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Small Launchers - 2023 Industry Survey and Market Analysis

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Abstract

The field of small launchers continues to grow, but there may be some signs of a slowdown. NewSpace Index (www.newspace.im) has been tracking small launch vehicles since 2016 and includes 203 entries, compared to 180 in the previous industry survey presented at IAC 2021. The public directory focuses on new private rockets that were, are or will be available on the worldwide commercial launch market. A small rocket is defined as being capable of launching up to a 1500 kg payload to a 700 km SSO orbit.

The first half of the paper provides an updated statistical overview of small launchers. Development status, payload performance, first orbital launch years, development years and delays, launch costs, geographical distribution, propellant types, reusability plans, and funding amounts will be reported where available.

The second part will discuss small launcher trends, market context, and competition. Since the previous IAC 2021 study, outcomes have been mixed and delays are still common. Rocket Lab has had positive results, with 6 launches in 2021 and 9 in 2022, including the first from the USA in early 2023. Firefly made it to orbit on their second attempt. There have also been failures. ABL's and Relativity's first rockets launched in early 2023, but did not reach orbit. Virgin Orbit failed to make it to orbit during their first takeoff from the UK. Astra and Virgin Orbit went public, but stocks have not performed well. Astra discontinued Rocket-3 and is focusing on Rocket-4 and propulsion systems. Virgin Orbit and SpaceRyde went bankrupt. Some startups, such as SmallSpark and Launcher (Vast), have pivoted to space tugs.

The next few years in the small launcher industry will be the most interesting, with many more first and continued launches expected, particularly in Europe, China, and the USA. However, payload readiness may pose a challenge to increasing the cadence and SpaceX's rideshare missions launching 3-4 times per year are offering strong competition together with orbital transfer vehicles. Whether there is enough market demand for numerous small launchers to achieve economic sustainability remains to be seen, but getting to orbit would at least prove the executability and technology of the companies. Nonetheless, more mergers, pivots, and bankruptcies are likely throughout 2023 and beyond.

Keywords: launchers, rockets, small launchers, small lift launch vehicles, dedicated launchers

1. INTRODUCTION

This survey gives an overview about the current state of the small launch industry and discusses changes during the 2 years since the previous study by the author was published. For a more complete picture, please also see the paper from IAC 2021.[1]

NewSpace Index (www.newspace.im) has tracked new small launch vehicles since 2016. There are 203 entries as of September 2023, which makes it one of the largest public databases. There were about 30 launchers listed in 2016, 60 by the end of 2017, and 180 in the previous 2021 study.

A short history of small launchers was covered in the previous study.[1] Commercial, private, rapidly deployable or even re-usable launch vehicles are not a novel concept, but most of them have not completed development or continued to be operational. However, the quantity is now much larger, prices should become lower, and demand is likely larger.

The 2021 paper also includes a more complete literature review.[1] C. Niederstrasser has presented small launcher surveys since 2015, with the latest from August 2022.[2] SpaceFund has curated Launch Database since 2018, including suborbital and larger launchers, with a last update from October 2022.[3] P. Lionnet has continued to write about launch vehicles and their economics.[4,5] Gunter's Space Page[6] (Gunter D. Krebs), Jonathan's Space Report[7] (Jonathan McDowell) and Space Launch Report[8] (Ed Kyle) have been keeping lists of space launches and launch vehicles for more than 2 decades. Ashlee Vance's book "When the Heavens Went on Sale" was released in May 2023 and includes stories and history about Astra, Rocket Lab and Firefly.[9]

2. JOURNEY SINCE 2021

Martin Attiq, Astra's Chief Business Officer, said in 2022 that customers want an affordable, frequent and reliable launch system.[10]

About two years ago was when many space companies, including Astra, Rocket Lab and Virgin Orbit, went public via SPACs, and many very optimistic predictions were published. During 2022, the overall sentiment towards small launch started to turn negative as startups were in the news about declining stock prices, launch failures and delays, dwindling cash reserves, and slowly increasing launch cadences. More opposing view have started to be published. For example, U.S. national security space organizations released a report "State of the Space Industrial Base 2021", which noted that there is too much emphasis and investment in launch.[11]

During the last 2 years, small launch industry has seen some high-profile retirements, such as Astra's Rocket 3 and Relativity Space's Terran 1. Launcher (company), after acquired by Vast, cancelled the launch vehicle and focused on space tugs. A few others such as SmallSpark have done the same.

There were also bankruptcies such as Virgin Orbit and SpaceRyde. Before that, Virgin Orbit's first launch from the UK failed in early 2023. They paused operations in March 2023.[12] Late March, most employees were laid off as new investors were not found.[13] Around May, Virgin Orbit sold its assets and equipment to Rocket Lab, Stratolaunch, and Vast's Launcher in a bankruptcy auction.[14]

Stock valuations have dropped significantly. Astra's SPAC valuation was about $2.1 billion but is now only about $41 million as of September 19th 2023.[15] Rocket Lab's valuation is about $2.2B, down from $4.1B.[16] Virgin Orbit's stock price also had a general downward trend until bankruptcy.

Delays for maiden launches continue to be common, often measured in years. First launches from ABL and Relativity were in 2023, after about 3 years of delays, but both were unsuccessful. Multiple European launch companies were supposed to have maiden launches in 2022-2023 but are now delayed to 2024 or later. It is possible that no further first launches will be performed in 2023. Many still are publicly stated for 2023 but delays are likely.

In March 2023, Astra said Rocket 4 first flight was scheduled for late 2023. Rocket 4 has a payload capacity of up to 600 kilograms to mid-inclination orbits.[17] However, in August, a quarter of the workforce were laid off and 50 of the remaining were reassigned to satellite propulsion development due to low cash reserves.[18]

Among new, Stoke Space is developing a fully reusable rocket with 24-hour turnaround. It has a capacity of 1650 kg to LEO,[19] thus likely <1500 kg to SSO. At the last moment, now it is 5000 kg.[20] Performed 2nd stage hop tests in Sept 2023.[19,21]

Rocket Lab's helicopter reuse plans have been cancelled in favour of a splashdown in the ocean. A pre-flown Rutherford engine was reused in August 2023, which previously launched in May 2022, and was temporarily caught with a helicopter.[22] Rocket Lab has performed 41 Electron launches as of September 2023, up from 21 in Oct 2021, including one recent failure and one suborbital mission.[22,23]

Launch rates for some organisations have steadily increased. Rocket Lab has reached 41st launch. China's Galactic Energy conducted its first Ceres-1 sea launch from a mobile sea platform in September 2023, a ninth successful launch.[24]

Larger rocket development is continuing. The market is larger but most upcoming vehicles such as Neutron and Terran R are not considerably cheaper than Falcon 9 and still 2-3 years away. SpaceX has already performed a Starship maiden flight in April 2023 and the next should happen this year.

