adding small launchers is valuable to ensure that all niches of the space market are fully served, but they do not address the source of potential capacity gaps.

Potential benefit: non-traditional launch sites build resiliency

Resilience is the ability to withstand and recover rapidly from deliberate attacks, accidents, and natural disasters (DOE 2021). U.S. launch infrastructure may be at risk from deliberate attacks by state actors, terrorists, or other criminals. Hurricanes are a major risk to infrastructure at the

Cape and natural disasters could damage the infrastructure at other sites. An explosion on base could take certain infrastructure offline as well. Like the discussion about launch capacity, non-traditional launch sites could build launch resiliency in some instances by diversifying the geographic locations of U.S. launch infrastructure. This would require careful planning and design.

For a payload operator to gain resiliency benefits, they must have the ability to shift the launch of their payload from the affected site to the non-traditional site faster than waiting for the affected site to reopen. This is influenced by the following factors:

- what stage of launch preparations the payload was in when the disruption occurred;
- whether a traditional site exists that could also meet all the requirements;
- whether a mobile-launch option is available (for defense payloads);
- whether the new site can reach the desired orbital inclination;
- whether the new site hosts a launch vehicle that is compatible with the payload;
- the duration of expected downtime at the affected site compared to the time required to shift operations to the new site; and
- whether the benefits associated with shifting operations to the new site outweigh the costs.

Defense users may have the most credible need for resiliency; in which case, the non-traditional sites must be able to host vehicles compatible with the specific payloads that the DoD would need to launch. This may require larger launch vehicles than non-traditional spaceports have historically attempted to attract.

With non-traditional sites, launch resiliency benefits are possible, but not assured. To gain clarity requires the identification of high-priority demand scenarios that need risk mitigation. These scenarios can then be used to design resiliency plans that incorporate non-traditional launch sites as one of the possible risk-mitigation measures. This process will define the requirements of an appropriate non-traditional site. Building a non-traditional site without such requirements may lead to infrastructure that cannot adequately support resilience for the high-priority demand scenarios.

B. Challenges

1. Key infrastructure for a vertical-launch spaceport

For the non-traditional sites, their level of development varies by site. Some sites have most or all the infrastructure needed to host vertical launches while others are closer to greenfield sites. With the exceptions of PSCA in Alaska and Starbase in Texas, no other non-traditional sites currently appear to have all the needed infrastructure to host vertical launches at a reasonable cadence.

Any spaceport to host vertical launches likely needs the following:

- **Launch area**. A launch pad with a launch mount, flame deflector, water deluge system, and lightning protection system.
- **Propellant facilities**. A propellant storage and transfer system to supply the launch vehicles. Vehicles that use methane may need conditioning facilities to convert liquid

natural gas into rocket-grade propellant. Facilities must also be able to provide propellant to the payloads. Some propellants may be highly toxic, such as hydrazine. Common propellants for electric propulsion systems include xenon and krypton.

- **Payload processing.** A facility that accepts delivery of payloads from their operators, provides a clean room for preflight assembly and testing, and allows encapsulation of the payload inside the fairing.
- **Vehicle integration.** A facility that integrates the various stages of the rocket and the encapsulated payload fairing.
- **Intermodal connections**. Surface transportation routes that allow for propellant tankers and full rocket stages to be brought onto base and moved repeatedly while on base. Further, transportation of the fully integrated vehicle, most likely on a mobile transporter-erector-launcher, from the vehicle integration facility to the launch area. Roads and bridges must be capable of handling the expected loading and frequency of vehicle traffic. If the operator will use maritime recovery to reuse rocket stages, they may need a nearby port that can accommodate the recovery.
- **Utilities**. Some utilities may be relatively straightforward to provide, such as ensuring power and internet hookups. However, others may prove more difficult. For example, even small launchers use water deluge systems to dampen noise and protect launch infrastructure at traditional ranges. This requires the ability to provide very high volumes of pressurized water to the deluge system and wastewater management systems to process the water after it has been used.
- **Stormwater management**. If flooding near the spaceport is possible, infrastructure to divert flood waters and protect assets on base may be required.
- **Emergency response**. Fire and emergency response infrastructure may be required to ensure safety on base, especially in the event of an accident. This includes fire suppression systems, a fire response vehicle, emergency medical capability, and hazardous materials response capability.
- **Infrastructure to ensure safety downrange.** Non-traditional sites might not receive support from the Eastern or Western range, in which case, the functions of the range must be provided by alternative means. This includes downrange surveillance, weather monitoring and modeling, hazard mitigation procedures from potential launch mishaps, and access to space communications systems[10] for vehicle monitoring and control.
- **Mission operations and control center**. A launch control and operations center that serves as the center of launch operations and mission coordination with airspace, maritime, and transportation authorities. Control center capabilities also would include range safety and tracking for vehicle telemetry and trajectory monitoring, meteorological weather monitoring.

2. Capital and operating costs

Interviewees consistently indicated that one of the biggest challenges for a non-traditional spaceport is the capital costs required to reach a flight rate of 10 to 20 launches per year. For

---

[10] These may be ground stations; however, there are increasing options for space-based communications systems to communicate with launch vehicles during flight.

example, PSCA estimated the cost of a new launch pad and associated infrastructure costs for a small launch vehicle at $183 million in 2026 dollars (AAC 2012).[11] Similarly, Spaceport America reports that the final cost to construct their spaceport was $218.5 million (Spaceport America n.d.); however, it is geared more toward horizontal take-off launches. Table 5.1 presents component-level cost estimates to illustrate cost ranges for key infrastructure elements.

Table 5.1. Cost estimates of various launch infrastructure elements.