Importance of reusability is further becoming self-evident but many well-funded small launchers have yet to announce new plans. Peter Beck said in November 2021 that "I think anybody who's not developing a reusable launch vehicle at this point in time is developing a dead-end product because it's just so obvious that this is a fundamental approach that has to be baked in from day one."[25]

Hypersonics is one new alternative revenue source for many. Rocket Lab has flown one suborbital HASTE mission and 4 more booked.

SpaceX added a 50 kg rideshare option for $275k[26] and started to offer mid-inclination rideshare launches,[27] further cutting out brokers.

Among the largest funds raised since October 2021, Expace raised $237M Series B in June 2022,[28] Galactic Energy raised $200M in the second half of 2021,[29] Isar raised $165M in 2023[30] and Stoke raised $100M series B in Oct 2023.[31]

Nevertheless, Rocket Lab has shown that small launch has a market. However, Rocket Lab's launch rates are driven by market demand, not rocket readiness.[32,33] Thus, more customers would result in more launches. Launch market elasticity is difficult to prove, but currently the gap between the $1M SpaceX 200 kg rideshare and approx $7.5M Electron dedicated launch is large for most space startups.

Question arose, with all the bankruptcies, cancellations and pivots, who will be left to offer more affordable and reliable small satellite launches?

3. MARKET SURVEY

This section describes the survey criteria, which has resulted in the 203 entries, and provides explanation about some of the classifications used to categorize and compare the small launch vehicles.

3.1 Survey Criteria

- **Small launcher** - up to 1500 kg to 700 km Sun-Synchronous Orbit (SSO). In literature, micro-launchers have been defined as <500 kg and small launchers as 501 kg - 2000 kg.[34–36] NASA has also used <2000 kg for the small launch vehicle class.[37]
- **Commercial and civilian** - It is preferred that rockets must be or are planned to be available in the commercial market or they have launched such missions. This criteria excludes e.g. small launchers from Israel (Shavit), Iran (Safir) and North Korea (Unha).
- **Performance to SSO orbit** - Different entities publish varying payload performance values for the rockets. In this case, payload to 500 km SSO is preferred. Thus, some values might look smaller when compared to other sources. When matching official values have not been found, then no effort has been made to re-calculate payload masses. In other words, performances are not strictly comparable, because the orbits can be different.
- **Orbital class** - Must be capable of putting a payload into orbit. Suborbital launch vehicles have not been included in this survey.
- **First launches after 1990** - This limit exists to include commercial Pegasus and Athena launchers, while excluding early and often non-commercial rocket families such as Scout (USA), Thor-Delta (USA), Diamant (France), Long March 1 (China), M or Mu (Japan), Kosmos-3M (Russia) and others.
- **Single entry per organisation preferred** - Many organisations are developing multiple launchers as presented on their websites. In most cases, only the first-to-fly or the most prominent launch vehicle has been included. Next ones are added when the initial vehicle becomes operational or is retired or cancelled. This avoids multiple conceptual rockets from the same entity in case all of them have a low probability of performing an orbital flight.

3.2 Status Classification

One of the following statuses has been assigned to each small launcher, based on available public information, and in some cases by the lack of it.

- **Retired** - Launchers that were operational, but have since been officially discontinued, or no further launches have been announced, or many years have passed since last news.
- **Operational** - Launches to orbit have been performed (successfully or not) and the next launches will likely have useful payloads and high likelihood of achieving orbital velocity.
- **Development** - Suitable indicators are two or more from: the company and project is visibly active, the year for the first launch has been announced, relevant updates on social media channels and in the news, team size is increasing, private funding has been announced and/or governmental projects awarded.
- **Concept** - Alternatively, idea or study stage. Possible indicators are: study project and not yet approved for hardware development, lack of proof about sustained technical development, active development is unlikely based on funding level, types of updates on social media and via news media, team very small and not increasing and have alternative jobs based on LinkedIn. In other words, creating a website with some renders and specifications (in the best case) does not equal a new launcher in development. This status may be the most debatable, but it still leaves a possibility that active development will start in the future.
- **Dormant** - The first step towards Cancelled. Possible indicators are offline website, lack of recent (1+ year) posts on social media channels, very small team or a single person according to LinkedIn, no announced funding. Some could be in stealth mode and will know in the future. For example, Astra developed in stealth, but they still had 50+ persons on LinkedIn, and plethora of activity and rumours in the space industry.[38]
- **Cancelled** - Indicates a small launcher, which project has been announced to have been stopped, or which website has been offline for years, or no indication of the launcher on the organization website anymore when it used to be there before, or company officially bankrupt and closed.

4. SURVEY RESULTS

Figure 1 lists 119 of 203 surveyed small launchers, leaving out the ones designated with Cancelled, Dormant and Concept statuses for readability. Full list and all figures will be online on NewSpace Index.[39]