Infrastructure	Relevant Cost Estimates (2026 dollars*)
Launch pad	$7M for a conceptual launch pad that includes $1.1M for 900 sqft concrete pad, $2.6M for launch mount, $0.3M for flame deflector, $1.2M for lightning protection, $1.3M for water deluge system (Kimley-Horn 2020)
Payload processing and vehicle integration facilities	$40M for Wallops Payload Processing Facility - 21,760 sqft (Vaughn 2019) $77M for Florida Space Life Science Laboratory - 109,000 sqft (Florida Senate 2004) $5M to $26M for a conceptual payload processing facility - 4,000 to 14,400 sqft (Kimley-Horn 2020) $31M for Colorado Air and Space Port Launch Vehicle Processing Building (GSA 2020) $9M to $30M for a conceptual integration facility - 5,800 to 11,300 sqft (Kimley-Horn 2020)
Mission operations and control center	$14M for NASA Wallops Mission Operations Control Center - 14,000 sqft (NASA 2024) $4M to $16M for a conceptual launch control center - 7,325 to 19,225 sqft (Kimley-Horn 2020) $19M for Spaceport America range radar, optical, and telemetry tracking instrumentation (GSA 2020) $7M for PSCA tracking and command destruct system (GSA 2020) $3M for Spaceport America weather instrumentation (GSA 2020) $3M for PSCA weather tracking computer and anemometer systems (AAC 2021b)
Propellant and fuel facilities	$2M for PSCA LOX/N2 Cryogenic production plant (GSA 2020) $3M for Cecil Spaceport liquid propellant storage (GSA 2020) $2M for PSCA launch vehicle propellant storage area (AAC 2021b)
Emergency response	$3M for PSCA emergency station (GSA 2020)
Other facilities	$6M for Houston Spaceport operations hangar (GSA 2020) $38M for Colorado Air and Space Port rocket engine test facility (GSA 2020)

* Inflation adjusted using NASA New Start Inflation Index (NASA 2025b)

In addition to the upfront costs, annual maintenance and operations expenses must also be accounted for. These annual costs averaged about $36 million at MARS and $13 million at PSCA over the last five fiscal years (VCSFA 2021, 2022, 2023, 2024, 2025; AAC 2021a, 2022, 2023, 2024, 2025). Neither spaceport covers these costs from commercial revenue. MARS reported average annual operating revenue of $9.8 million, which they attribute to commercial customers, producing an average operating loss of $26.5 million per year for the same accounting period. MARS received an average of $44.8 million annually in state appropriations, state grants, and federal contracts that enabled the spaceport to sustain operations. PSCA's total operating revenue averaged $17.8 million over the last two fiscal years during which they hosted launches,

---

[11] They reported that it would cost $125M in 2012 dollars for a launch vehicle with 5,000 kg payload capacity. We have adjusted this cost for inflation using the NASA New Start Inflation Index (NASA 2025b).

but approximately $12.0 million (67 percent) is attributable to federal government launch contracts, and $5.6 million from commercial customers.[12]

Government funding at these spaceports takes different forms. MARS relies on appropriations and grants—direct subsidies to offset operating losses. PSCA's federal revenue, by contrast, is earned contractually for launch services rendered. Yet in both cases, revenue from commercial activities alone falls short of sustaining operations and the spaceports rely on government funding. The same economic constraints may apply to future non-traditional launch sites; they will require government funding until there is an increase in relevant commercial launch demand.

3. Integration into local economies

Interviewees noted that overall economic development and accessibility pose another challenge to expanding use of non-traditional sites. At a high level, new spaceports may tend to be in places that are more sparsely populated for safety reasons, but that also makes it harder to support growing workforces. A simple comparison of the counties in which traditional and non-traditional spaceports are or have been proposed, shown in Table 5.2, highlights this point. The second column shows the metro area classification based on Rural-Urban Continuum Codes (RUCC). RUCC is used by the U.S. Department of Agriculture's Economic Research Service (USDA ERS) to distinguish U.S. counties by the population size of their metro area, degree of urbanization, and adjacency to metro areas (USDA 2025). The third column shows the size of the labor force within the commuting zone. Economic research has found that larger metro areas and larger commuting zone labor forces support more robust labor markets (Moretti 2011).

Table 5.2. Characteristics of some counties with existing or proposed launch sites.

Launch Site	Metro area classification	Commuting zone labor force
Non-traditional		
Spaceport Colorado	Metro area, 1M+ population	1.92M
Boca Chica	Metro area, 250K-1M population	0.19M
Midland	Metro area, <250K population	0.21M
Camden	Non-metro area, urban population >20K, metro-adjacent	0.91M
Kodiak	Non-metro area, urban population 5-20K, not metro-adjacent	<0.01M
Spaceport America	Non-metro area, urban population 5-20K, metro-adjacent	0.52M
Traditional		
Cape/KSC	Metro area, 250K-1M population	1.36M
VAFB	Metro area, 250K-1M population	0.36M
Wallops/MARS	Non-metro area, urban population <5K, not metro-adjacent	0.02M

Source: Metro area classification based on USDA ERS 2023 RUCC (Sanders and Cromartie 2024), commuting zone population based on USDA ERS 2020 commuting zones and American Communities Survey 2023 5-year estimates.

---

[12] PSCA's operating revenue is reported as a single aggregate line item in its financial statements, which is not an audited report. The commercial-federal breakdown is derived from management-prepared revenue charts in Alaska Aerospace Corporation's FY2024 and FY2025 annual reports. The analysis is limited to these two years because earlier reports do not provide this breakdown.

4. Demonstrating regulatory compliance

At the Federal ranges, the USSF handles risk assessments and mitigations for the launchers. Thus, companies can easily demonstrate compliance with regulations because the USSF is a trusted entity. For example, aircraft hazard areas generated by the USSF will be easily approved for use by the FAA. However, non-traditional sites may not benefit from the services provided by the range and must demonstrate regulatory compliance on their own.

Safety analyses could be provided by the launch companies or procured commercially. However, interviewees noted that FAA regulations require years of work to prove that safety analysis methodologies are sufficiently accurate and safe. The workforce that currently knows how to perform these types of safety calculations is incredibly limited and difficult for companies and the government to hire. As previously discussed, only a single company appears to exist that currently provides these services.

5. Range safety

A rocket launch that experiences a failure can create hazards from the release of toxic gases, blast overpressure, and falling debris. Range safety procedures mitigate these risks by placing restrictions on the 1) expected casualties to the public on the surface, 2) probability that debris strikes an aircraft, and 3) probability that critical assets are lost. This report has previously touched on protection of critical assets and some aspects of aircraft safety; we did not discuss expected casualties because traditional sites offer trajectories over water, where the dominant risk is to aircraft. However, inland sites require the launch vehicles to fly over land, potentially putting populations at risk. For the following discussion, we focus on safety of aircraft and the public on the ground.

Aircraft hazard areas

We opportunistically collected a sample of historical aircraft hazard areas, shown in Table 5.3. This table shows that aircraft hazard can extend from 400 to 1,800 miles downrange of the launch site. During a launch from a traditional site, these hazard areas are almost exclusively over oceanic waters; while they may cross high-traffic air corridors just offshore, the number of places where flights may cross the hazard areas are somewhat limited. However, inland launches may have hazard areas imposed over the entire length of the hazard area; these also have the potential to be highly disruptive to air traffic if they intersect with enough inland flight routes or potentially an airport.

Table 5.3. Summary statistics for a sample of aircraft hazard areas.