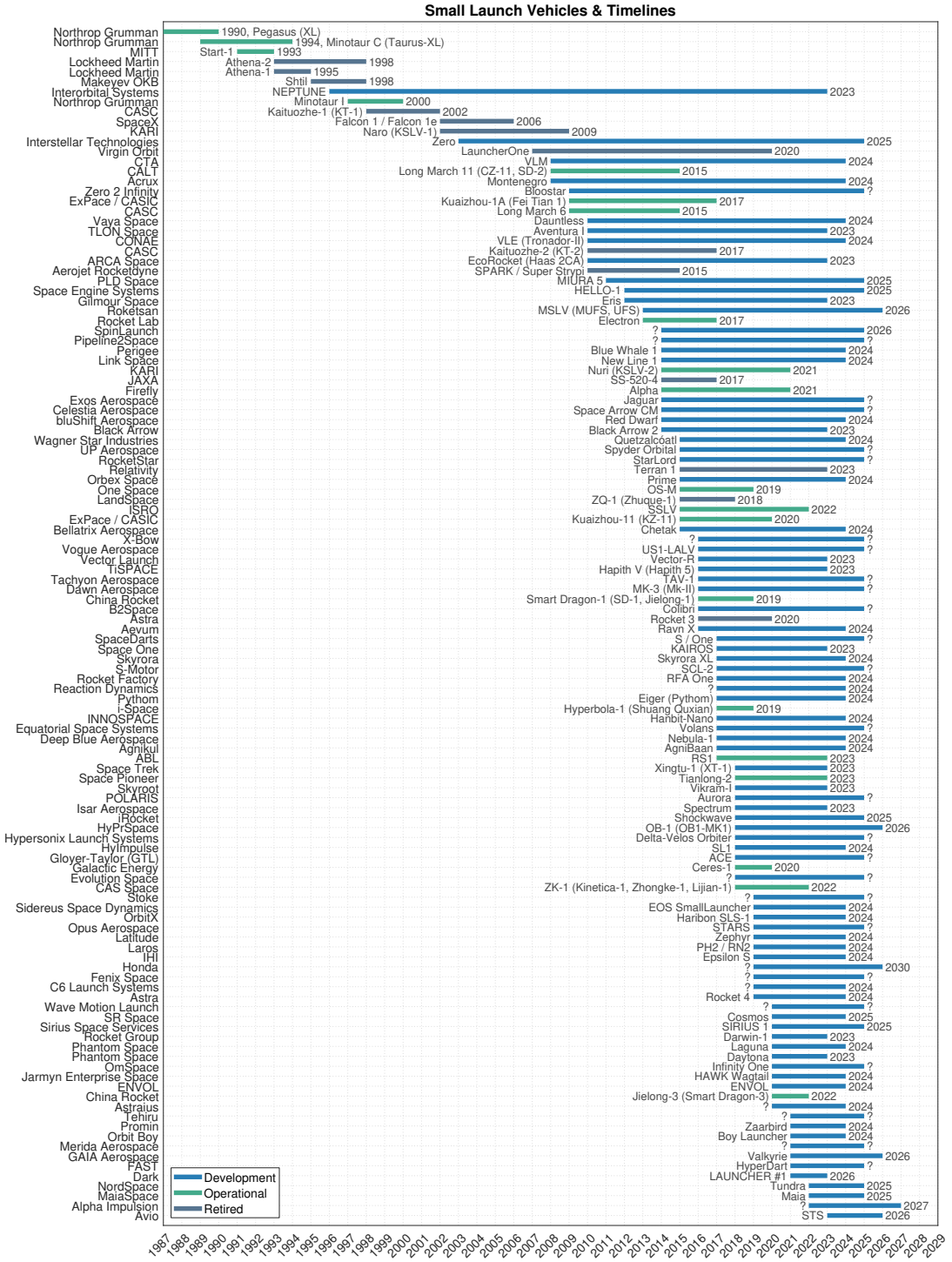

Figure 1: Small Launcher Timelines

5. STATISTICAL OVERVIEW

This section presents the statistical overview of the 203 entries included in this 2023 small launchers survey. There were 180 entries in 2021.[1]

5.1 Development Status

Figure 2 depicts the current status of 203 small launch vehicles. 23 entries have been added during the last 2 years. Some additions are second launch vehicles from same organisations, some of the entries were already dormant or cancelled, and the rest are newly discovered or founded startups.

13 small launchers have been retired. This has increased from 9 with notable additions of Astra's Rocket 3, Virgin Orbit's LauncherOne and Relativity's Terran-1. Retired means that at least one orbital flight was attempted before cancellation. Status of One Space is unclear after the first launch of OS-M failed in 2019, but the company seems active in developing launch support equipment.

20 are operational, including Electron, Long March 6, Hyperbola-1 and Ceres-1. Notable additions are ABL's RS1, Nuri, ZK-1, Jielong-3, SSLV, Tianlong-2. RS1 had a first partially successful flight in 2023. Many of them had a last mission over a year ago and possibly have rare or no future launches.

88 are in the development phase (down from 99) and over half have announced maiden flight year.

19 are in the concept phase and 43 are in dormant stage. Both counts in those categories have increased considerably during the last 2 years, and they are likely even higher, which time will reveal.

20 have been cancelled during development without performing an orbital flight. This has increased from 9 and additions include SmallSpark, Launcher (Vast), SpaceRyde and Pangea Aerospace. The first two are focusing on space tugs. SpaceRyde went bankrupt and Pangea focused on producing engines.

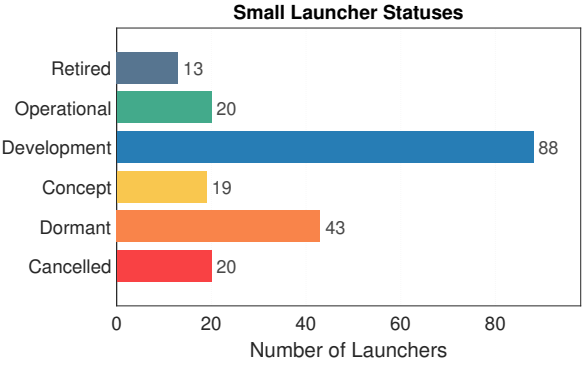

Figure 2: Current Status of Small Launchers

5.2 Performances

As seen on Figure 3, most launchers are aiming to offer payloads to orbit in the 50-150 kg and 150-300 kg ranges. Most of the collected specifications are for 500 km SSO orbits when data is available.

Rocket Lab's Electron is set at 200 kg.[40] Astra's Rocket 3 was at 150 kg[15] and Rocket 4 is 500 kg, but initial missions will have de-rated engines achieving about 350 kg.[41] Virgin Orbit's LauncherOne is set at 300 kg.[42] Firefly Alpha is set at 630 kg.[43] Relativity's Terran-1 is at 900 kg.[44] Isar's Spectrum is 700 kg[45] and ABL's RS1 is 1000 kg to SSO.[46]

Stoke Space has a capacity of 1650 kg to LEO in fully reusable mode,[19] which should be less than 1500 kg to SSO, and thus still in scope.

There are approximately 3 dozen single-CubeSat launchers for masses less than 50 kg to SSO orbit, but none are yet operational and JAXA's SS-520-4 has likely been retired.

Payloads can be volume limited due to fairing size. Based on retirements and cancellations, there is a trend towards larger launch vehicles.

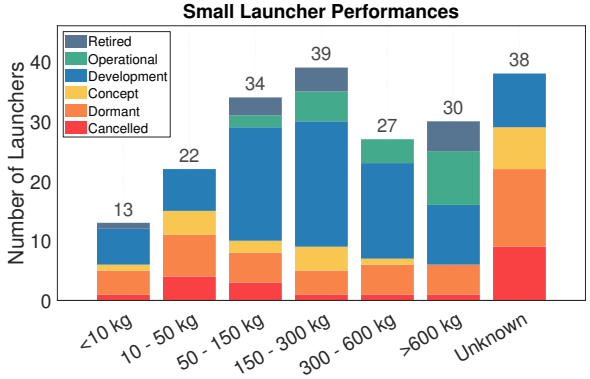

Figure 3: Payload Capacity of Small Launchers

5.3 Absolute Prices

Figure 4 shows the absolute prices for dedicated launches. Mission costs for over a half of the small rockets have not been publicly revealed.

None of the very low cost launchers are operational yet, which matches Figure 3, as most of those are planned to be for dedicated CubeSat missions.

Rocket Lab's Electron is about $7.5M[47] and P. Lionnet has noted a general increase trend.[48] Astra's Rocket 3 was about $2.5M,[49] but in the Investor Presentation from Feb 2021, $3.75M has been used for 2025 launch revenue estimation.[50] Virgin's LauncherOne was often stated to be $12M.[51] Rocket Factory (RFA) is aiming for $3.6M.[52] Firefly Alpha

is $12M.[43] Relativity's Terran-1 is $12M.[44] ABL's RS1 was $12M.[46] SpinLaunch is aiming for $0.5M.[53]

There have been only a few changes in pricing in the last 2 years. More details in section 5.5 and Figure 7.

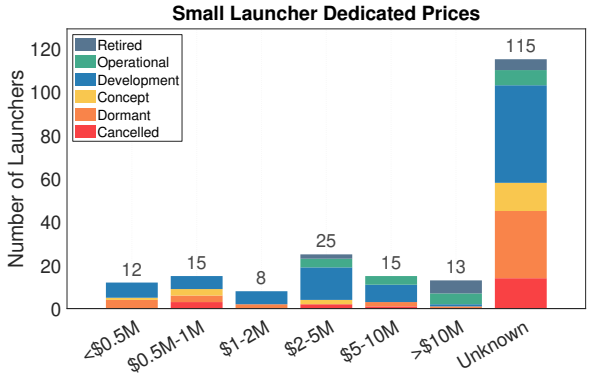

Figure 4: Dedicated Costs of Small Launchers

5.4 Prices per Kilogram

Figure 5 illustrates the dedicated launch prices per kilogram by different ranges. There are only about 10% out of all small launch vehicles, which are aiming for less than $10,000 per kilogram prices. That would be comparable to rideshare missions, but most will have noticeably higher prices.

In the 5000-10000 $/kg range, ISRO's SSLV is operational and approximately $8400 per kilogram.

For comparison, SpaceX Smallsat Rideshare Program is offering $1M for 200 kg to SSO. Payloads with mass less than 200 kg still have to pay the full amount when bought directly.[26] A new service is now $275k for 50 kg to SSO, with additional mass at $5.5k/kg when paying per additional kilograms.[26] However, that price is increasing annually by $500 per kilogram.[27] These do not account for the adapters and deployers.

More information in section 5.6 and Figure 6.

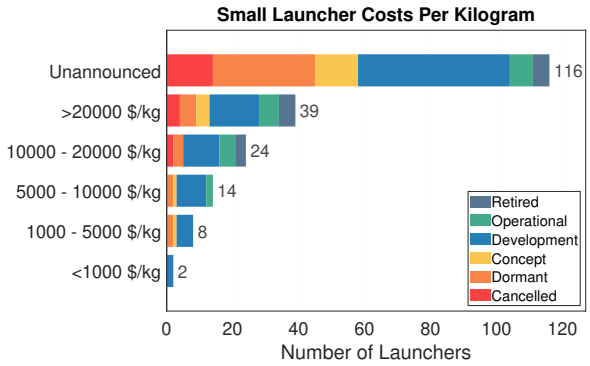

Figure 5: Kilogram Prices of Small Launchers

5.5 Absolute Costs vs Performance

Figure 6 plots the absolute prices of the rockets in relation to payload capabilities in kilograms. As seen from the chart, Pegasus is relatively expensive at about $56 million for dedicated launches and the upcoming Epsilon S stands out too at $25-30 million per mission.[54]

Among the operational launchers, SSLV is about $4.2-4.4 million for 500 kg,[55,56] Ceres-1 is $4M for 300 kg[57] and Hyperbola-1 is $5M for 300 kg.[58]

SSLV could be competitive with Electron by having a lower price and higher performance. ISRO announced in July 2023 that they are transferring the SSLV technology to the private sector and 23 companies expressed interest.[59] Future will show what will be the commercial mission price and demand.

At any payload capacity and operational status, Astra Rocket 3 was among the lowest cost for dedicated missions with the stated launch costs between $2.5 - 3.75 million for Rocket 3.[49,50]

Among the upcoming launchers, Rocket Factory Augsburg (RFA) has one of the lowest costs at $3.6 million per launch, while still being capable of launching over 1 ton spacecraft. Some others have even lower prices, but their prospects are unclear.

Interesting to note that SpaceX's Falcon 1 cost less, when not taking inflation into account, and planned to have more payload capability, than Relativity's Terran-1, Firefly's Alpha, Virgin Orbit's LauncherOne and ABL's RS1.

Lockheed Martin's Athena-1 was also similar in cost and payload capability when compared to the many well-funded upcoming launch vehicles. Perhaps they should have reintroduced it as was planned around 2010.[60]

There are numerous lesser-known and lesser-funded startups offering even lower dedicated launch costs, but they continue to have much work to do to make it to the launch pad and to attempt orbital launches.

Currently, there is a large gap between the $1 million for 200 kg of SpaceX rideshare and the $7.5 million for a dedicated Electron, which is a significant amount for most commercial space startups. Thus, a launcher with $1-3 million price tag should be able to find more customers, who would have otherwise chosen rideshare. However, elasticity of small satellite launch market is a complicated subject with limited data available.