Site	Vehicle	Flight	Hazard Length (mi)	Orbit Insert km	Orbit deg
KSC	Falcon	CRS-26 (2022)	400	400	52
VAFB	Falcon	Starlink g17-13 (2026)	400	250	97
Cape	Falcon	MPower-E (2024)	500	-	-
Cape	Astra	Demo 2 (2022)	650	500	41
Wallops	Electron	RL-33 (2023)	1,500	550	40
Cape	Vulcan	USSF-87 (2026)	1,600	GEO	GEO
Kodiak	RS1	Space Launch (2023)	1,700	300	87
Boca Chica	Starship	FLT 9 (2025)	1,800	Suborbital	26

Expected casualties

If a rocket explodes, it may generate debris that can cause casualties to people on the ground. Even a nominal rocket launch generates casualty risk because the first stage does not make it to orbit. These concerns are mitigated at traditional sites because there are relatively few people downrange, concentrated on islands and ships at sea. There is relatively little literature and analysis on the extent of these risks or the effectiveness of mitigation procedures for inland launches.

Effects of risk mitigation on mass to orbit

It is clearly possible to design launch trajectories that mitigate these risks, at least somewhat. For example, SpaceX has shown the ability to perform dogleg maneuvers that allow the Falcon 9 to safely reach orbits that are not safe to reach via direct means. For example, to launch the SAOCOM 1B in 2020, Falcon 9 flew southeast along the coast of Florida until it could turn southwest without overflying the United States (Clark 2020). This maneuver is illustrated in Figure 5.2. Likewise, launch operators who reuse their first stages may have the capability to precisely control the first-stage reentry, substantially reducing risk; however, uncontrolled reentries can place large areas at risk.

While these mitigations improve the safety of non-traditional launches, they require the launch vehicle to spend propellant flying a trajectory that creates these safety benefits. This use of propellant detracts from the mass of payload that can be delivered to orbit–a penalty that launch operators would not experience if launching from traditional or sea-based sites. None of our interviewees who mentioned this as a concern were able to provide a heuristic for the reduction in payload capacity, but they believed it to be substantial. Some inland launch sites have a natural altitude that is a few thousand feet above sea level, which may help offset the payload-to-orbit penalty. Non-traditional launch sites tend to pursue small launchers as customers; however, these are the launchers that are most sensitive to reductions in payload capacity.

Figure 5.2. Illustrative dogleg trajectory from Cape Canaveral to sun-synchronous orbit, based on the SAOCOM 1B mission profile (SpaceX, August 30, 2020). Source: Rational Futures rendering; coastlines from Natural Earth (public domain).

6. Demand for new launch sites

Non-traditional launch sites have historically pursued operators of Small and Micro launch vehicles as their vertical-launch customer, but these operators do not exhibit clear demand for a non-traditional launch site. To make a non-traditional launch site economically viable would require a level of demand for Small and Micro launch services that exceeds supply. In a previous section of this report, we used available permits as a way to assess the current capacity of small launchers. However, permits do not appear to be as meaningful of a supply constraint for the small launchers compared to the larger vehicles.[13] Assuming permitting is not the issue, unused pads at traditional sites exist that could be used by such launchers relatively quickly compared to developing a new site.

For demand to exceed supply would require the previously discussed challenges with traditional launch sites to limit launch providers from reaching their desired launch cadence. This may occur in the future. Recall Table 5.4 showed that if permits for all types of launch were unlimited, there may be upwards of 100 annual launches demanded for Small and Micro vehicles. Whether and when such demand materializes is highly uncertain. Further, since a single launch complex could

---

[13] For example, LC-48 at the Cape was built by the U.S. Government, completed in 2020, and designed to host 104 launches per year. Despite not having a licensed operator, it seems likely that an operator could easily get a license for that number of launches from the pad.

likely support over 100 launches per year,[14] one or two launch sites placed in locations that can reach all the demanded orbits may fully absorb this demand. Based on this back-of-the-envelope argument, there may not be enough demand in the future to need more than two sites. Non-traditional sites may be competing with Wallops and VSFB to service this demand.

Several interviewees expressed views consistent with this assessment. Small launchers do not appear to be facing range- or spaceport-related constraints that would prevent them from launching their announced manifests. Some interviewees also noted that DoD appears to have a greater need for the types or services a non-traditional site could provide, such as resilient and operationally responsive launch. And yet, despite the presence of non-traditional spaceports that have been licensed for vertical launch for many years, DoD has not exhibited much interest in their use.

We can only speculate about possible reasons for weak DoD demand. It may be that mobile launch infrastructure is more attractive for responsive and resilient launch; though non-traditional spaceports could offer a home base for such operations. Another possibility is that DoD purchases launches commercially, effectively precluding the Department from specifying that contracted launches must occur from a specific location. DoD may believe that the market will provide non-traditional launch facilities, leading it to prioritize investments into the ranges it controls while waiting for the market. Finally, DoD controls nearly all existing launch infrastructure and can claim priority any time it needs, reducing its need for new locations that it does not control. Regardless of the potential reasons, DoD demand for such sites is unproven.

The market case that would enable non-traditional launch was a recurring question with most of our interviewees. No one was able to provide a rough estimate on the minimum launch cadence required for such a site to be profitable. However, most seemed to agree that the necessary demand would require substantial government assistance. As one interviewee quipped, “I fault my former self for saying the commercial market needs to take care of it; it’s just an awful lot of money.”

C. Inland sites

There are several inland launch sites already under development; sites approved by the FAA were shown previously in Figure 5.1**.** A major benefit of pursuing inland launch is that their operation is similar to the traditional sites, so costs and benefits can be confidently assessed. Relatively few operational changes may be necessary compared to sea-based platforms that require new concepts of operation, allowing for vehicles already at traditional sites to shift to non-traditional sites with limited friction.

Another benefit is substantial infrastructure already exists at some sites, reducing the required capital improvements to prepare for vertical launch compared to a green field site. We have also seen states’ willingness to spend hundreds of millions of dollars to fund these sites, indicating that

---

[14] Completed in October 2020, LC-48 at the Cape was designed for 104 launches per year of a small launch vehicle (NASA 2019). It currently does not have a user.

even green field sites could potentially garner the needed funding to build a vertical launch complex.

Interviewees generally indicated that the major hurdles specific to an inland site were 1) the upfront capital to build it and 2) range safety concerns. Regarding range safety, we do not know if such challenges can be overcome; however, in the following discussion, we present considerations that may enable safe operations from inland sites.