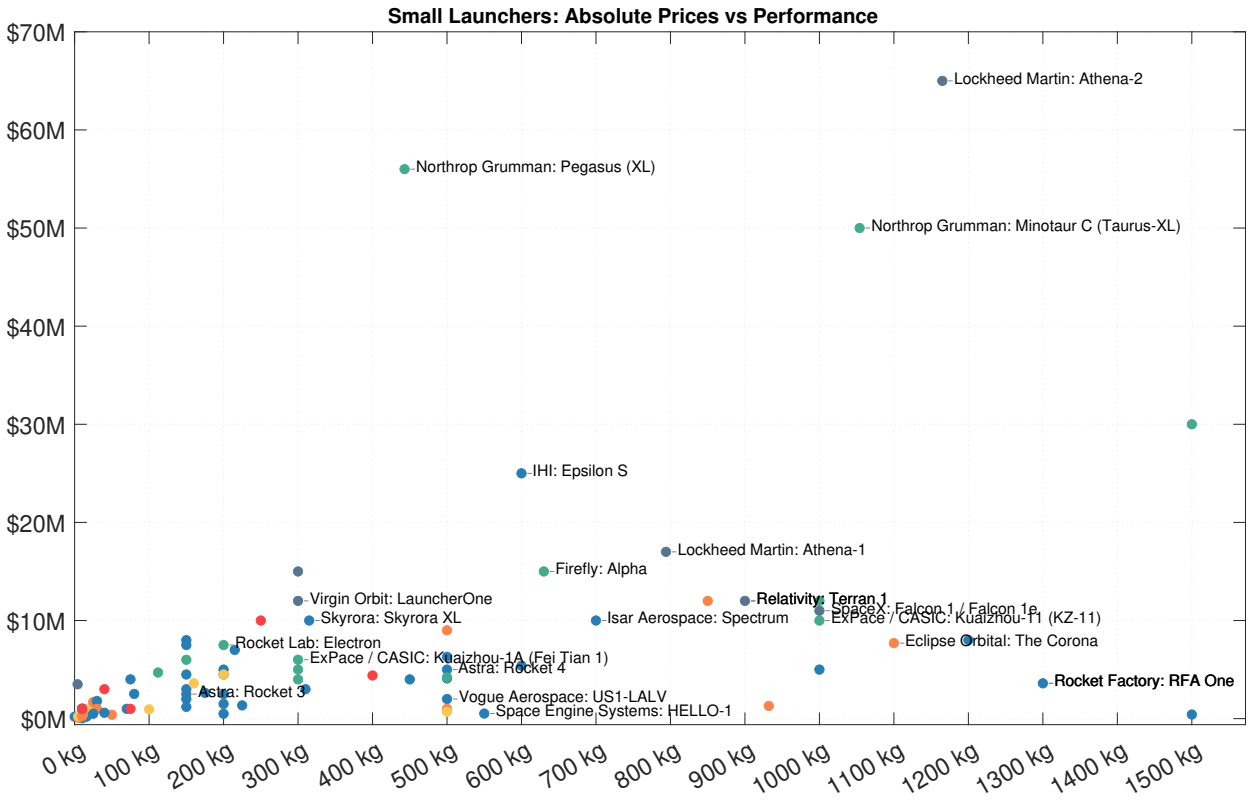

Figure 6: Absolute Costs per Kilogram vs Performance of Small Launchers

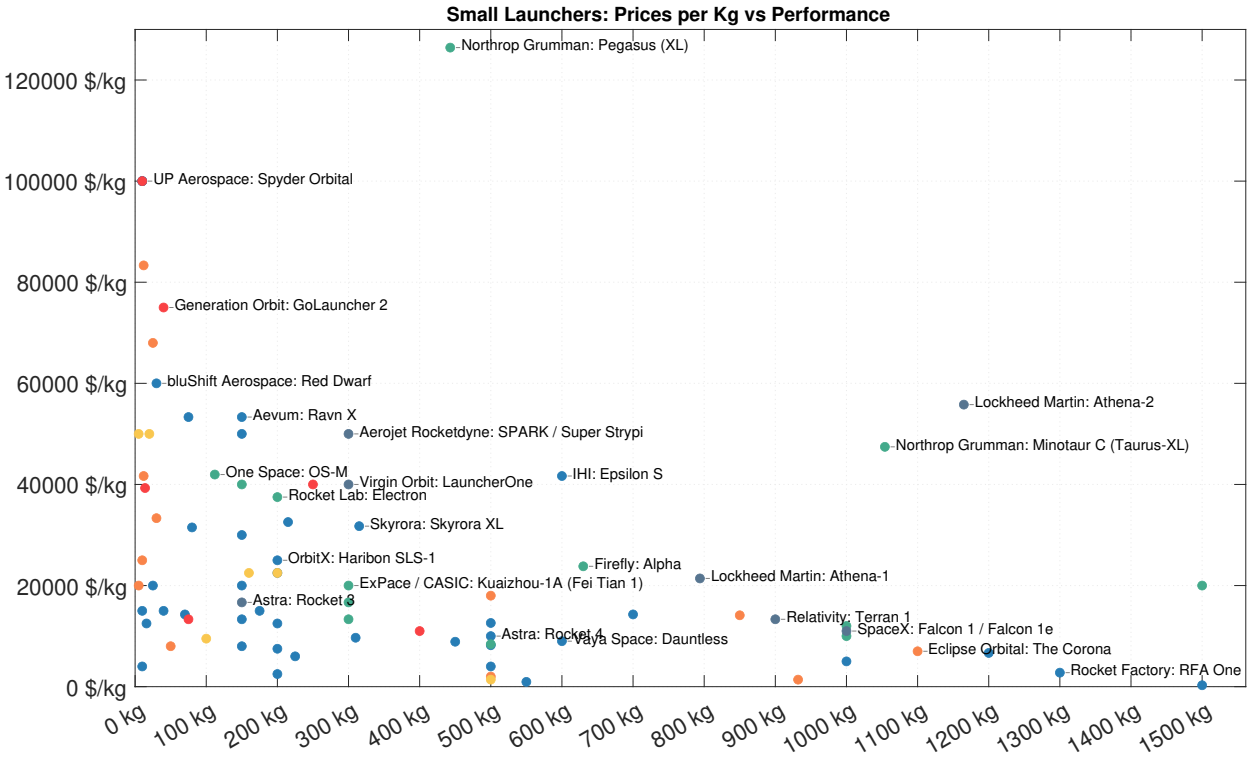

Figure 7: Costs per Kilogram vs Performance of Small Launchers

5.6 Costs per Kilogram vs Performance

Figure 7 plots the kilogram costs of launchers in relation to payload capabilities in kilograms. Some values may seem higher, because payloads to SSO orbits are preferred where available.

Dollars per kilogram is not the single best way to estimate launch prices, because of additional adapters and there can be volume limitations, it is still a good starting point for comparing launch options.[61]

Japanese SS-520-4 is very expensive at approximately $875,000/kg. Pegasus also stands out with high launch costs of about $126,000/kg.

Among the retired launchers, without accounting for inflation, Lockheed Martin's Athena-1 was $21,400/kg, SpaceX's Falcon 1e was $11,000/kg, Astra's Rocket 3 was $16,700/kg; LauncherOne was $40,000/kg and Terran-1 was $13,300/kg.

Among the well-known or operational launchers, Electron is at $37,500/kg; Firefly's Alpha is $23,800/kg, ABL's RS1 is $12,000/kg; Galactic Energy's Ceres-1 is $11,400/kg; iSpace's Hyperbola-1 is $16,700/kg; One Space OS-M is $42,000/kg; and Rocket Factory's RFA One is a low $3,000/kg.

Astra's Rocket 4 will be about $10,000/kg to SSO or $8,300/kg to LEO.

However, P. Lionnet has written in August 2023 that the average mass launched by Electron is about 90 kg, and not increasing, thus the average price is instead approximately $70,000/kg.[48]

Other lower cost per kg are Space Engine Systems HELLO-1 at $950/kg; United Frontiers Discovery-2 at $2,000/kg; SpaceDarts S/One at $3,000/kg; Vogue Aerospace's US1-LALV at $4,000/kg; SpinLaunch at $5,000/kg and Vector Launch's Vector-R at $7,000/kg.

5.7 Launch Types

Launch methods or types have been categorized on Figure 8. Launching from land is the most popular choice followed by a plane and a balloon.