Dynamic airspace management

In the discussion of non-traditional sites, we noted disruptions to air traffic may be worse from some inland sites and that efforts to mitigate these risks by changing launch trajectories will hurt the performance of the rocket. Regarding traditional launch sites, we covered how the FAA has been working to make aircraft hazard areas less disruptive by reducing the amount of time that they are activated. However, there may be substantial reductions in the size of the hazard areas as well. The combination of size and timing reductions may be able to nearly eliminate the disruptions to air traffic while preserving the same level of safety as current operations (Colvin 2016). These gains in efficiencies would benefit all launch sites, but may be most beneficial for inland launch sites.

The concept of operations that enables such a reduction relies on three factors: 1) real-time monitoring of the launch vehicle, 2) data communication links, and 3) realistic reaction times (Colvin 2016). Real time monitoring of launch vehicles has been effectively demonstrated by SDI, as previously discussed. If a launch vehicle fails in flight, SDI can immediately provide ATC with information on the failure and the vehicle's last known state-vector. Using this information, ATC could calculate aircraft hazard areas[15] and rerouted flight plans for all aircraft that may be affected. Historically, new flight plans would be relayed vocally over radio, precluding the ability to rapidly reroute large numbers of aircraft; however, data communications would allow controllers to simultaneously send new flight plans to all aircraft in flight digitally. This capability was developed by the FAA's Data Communication Program as a part of NextGen and is now fully operational (FAA 2025b).

Finally, the air traffic controllers and pilots must be able to respond promptly to clear new hazard areas. Once a rocket is two to three minutes into its flight, the hazard areas it may create are generally long and thin, shown previously in Figure 4.5; aircraft can escape from such hazardous areas quickly. Discussions with experts at the FAA indicated that air traffic controllers and pilots could safely respond to an off-nominal launch event with only three minutes of warning (Colvin 2016). This means that airspace does not need to be overly restricted in advance if it can be safely protected dynamically. The size of hazard areas can shrink and for nominal operations, they need only be activated about three minutes prior to launch or first-stage reentry. The hazard areas can also be turned off immediately once the vehicle is known to have safely cleared the area. Analysis suggests this can nearly eliminate the disruption to air traffic from vertical launches

---

[15] Currently, this appears to be done manually by controllers actively managing the airspace–an unnecessarily time-consuming process.

(Colvin 2016); however, implementation of similar styles of dynamic airspace management remains to be seen.

Controlling expected casualties

Literature on expected casualties associated with inland launches is sparse. Some inland sites can partially mitigate casualty risks if they are near enough to an ocean or gulf that the first stage of the rocket can reenter in the water. However, a launch mishap could create debris at any point along the rocket's trajectory. The operator would likely need to design a trajectory that avoids overflight of major cities along the path. Even with such a trajectory, there may remain many smaller towns underneath the trajectory. To determine the potential safety of such a flight depends on several factors such as population densities, fractions of the population that are shielded (e.g., indoors) at the time of failure, probabilities of failure at all points along the trajectory, total dry mass of the launch vehicle, and the characteristics of any debris generated.

Overflights of population centers are not unprecedented. For example, reentries of the space shuttle often flew over large swaths of the continental United States, as shown in Figure 5.3. While NASA management believed the shuttle to have a risk of failure less than 1-in-100,000, its empirical failure rate was shown to be closer to 1-in-100 during the investigations of the Space Shuttle Challenger disaster of 1986 (Feynman 1986). Despite an empirically high probability of failure, the U.S. government permitted overflights until the final shuttle flight in 2011.

Figure 5.3. Ground track for STS-131 Discovery landing opportunity during Orbit 237. The overflight path included two major cities. Source: NASA.

It appears that SpaceX is pursuing permission to use overflights for its Starship vehicle (FAA 2026c). Specifically, they are exploring overflights of northern Florida during launches from Boca Chica, which would allow them to reach orbits with higher inclinations than currently approved. Also, to return the Starship upper stage to the launch site will require a trajectory that passes over northern Mexico and southern Texas. If SpaceX can design safety mitigations and gain regulatory approval for these trajectories, that could provide a modern proof-of-principle and template for other commercial operators to follow, especially those hoping to launch from inland sites.

D. Sea-based sites

Some U.S. companies are pursuing maritime platforms that can host orbital launches. For such a launch, payload processing and horizontal rocket integration would occur shoreside, with the integrated rocket loaded onto the launch platform at port. The launch platform would travel to its intended location, where the launch vehicle would be erected and launched. This concept of operations is designed to be cheaper and simpler than those used by the Sea Launch company, which ceased operations. Notably, China has been pursuing sea-based launch platforms, having completed at least 16 such launches since 2019 (Neale 2026).

This concept is not without challenges. The launch platform itself must be stable enough to support the launch, even in the face of waves and other challenging maritime conditions. The logistics chain of such a launch is also more complex than land-based launch sites. Any late-breaking issues with the launch vehicle or its payloads may be more difficult to address, since the payload and vehicle integration facilities are shoreside. Depending on the time between vehicle integration and lift-off, it may be challenging to provide sufficient power to all of the payloads. Further, fueling of launch vehicles generally occurs within the hour before launch; the logistics of providing cryogenic propellants at sea may be challenging.

A major benefit of a sea-based launch is that most range safety risks are naturally mitigated. All launches take place at sea and can be placed in locations that minimize disruptions to airspace and expected casualties to the public. This feature also allows a wide range of orbits not easily available even from traditional launch sites without reducing the payload capacity of the launch vehicles. For example, instead of a dogleg maneuver from the Cape, a launcher on a sea-based platform could take off from a spot in the Atlantic Ocean where it directly flies a southwest trajectory between Florida and the Bahamas. Even safer may be launches from the Gulf Coast of Florida, which would remove overflights of Cuba. Likewise, launches from the West Coast could reach lower inclination orbits if they began further out into the Pacific.

Sea-based launch may ease environmental issues associated with launches from land. Terrestrial launch sites are often collocated with sensitive habitats; while environmental concerns will still exist at sea, the mobile nature of a sea-based launch pad may offer more flexibility in mitigating them. Interviewees noted that California is a particularly difficult state to launch from due to its environmental rules; moving the launch site away from sensitive habitats and population centers may ease the ability to perform west coast launches.

Sea-based platforms have the potential to be somewhat scalable. If the logistics and other challenges can be solved for a single sea-based platform, the process to approve subsequent platforms would be largely identical. Being mobile and potentially scalable would increase launch resiliency. These platforms can move away from potential threats and exist in numbers that make it difficult for natural disasters or adversarial actions to reduce U.S. launch capacity.