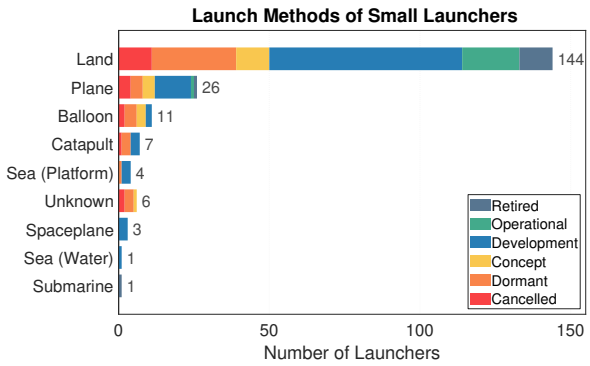

Figure 8: Launch Types of Small Launchers

For air launched or horizontal launchers, it is unknown when the next such flight may happen because Pegasus has not flown since 2021 and LauncherOne went bankrupt in the first half of 2023.

None of the balloon and catapult projects have made an orbital launch demonstration attempt. SpaceRyde went bankrupt in early 2023.[62]

Virgin Orbit's first launch from the UK failed in January 2023.[63] Ana Holdings (All Nippon Airways) announced a MoU with Virgin Orbit in Nov 2021 to procure twenty flights of LauncherOne and launch them from Japan as soon as 2022.[64]

Galactic Energy's Ceres-1 conducted its first sea launch from a mobile sea platform in September 2023, which was also the ninth successive launch.[24] The Figure 8 only supports one launch method per launcher at the moment, thus it is not shown on the graph.

SpinLaunch is the best known catapult project and has raised over $150 million.[65,66] Second stage would still have to be a rocket to circularize orbit. There is some scepticism towards satellites being able to survive the g-forces, but it could also be used to send up bulk mass like water, propellant and other raw materials.[67] However, their publicized $0.5M and 100 kg per launch comes to $5000/kg, which is comparable to SpaceX's Falcon 9. Longshot Space's systems catapult is very horizontal and aiming for as low as $10 per kilogram to orbit.[68]

Spaceplanes intend to fly much higher and faster than conventional aircraft or can be Single-Stage-To-Orbit (SSTO), which take off from a runway. All are in early stages, e.g. POLARIS from Germany.[69] Dawn Aerospace is flying the suborbital Mk-II and is hoping to start finalizing the design for the orbital-class two-stage Mk-III by the end of 2024.[70]

With propellant costs being relatively low, land launches seem to be more practical even if rockets are larger for the same performance, due to easier propellant loading, ease-of-access, last minute issue debugging and easier scalability.

5.8 First Launches

Figure 9 shows the first orbital launch attempts by years as they happened or the upcoming by the latest public announcements.

Numerous dormant and cancelled small launchers had initially announced their first missions for 2020-2024. These entries have been removed from this chart because the launches did not happen in reality. When orbital launches were attempted, then the status would be operational or retired.

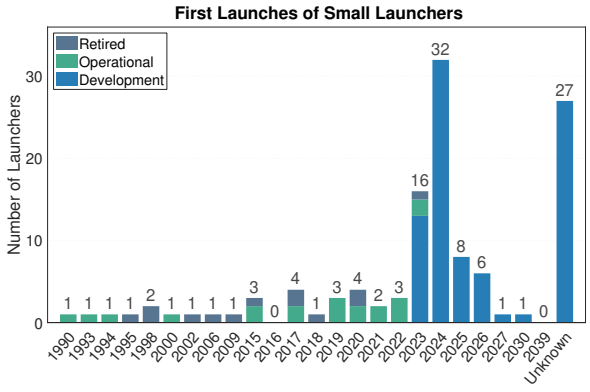

Figure 9: First Launch Years of Small Launchers

In the 2021 figure, maiden flights for 14 launchers were scheduled for 2021, 28 for 2022, 17 for 2023 and 12 for 2024. At the time, for example, Gilmour Space was aiming to launch in 2022; Relativity in 2022; Skyrora in 2022; Isar Aerospace in 2022; Rocket Factory in 2022 and HyImpulse in 2023.

When looking back to what happened, then in the year 2021, only 2 small launchers made first orbital launch attempts and they were Firefly's Alpha[71] and KARI's Nuri (KSLV-2). In 2022, first orbital launch attempts were by ZK-1 (Kinetica-1, Zhongke-1, Lijian-1) from CAS Space, Jielong-3 (Smart Dragon-3) from China Rocket and SSLV from ISRO.

In 2023, first orbital launch attempts have been made by Tianlong-2 from Space Pioneer (Beijing Tianbing Technology), RS1 from ABL Space Systems and Terran 1 from Relativity Space.

As of September 2023, maiden flights for 14 more small launchers are scheduled for 2023 but it is possible that none of them will happen this year. They include Gilmour Space's Eris, Isar Aerospace's Spectrum, Phantom Space's Daytona, Skyroot's Vikram-I, Space One's KAIROS and TiSPACE's Hapith V.

There are 34 maiden flights scheduled for 2024 but most of them are also unlikely to happen. They include Astra's Rocket 4, Agnikul Cosmos's Agni-Baan, HyImpulse's SL1, INNOSPACE's Hanbit-Nano, IHI Aerospace's Epsilon S, Latitude's (Venture Orbital Systems) Zephyr, Rocket Factory Augsburg's RFA One, Sidereus's EOS SmallLauncher, Skyrora's Skyrora XL and Vaya Space's Dauntless.

Nine maiden flights are currently scheduled for 2025, for example MaiaSpace's Maia, Interstellar's Zero, PLD Space's MIURA 5 and Sirius Space Services's SIRIUS 1.

27 small launchers have not announced first maiden launches and that includes for example Stoke Space, Tehiru Space and Dawn Aerospace. The previous lists are non-exhaustive.

5.9 Founded

Founding years of small launcher organizations have been collected on Figure 10. The establishment year does not match the start of the launcher projects for older organizations, but it usually does correlate for new startups in the last two decades.

SpaceX was founded in 2002 and Rocket Lab in 2006. Virgin Orbit, then part of Virgin Galactic, announced LauncherOne in 2009, but development work had started in 2007.[72]

Gilmour Space was founded in 2012. Firefly in 2014. LandSpace in 2015. Relativity Space in 2015. Astra was founded in 2016,[50] but has history in Ventions.[73] ABL was founded in 2017. Skyrora in 2017. Isar Aerospace, Rocket Factory Augsburg (RFA) and HyImpulse were founded in 2018. Stoke Space was founded in 2019.

2021 saw the founding of for example Promin Aerospace, GAIA Aerospace, FAST Aerospace, Lesath, Merida Aerospace and Tehiru Space.

In 2022, for example MaiaSpace owned by ArianeGroup and NordSpace were founded.

The founding of new small lift launch vehicle companies peaked around 2016-2018, but has not yet collapsed. The amount for 2021-2023 will likely increase in the future as projects are made public and authors become aware of them. The peak years of 2016-2018 also have the largest amount of already dormant companies, which means they were founded during a broader boom, but most of them were never able to build a team, raise starting capital, or progress into hardware development.