6. Potential Paths Forward

We do not provide recommendations for future actions because we have not performed a cost-benefit analysis for actions to address the challenges. Instead, we synthesize actions that stakeholders explicitly or implicitly identified as priorities. The potential actions are grouped according to whether they primarily benefit traditional sites, non-traditional sites, or both equally.

A. Support traditional sites

Create a central authority to manage U.S. launch sites. Interviewees often framed their challenges as ones of coordination among stakeholders, each of whom operates and uses key portions of launch infrastructure. A central authority could coordinate and implement solutions to all the challenges at traditional launch sites. Multiple interviewees expressed a desire for such a central authority and were ambivalent about who provided it, whether NASA, DoD, or a third party. They simply noted that the current situation, especially at the Cape was not sufficiently coordinated to meet the needs of launch operators.

The central authority could coordinate and implement many of the subsequent actions we discuss below. These include coordination of:

- A zoning board function
- Investments in infrastructure upgrades
- A centralized platform to coordinate use of shared resources
- Reducing the size of evacuation zones
- Improve flight safety tools.

Create a zoning board function to more strategically assign operators to locations on base. As previously discussed, operators appear to be given access to launch pads and other infrastructure, without a long-term vision for how U.S. space infrastructure should be managed. Some zoning issues occur within a single base, such as where smaller launchers and heavy launchers should be placed. However, other issues go beyond a single base, such as whether certain launch vehicles should be encouraged to move to other sites or precluded from moving to other sites to protect existing operations.

Coordinate investments in infrastructure upgrades. All operators share common resources such as roads and utilities. Many operators share facilities, such as those for payload processing. Federal, state,[16] and private entities have invested heavily in developing new infrastructure, but interviewees expressed a desire for more coordination on such investments to meet broader operator needs. Some examples include coordinating the requirements for a new payload processing facility or simply making sure that operators have multiple roadways to access their infrastructure in case one road is blocked by the activities of another operator. Likewise, it may be possible to move a significant portion of the supporting infrastructure away from the launch

---

[16] E.g., Florida has invested over $500M in launch infrastructure to support operations near the Cape.

pads and potentially off Federal lands. These types of coordinated movements could reduce disruptions among operators.

Create a centralized platform to coordinate use of shared resources. The platform would support scheduling the use of payload processing facilities, access to propellant vendors, usage of roads for transporting heavy loads, tanking and testing operations that may cause road closures or evacuations, and launch scheduling or rescheduling. DoD told GAO that it lacked sufficient insight into commercial scheduling to manage operations (GAO 2025). We find that launch operators also lack and desire scheduling insight and transparency; however, no central authority has yet emerged to provide it.

Reduce the size of evacuation zones. Improved explosive analysis for methane engines may allow for a substantial reduction in disruptions on base. Some interviewees were hopeful that incorporation of test data and flight reliability from commercial launch providers could be combined with new safety procedures to create meaningful improvements. GAO indicates that the FAA, USSF, and NASA are coordinating research on the explosive effects of methane as a propellant (GAO 2025); however, no timeline is given for when such research may turn into updated procedures for evacuation zones. Private companies developing methane-based engines have test data and infrastructure that could inform the government's research. Even if such research does not substantially reduce evacuation zones, clarity regarding the explosive potential is needed for planning locations of new infrastructure and designing new operational procedures to manage associated risks.

B. Support traditional and non-traditional sites

Improve flight safety tools. The USSF could release its models for calculating hazard areas to the community. This would allow operators to more easily understand the underlying algorithms, suggest targeted improvements to the tools, and to run the tools themselves. Even if the USSF holds the final approval of such analyses, allowing operators to run these tools themselves enables operators to optimize their trajectories and take other actions that can reduce airspace disruptions. The FAA could also certify tools for flight safety to provide more robust commercial pathways for generating hazard areas that are compliant with regulations. Finally, weather models used to predict flight availability could be upgraded and mission-specific weather tolerances could be used.

Implement dynamic airspace management. As previously discussed, there is promising research to show that the national airspace system currently has the capabilities needed to nearly eliminate the disruption to air traffic caused by space operations. Real-time monitoring of launch vehicles can be used to detect launch failures, at which point air traffic controllers can rapidly upload safe flight plans to aircraft in flight. In this way, airspace that can be safely cleared dynamically does not need to be proactively blocked. While beneficial for operations out of the Cape, this approach may also enable inland launch sites where rocket trajectories will pass over a complex network of jetways. Such an approach may also allow spaceports to be nearly collocated with traditional airports.

Consider updating regulations related to rocket overflight. We are not in a position to judge the circumstances in which overflight is tolerably safe or whether requirements should be relaxed; however, rocket overflight in the United States has occurred numerous times in the past. The ability to safely perform overflights may enable or preclude many space operations at inland spaceports and all operations that involve a reentry vehicle landing inland. We have already discussed reentries of Starship, but the issue affects other companies and NASA priorities as well. For example, microgravity research and development experiments that return to Earth often need to be moved to a lab facility immediately; this is challenging if capsule reentries must occur over the ocean or in deeply remote areas of the United States. The closer such deliveries from space can be placed to their final destination, the faster the pace of science and innovation. The FAA could initiate a process to gather evidence or fund new research that may lead to a proposed rulemaking, ensuring regulations appropriately balance public safety and efficiency of space operations.

Pursue mobile payload processing facilities. Payload processing facilities appear to be a significant bottleneck. DoD has recently spent approximately $160 million to begin construction of two new facilities, each of which may allow for an added 16 payloads per year (Robinson-Smith 2025). These facilities can only support operations at the base where they are located. There may be value in pursuing mobile payload processing facilities. For a non-traditional spaceport to attract launch companies, it must have a payload processing facility; however, it is too soon to know where the most desirable such spaceport will be located. A mobile processing facility would be able to support traditional launch operations until a new spaceport emerges that needs its services. If the spaceport falters, the mobile facility can move to a new spaceport or back to a traditional site. Depending on the launch cadence, a single facility could support multiple non-traditional spaceports. For example, it is a six-hour drive from Spaceport America to Midland, Texas and a three-hour drive from VSFB to the port of Long Beach, which could be used to support sea-based launches. A mobile processing facility may also support DoD efforts to build responsive launch capabilities.

C. Support non-traditional sites

Fund analyses that show launch performance from non-traditional sites. At present, we were unable to find literature on the trajectories available from various inland launch sites nor estimates of the reduced payload capacity to orbit that would result from the more vertical trajectories required to mitigate risks. Likewise, interviewees identified this as a major gap. Such analyses must define the orbits that can be reached from each launch site and how much payload can be delivered per launch. They would incorporate realistic commercial vehicles and compliance with aircraft and casualty safety regulations. The analyses should also address infrastructure and operating cost estimates to reach a variety of flight rates. For maximum effect, the studies should be vouched for by the Federal government to increase their credibility with state and congressional funders as well as the launch providers themselves.

Extend Federal range services to non-traditional launch sites. Assuming overflight issues can be addressed, many U.S. Government range services could be extended to commercial launch operators, regardless of their location. The USSF already provides range services to launch operators from their own ranges and has the ability to charge for the service. The Virginia Spaceport Authority has also demonstrated this type of arrangement with NASA; a commercial operator can buy range services from MARS that are then provided by NASA. This includes "payload processing, vehicle and spacecraft integration, launch range instrumentation and control, emergency facilities, telemetry and data services, materiel handling and logistics, safety analysis and mission planning" (NASA 2024). Capital requirements for new spaceports could be eased if the Federal government were able to provide range services such as radar for range surveillance, telemetry, tracking, and command services along the rocket's flight path, and flight safety analyses.

Provide capital to create new launch sites and ranges. Our analysis and interviewee responses indicate that market forces alone are unlikely to support a new launch site in the near term. If the Federal government believes that non-traditional launch sites are valuable, it will need to support their creation directly. DoD could agree to become the anchor tenant of a facility, with a guaranteed flight rate. The U.S. Government could also provide funding for capital improvements of the spaceports or new technologies that launch providers could use to improve the safety of their launches.

References

AAC. 2012. *2012 Annual Report*. Alaska Aerospace Corporation. https://akaerospace.com/wp-content/uploads/2021/01/2012.pdf.

AAC. 2021a. *2021 Annual Report*. Alaska Aerospace Corporation. https://akaerospace.com/wp-content/uploads/2022/02/2021-AAC-Annual-Report-final-web.pdf.

AAC. 2021b. "Pacific Spaceport Complex - Alaska: Spaceport Master Plan 2020-2030." Alaska Aerospace Corporation, March. https://akaerospace.com/wp-content/uploads/2021/06/PSCA-Master-Plan-Final-Board-Approved-March2021.pdf.

AAC. 2022. *2022 Annual Report*. Alaska Aerospace Corporation. https://akaerospace.com/wp-content/uploads/2023/03/2022-AAC-Annual-Report-final.pdf.

AAC. 2024. *2024 Annual Report*. Alaska Aerospace Corporation. https://akaerospace.com/wp-content/uploads/2021/01/2012.pdf.

AAC. 2025. *2025 Annual Report*. Alaska Aerospace Corporation. https://akaerospace.com/wp-content/uploads/2021/01/2012.pdf.

AEI. n.d. "Global Space Data Navigator." American Enterprise Institute. Accessed January 10, 2026. https://spacedata.aei.org/.

Albon, Courtney. 2025. "New Blue Origin Facility To Boost Space Force Launch Cadence." Air and Space Forces Magazine, October 15. https://www.airandspaceforces.com/new-blue-origin-facility-to-boost-space-force-launch-cadence/.

Clark, Stephen. 2020. "SpaceX Launches First Polar Orbit Mission from Florida in Decades." *Spaceflight Now*, August 31. https://spaceflightnow.com/2020/08/31/spacex-launches-first-polar-orbit-mission-from-florida-in-decades/.

Coleman, Kelvin B., Timothy Arel, Hannah Browne, Brooke Teferra, Emily Sisneros, and John Sloan. 2023. "Airspace Integration of U.S. Commercial Space Launches and Reentries." Paper presented at 74th International Astronautical Congress, Baku, Azerbaijan. October 2. https://www.faa.gov/media/71916.

Young, Jessica, Marie Kee, and Christina Young. 2017. "Effects of Future Launch and Reentry Operations on the National Airspace System." *AIAA Journal of Air Transportation* 25 (May). https://doi.org/10.2514/1.D0039.

Larson, Erik, Steven Carbon, John Herndon, et al. 2018. "Protecting Aircraft in Real-Time From a Launch or Re-Entry Failure." *34th Space Symposium, Technical Track*. https://www.spacefoundation.org/wp-content/uploads/2019/07/Larson-Erik_Protection-of-Aircraft.pdf.

Colvin, Thomas J. n.d. *Compact Envelopes: An Efficient and Provably Safe Approach to Air and Space Traffic Integration*. https://searchworks.stanford.edu/view/11849254.

DiMascio, Jennifer, Rachel Lindbergh, and Hannah Dennis. 2026. Defense Primer: National Security Space Launch Program. No. IF12900. https://www.congress.gov/crs_external_products/IF/PDF/IF12900/IF12900.4.pdf

DOE. 2021. "Continuity Programs." U.S. Department of Energy, December 21. https://www.directives.doe.gov/directives-documents/100-series/0150.1-BOrder-b/@@images/file.

Erwin, Sandra. 2025a. "Astrotech Wins $77.5 Million Contract to Accelerate Pre-Launch Satellite Processing at Vandenberg." Space News, April 27. https://spacenews.com/astrotech-wins-77-5-million-contract-to-accelerate-pre-launch-satellite-processing-at-vandenberg/.

Erwin, Sandra. 2025b. "Blue Origin Wins $78.2 Million Contract to Expand Satellite Processing Infrastructure at Cape Canaveral." Space News, October 7. https://spacenews.com/blue-origin-wins-78-2-million-contract-to-expand-satellite-processing-infrastructure-at-cape-canaveral/.

Erwin, Sandra. 2025c. "Satellite Backlog Emerges as Key Constraint at the Nation's Busiest Spaceport." Space News, January 29. https://spacenews.com/satellite-backlog-emerges-as-key-constraint-at-the-nations-busiest-spaceport/.

FAA. 2001. "Concept of Operations for Commercial Space Transportation in the National Airspace System." Federal Aviation Administration, May 11. https://www.faa.gov/about/office_org/headquarters_offices/ast/media/CST_CONOPS_v2.pdf.

FAA. 2020a. "Commercial Space Integration into the National Airspace System: Concept of Operations." Federal Aviation Administration, May. https://www.faa.gov/sites/faa.gov/files/space/airspace_integration/Final_CSINAS_ConOps.pdf.

FAA. 2020b. "Rule 450 Final." Federal Aviation Administration, September 30. https://www.faa.gov/sites/faa.gov/files/space/additional_information/faq/SLR2_Final_Rule_450.pdf.