For market context, the amount of CubeSats started to grow quickly from 2013.[74] Planet and Spire also launched their first CubeSats in 2013 and their first larger batches followed in 2014.[75] Starlink and OneWeb were publicly announced in 2015, but there were already many news throughout 2014.

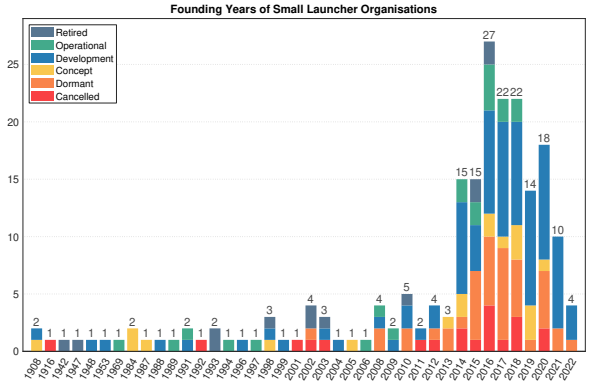

Figure 10: Small Launchers by Organisations Founding Years

5.10 Development Times

Small launcher development times in years is presented on Figure 12. The starting point is the founding year of the organization or an announced start of the project. End point is the first orbital launch attempt or the currently announced future goal, independent of the launcher making it to orbit.

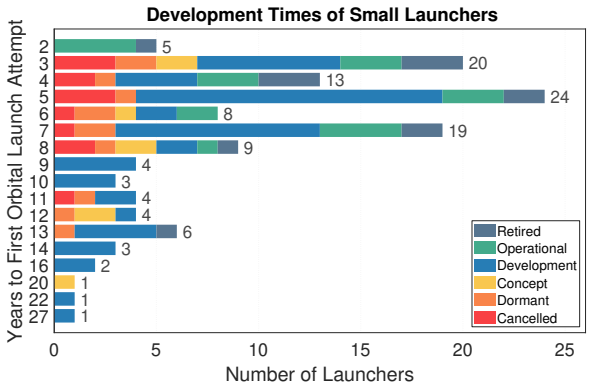

Figure 11: Small Launchers Development Periods

The chart shows that it is possible to develop an orbital-class rocket in 3-5 years and many have achieved it. For example, Pegasus was developed in about 3 years. Lockheed Martin's Athena took about 5 years. SpaceX's Falcon 1 took 4 years until the first launch attempt and 6 years until the fourth successful launch. Astra took 4 years, but Ventions heritage likely helped. Firefly's Alpha took 7 years, but that included a bankruptcy period.

Chinese rocket startups have been relatively quick. iSpace was very fast with only 2 years required, while LandSpace needed 3 years. Most other Chinese rockets are also in the 2-4 year development timeline range, e.g. Jielong-3 (Smart Dragon-3), ZK-1 (Kinetica-1, Zhongke-1, Lijian-1), Ceres-1, OS-M and Smart Dragon-1 (SD-1, Jielong-1).

There were 11 years between the founding of Rocket Lab in 2006 and the first flight of Electron in 2017 but the development of Electron started in about 2013, thus 4 years is a better value.[9]

At the same time, some small launchers have also needed 10 and more years for development. Virgin Orbit's LauncherOne took 13 years since the start of the project until the first orbital mission attempt.

Terran 1 was about 8 years from the founding of Relativity Space in 2015 to an orbital launch attempt in early 2023. Now with the cancellation of Terran 1, it will be at least 11 years from the founding until the debut of Terran R in 2026.

RS1 took approximately 6-7 years from the founding of ABL in 2017 and orbital launch attempt.

5.11 Development Delays

Development delays in years are on Figure 12. Originally announced launch years have been compared with the latest announcements or performed launches. Negative number means the launch dates have been brought forward, but it remains to be seen whether that stays true. A 2-3 years of delay is common. Even 4 years may become common by the next survey. Small rockets from China have a better track record. Large amount of launchers are unknown, because the flight date goals have not been announced or not updated when the previous date(s) passed.

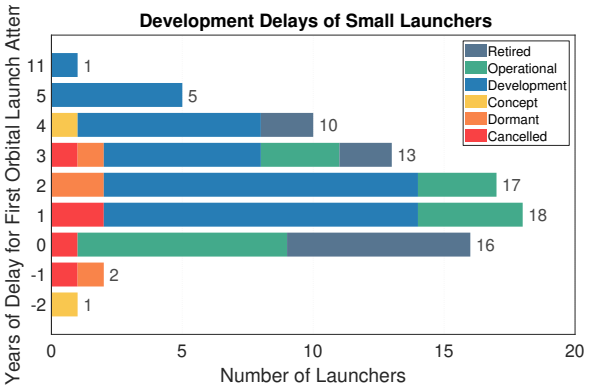

Figure 12: Small Launchers Development Delays

Virgin Orbit originally aimed to perform first launch in 2016-2017.[76,77] Electron and Alpha had about 2 years of delays. Falcon 1 required extra 2 years and 4 flights to make it to orbit. Some more examples are:

- In February 2019, ABL's RS1 was on scheduled to have first launch in the third quarter of 2020.[78]
- In May 2019, Relativity's Terran 1 maiden flight was scheduled for very end of 2020.[79]
- In 2017, ISRO was developing a launch vehicle exclusively for small satellites that was slated to launch in early 2019.[80]
- ZK-1 (Kinetica-1, Zhongke-1, Lijian-1) and Jielong-3 (Smart Dragon-3) had about 1 year of delays for the first launch.
- In 2011, Interorbital Systems's Neptune orbital flights were planned for 2012.[81]
- In October 2020 and earlier, Isar Aerospace was planning maiden launch in 2021.[82,83]
- In November 2020, Phantom Space was hoping to have a first launch in about 2 years.[84]
- In August 2020, Skyroot Aerospace was on track for a first launch in December 2021.[85]

- In June 2021, Astra Rocket 4 was planning to debut in 2022 but since it has grown in size.[86]
- In August 2020, HyImpulse was planning small launcher debut in late 2022.[87]
- In 2021 October, Skyrora's first missions were planned to start in 2022.[88]
- In April 2020, RFA (Rocket Factory Augsburg) first flight was scheduled for late 2021.[89]
- In 2018, Interstellar Technologies was planning to conduct first flight test of Zero in 2020. It is currently scheduled for 2025 after increasing the payload due to little customer demand.[90–92]
- Epsilon S was scheduled to launch in 2023 as announced in 2021, which was delayed to 2024, but that is at risk due to the second stage explosion during a test in July 2023.[54,93]

5.12 Launch Frequency

Planned launch frequencies or launch cadences have been collected on Figure 13. While many small launchers have recently become operational, none have achieved the planned flight rates and can be far from them. Depending on the launcher, this is due to a mix of rocket readiness, in terms of scaling up the manufacturing and launch rates, but also due to customer readiness.