FAA. 2023b. *Flight Planning in the Vicinity of Launch or Reentry Vehicles - What Pilots Need to Know*. Federal Aviation Administration. https://www.faasafety.gov/files/gslac/library/documents/2023/Oct/390238/Aircraft%20Hazard%20Areas%20-%20What%20Pilots%20Need%20to%20Know%20July%20Rev%206d%20Final.pdf.

FAA. 2023b. FAA Safely Keeps More Airspace Open During Most Florida Space Launches | Federal Aviation Administration. June 15. https://www.faa.gov/newsroom/faa-safely-keeps-more-airspace-open-during-most-florida-space-launches.

FAA. 2025. “The Space Data Integrator.” Federal Aviation Administration, August 4. https://www.faa.gov/newsroom/space-data-integrator-sdi-0.

FAA. 2026a. *SpaceX Starship-Super Heavy Launch Vehicle at Launch Complex 39A at the Kennedy Space Center, Merritt Island, Florida*. Federal Aviation Administration. https://www.faa.gov/space/stakeholder_engagement/spacex_starship_ksc/SpaceX-SSH-LC-39A-Final-EIS-Volume-I.pdf.

FAA. 2026b. “U.S. Spaceports.” Office of Spaceports, Federal Aviation Administration, February 10. https://www.faa.gov/space/office_spaceports.

Fabey, Mike. 2017. “SpaceX Forces Air Force to Revise Launch Mindset.” Space News, September 20. https://spacenews.com/spacex-forces-air-force-to-revise-launch-mindset/.

Fernholz, Tim. 2026. “Starcloud Raises $170 Million Series A to Build Data Centers in Space.” TechCrunch, March 30. https://techcrunch.com/2026/03/30/starcloud-raises-170-million-series-ato-build-data-centers-in-space/.

Firefly. 2025. “Northrop Grumman Invests $50 Million in Firefly Aerospace to Advance Medium Launch Vehicle Named Eclipse.” Firefly Aerospace, May 29. https://fireflyspace.com/news/northrop-grumman-invests-50-million-in-firefly-aerospace-to-advance-medium-launch-vehicle-named-eclipse/.

Firefly. n.d. “Upcoming Mission - Alpha - QuickSounder.” Firefly Aerospace. Accessed November 25, 2025. https://fireflyspace.com/missions/quicksounder/.

Florida Senate. 2004. *Florida Space Industry*. Interim Project Report Nos. 2005–151. The Florida Senate. https://www.leg.state.fl.us/data/Publications/2005/Senate/reports/interim_reports/pdf/2005-151cm.pdf.

Foust, Jeff. 2023. “SpaceX Experiencing Problems with First Upgraded Starlink V2 Satellites.” *SpaceNews*, March 22. https://spacenews.com/spacex-experiencing-problems-with-first-upgraded-starlink-v2-satellites/.

GAO. 1978. *A Second Launch Site for the Shuttle? An Analysis of Needs for the Nation’s Space Program*. PSAD-78-57. Government Accountability Office. https://www.gao.gov/assets/psad-78-57.pdf.

GAO. 2020. FAA Should Examine a Range of Options to Support U.S. Launch Infrastructure. Gao-21-154. https://www.gao.gov/assets/gao-21-154.pdf.

GAO. 2021. *Matter of Blue Origin Federation LLC; Dynetics, Inc.-A Leidos Company (File B-419783; B-419783.2; B-419783.3; B-419783.4)*. Decision. Government Accountability Office. https://www.gao.gov/assets/b-419783.pdf.

GAO. 2025. *National Security Space Launch: Increased Commercial Use of Ranges Underscores Need for Improved Cost Recovery*. GAO-25-107228. Government Accountability Office. https://www.gao.gov/assets/gao-25-107228.pdf.

Goldman, David. 2022. “Letter to Marlene H. Dortch, Secretary, Federal Communications Commission. Re: IBFS File Nos. SAT-LOA-20200526-00055 and SAT-AMD-20210818-00105.” Space Exploration Technologies Corp., October 4. https://planet4589.org/astro/starsim/papers/StarGen2.pdf.

GSA. 2020. *National Spaceport Network Development Plan*. The Global Spaceport Alliance. https://www.faa.gov/about/office_org/headquarters_offices/ast/advisory_committee/meeting_news/media/2020/june/National_Spaceport_Network_Development_Plan.pdf.

Iturbide-Sanchez, Flavio. 2024. “The NOAA Near Earth Orbit Network (NEON) QuickSounder Mission: Preparatory Calibration and Validation Activities for the QuickSounder ATMS Instrument.” The EUMETSAT Meteorological Satellite Conference, September 30. https://ntrs.nasa.gov/api/citations/20240012278/downloads/EUMETSAT_2024_QuickSounder_ATMS_Flavio_et_al.pdf.

Kan, Michael. 2023. “Boeing Halts Plan for Starlink Competitor | PCMag.” PC Magazine, October 31. https://www.pcmag.com/news/boeing-halts-plan-for-starlink-competitor.

Kan, Michael. 2025. “SpaceX Offers New Look at V3 Starlink Satellite for Gigabit Speeds.” *PC Magazine*, October 14. https://www.pcmag.com/news/spacex-offers-new-look-at-v3-starlink-satellite-for-gigabit-speeds.

Kimley-Horn. 2020. *Michigan Spaceport: Spaceport Site Selection and Feasibility Study*. Kimley-Horn and Associates, Inc. https://citizensforsuperior.org/wp-content/uploads/2024/04/MAMA-Michigan-Spaceport-Site-Selection-and-Feasibility-Study.pdf.

Launcher. n.d. “Launcher Calculator.” Accessed January 2, 2026. https://launchercalculator.com/.

Longo, Alex. 2025. “Op-Ed: How NASA Could Still Land Astronauts on the Moon by 2029.” *AmericaSpace.Com*, May. https://www.americaspace.com/2025/06/09/op-ed-how-nasa-could-still-land-astronauts-on-the-moon-by-2029/.

Mogg, Trevor. 2025. “Could This Lander Return Astronauts to the Moon Instead of SpaceX’s Starship?” *Digital Trends*, October 21. https://www.digitaltrends.com/space/could-this-lander-return-astronauts-to-the-moon-instead-of-spacexs-starship/.

Moretti, Enrico. 2011. “Chapter 14: Local Labor Markets.” In *Handbook of Labor Economics*, 1st ed., vol. 4B. Elsevier. https://econpapers.repec.org/bookchap/eeelabchp/5-14.htm.

NASA. 2019. *Draft Environmental Assessment for Launch Complex 48 John F. Kennedy Space Center*. National Aeronautics and Space Administration. https://netspublic.grc.nasa.gov/main/LC%2048%20Environmental%20Assessment%20with%20Appendices_02.19.2019.pdf.

NASA. 2024. “Wallops Range User’s Handbook.” National Aeronautics and Space Administration, April 1. https://www.nasa.gov/wp-content/uploads/2023/09/wallopsrangeusershandbook-2024.pdf.

NASA. 2025a. “FY 2026 Budget Technical Supplement.” National Aeronautics and Space Administration, June 9. https://www.nasa.gov/fy-2026-budget-request/.

NASA. 2025b. *NASA New Start Inflation Index*. National Aeronautics and Space Administration. https://www.nasa.gov/ocfo/ppc-corner/ppc-models-tools/.

NASA. n.d. “Launch Schedule.” NASA Events, National Aeronautics and Space Administration. Accessed December 10, 2025. https://www.nasa.gov/event-type/launch-schedule/.

NOAA. n.d. “Near Earth Orbit Network (NEON).” NESDIS. Accessed November 25, 2025. https://www.nesdis.noaa.gov/our-satellites/future-programs/near-earth-orbit-network-neon.

Ralph, Eric. 2022. “SpaceX CEO Elon Musk Reveals Next-Generation Starlink Satellite Details.” Teslarati, May 30. https://www.teslarati.com/spacex-elon-musk-next-gen-starlink-satellite-details/

Rao, Akhil, and Thomas Colvin. 2025. “Opportunity Costs Drive the Market Price of Starship Launches.” Rational Futures Inc., May. https://rationalfutures.com/2025/10/opportunity-costs-drive-the-marketprice-of-starship-launches/.

RCC. 2020. *Common Risk Criteria Standards for National Test Ranges: Supplement*. SUPPLEMENT: STANDARD 321-20. Range Commanders Council - U.S. Army White Sands Missile Range. https://apps.dtic.mil/sti/tr/pdf/AD1099047.pdf.

Robinson-Smith, Will. 2025. “U.S. Space Force Picks Blue Origin Bid for Expanding Satellite Processing at Cape Canaveral.” *Spaceflight Now*, October 9. https://spaceflightnow.com/2025/10/09/u-s-space-force-picks-blue-origin-bid-for-expanding-satellite-processing-at-cape-canaveral/.

Rocket Lab. n.d. “Neutron: Next-Generation Launch Challenger.” Rocket Lab USA. Accessed February 21, 2026. https://rocketlabcorp.com/launch/neutron/.

SAM.gov. 2025. *Cape Canaveral Space Force Station Request for Information for Space Launch Complex-46 Lease*. https://sam.gov/workspace/contract/opp/fa2458d43f04463982a4d0735b99ae0b/view.

Sanders, Austin, and John Cromartie. 2024. *2023 Rural-Urban Continuum Codes*. U.S. Department of Agriculture. https://ers.usda.gov/data-products/chart-gallery/chart-detail?chartId=108333.

SDA. 2025. “Space Development Agency Completes Successful Launch of First Tranche 1 Satellites.” *Space Development Agency*, September 10. https://www.sda.mil/space-development-agency-completes-successful-launch-of-first-tranche-1-satellites/.

Sierra Space. 2025. “Sierra Space’s Dream Chaser Spaceplane Successfully Completes Critical Pre-Flight Milestones.” *Sierra Space Corporation*, November 13. https://www.sierraspace.com/press-releases/sierra-spaces-dream-chaser-spaceplane-successfully-completes-critical-pre-flight-milestones/.

SMC. 2019. “Orbital Services Program-4.” Space and Missile Systems Center, May 21. https://sam.gov/api/prod/opps/v3/opportunities/resources/files/c3e7c71dc3973ea0952827cc789aa7b5/download?&status=archived&token=.

Smith, Marcia. 2025. “Here’s the mass of the 27 Project Kuiper satellites.” Tweet. Twitter, April 29. https://x.com/SpcPlcyOnline/status/1917312706756886761.

Spaceport America. n.d. “FAQs - Frequently Asked Questions.” Spaceport America. Accessed February 15, 2026. https://www.spaceportamerica.com/faq/.

SpaceX. 2020. *SAOCOM 1B Mission*. YouTube Video. https://www.youtube.com/watch?v=P-gLOsDjE3E.

SpaceX. 2025. Starlink Progress 2025. https://starlink.com/public-files/starlinkProgressReport_2025.pdf

Spinlaunch. n.d. “SpinLaunch Website: About Meridian.” Accessed March 20, 2026. https://www.spinlaunch.com/meridianspace.

USCG. 2026. “Space Operations Launch and Recovery (SOLAR) Chart.” Navigation Center, United States Coast Guard, February 10. https://navcen.uscg.gov/chart.

USDA. 2025. *Rural-Urban Continuum Codes*. U.S. Department of Agriculture. https://www.ers.usda.gov/data-products/rural-urban-continuum-codes.

Vaughn, Carol. 2019. “NASA Wallops Opens New Payload Processing Facility.” Delmarva Now, July 12. https://www.delmarvanow.com/story/news/2019/07/12/nasa-wallops-has-new-payload-processing-facility/1701765001/.

VCSFA. 2021. *Virginia Commercial Space Flight Authority (A Component Unit of the Commonwealth of Virginia): Financial Report, June 30, 2021*. Virginia Commercial Space Flight Authority.

VCSFA. 2022. *Virginia Commercial Space Flight Authority (A Component Unit of the Commonwealth of Virginia): Financial Report, June 30, 2022*. Virginia Commercial Space Flight Authority.

VCSFA. 2023. *Virginia Commercial Space Flight Authority (A Component Unit of the Commonwealth of Virginia): Financial Report, June 30, 2023*. Virginia Commercial Space Flight Authority.

VCSFA. 2024. *Virginia Commercial Space Flight Authority (A Component Unit of the Commonwealth of Virginia): Financial Report, June 30, 2024*. Virginia Commercial Space Flight Authority.

VCSFA. 2025. *Virginia Commercial Space Flight Authority (A Component Unit of the Commonwealth of Virginia): Financial Report, June 30, 2025*. Virginia Commercial Space Flight Authority.

Winingham, Kramer, Christopher A. Erickson, and Lucinda Vargas. 2025. *Economic Impact of Spaceport America, 2019-2024*. Arrohead Center/New Mexico State University. https://www.spaceportamerica.com/wp-content/uploads/2025/08/Economic-Impact-of-Spaceport-America-2019-2024.pdf.