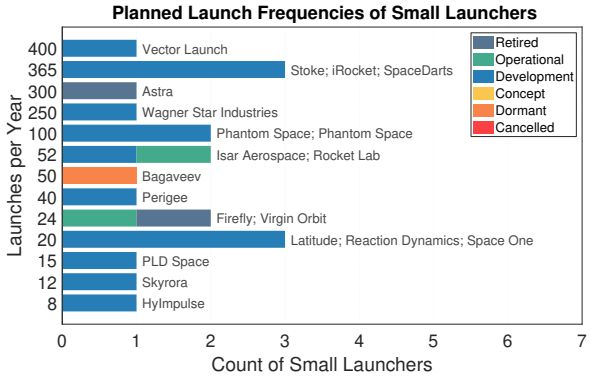

Figure 13: Small Launchers Planned Frequencies

In 2014, Rocket Lab was planning weekly launches.[94] In March 2019, Electron's launches were planned to be every 2 weeks by the end of the year.[95] In June 2020, monthly Electron launches were planned.[96] In reality, Electron launched 6 times in 2019 and 7 times in 2020 with 9 estimated for 2021 before the pandemic and launch failure.[97] Rocket Lab ended up launching 6 times in 2021, 9 times in 2022 and 10 launches until September 2023 including the sub-orbital mission and the recent failure.[98]

As of 2022, Rocket Lab launch rates are driven by customer readiness, which could be compared to market demand, not launcher readiness.[32,33]

In 2021, Astra was aiming to perform 300 flights per year by 2025.[50] Even for Rocket 4, Astra is planning a production line that can complete one rocket per day.[99]

Ceres-1 performed the maiden launch in November 2020, second in December 2021, two in 2022 and six in 2023 as of September 2023. The last one, which was the tenth overall, had a failure.[100,101]

In 2021, Firefly's long-term goal was 2 launches per month.[43] The first failed launch happened in September 2021, second partially failed launch (lower orbit) was in October 2022 and third successful launch was in September 2023 with more scheduled for 2023.[102]

In late 2017, Virgin Orbit was expecting to fly twice per month in 2020[103] and in 2021 they were aiming for 2 launches per month.[104]

In 2021, ABL was projecting 8 launches in 2022 and 16 in 2023.[105] After the first failed orbital launch in January 2023, ABL has yet to try again.[106]

In 2021, Space One aimed for a launch frequency of 20 KAIROS launches per year by the mid-2020's.[107]

In March 2023, Isar was planning first flight later in 2023 and up to 4 launches in 2024, with a capacity in its current factory to produce up to eight rockets a year and plans for a second factory that would be able to produce up to one rocket a week.[30]

HyImpulse hoped to reach 8 launches in 2024 but that was in 2020, when the first launch was planned for late 2022.[87]

In August 2023, Skyrora said that in a few years they hope to launch a rocket every month.[108]

Stoke Space is developing a fully reusable launcher with a 24-hour turnaround designed to fly daily.[21,109]

Number of startups from the US are participating in the responsive space access programs to launch on a very short notice, and some small launchers have heritage and history from participating in similar development programs about 10 years ago.

In September 2022, U.S. Space Systems Command announced it selected Firefly and Millennium Space Systems to demonstrate rapid-response space mission to LEO in 2023.[110] The Victus Nox mission launched in September 202 and the liftoff took place at the first available launch window, 27 hours after receipt of launch orders.[111] Firefly's contract for the mission was worth $17.6 million.[112]

In September 2023, ABL also got a $15M contract for a responsive short notice launch mission to take place in the next 2 years.[113]

5.13 Funding

Funding amounts for small launcher organizations have been grouped on Figure 14. For commercial organizations that have two or more entries, only one of the entries has the complete funding amount to avoid duplication.

SpaceX, Rocket Lab and Relativity have raised over $1 billion by now, but it took much less than that to develop Falcon 1 and Electron for example.

Many launcher projects inside larger organizations must have received large amounts of funding too, but those values have not been made public.

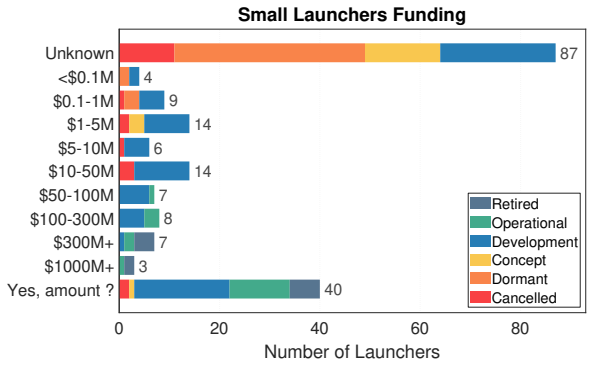

Figure 14: Small Launchers Funding Amounts

Between October 2021 and September 2023, most of the collected funding rounds are:

- Expace raised $237M Series B in June 2022.[28]
- Galactic Energy raised $200 million in the second half of 2021 as reported in January 2022.[29]
- Isar Aerospace raised $165 million in March 2023 for a total of over $330 million.[30]
- Stoke Space raised $65M series A in Dec 2021 and $100M series B in Oct 2023 for a total of over $175M.[19,31,114]
- ABL raised $60 million in March 2023, half in government funding and half in matching funds from the company's investors, for responsive launch demonstrations.[115]
- Skyroot raised $51 million in September 2022.[116]
- Orbex raised $49M series C in October 2022.[117]
- Deep Blue Aerospace raised $31.5M Series A and undisclosed Series A+ in early 2022.[118]
- Interstellar Technologies raised $30M series D in January 2023 and a $13.5M grant in September for a total of about $55M.[119,120]
- PLD Space closed $28 million Series B in December 2021.[121]
- Innospace raises about $15 million in December 2022 for a total of $42.1 million and is working towards public offering in 2024.[122]
- Vaya Space raised $12 million in January 2023.[123]
- Latitude (Venture Orbital) announced closure of $10.6M series A in July 2022.[124]
- Sidereus raised $5.3M in September 2023 and aims to be the smallest orbital rocket ever.[125]

Among the operational launchers or close to it, almost all have raised over $100 million, some multiple times of that. LandSpace has raised about $370M, One Space about $116M, iSpace is over $270M, Virgin Orbit about $700M, Astra has raised over $670M.[126,127] Space Pioneer has raised over $438M. ABL Space Systems has raised about $480M.

Galactic Energy performed the first orbital launch attempt after having raised about $73M and is currently the lowest known commercial example.

Among the in-development launchers, Gilmour Space has raised about $132M including grants.[128] Orbex has raised about $110M. Skyrora has raised about $45M. SpinLaunch has raised over $80M. PLD Space has raised over $50M.[121] Rocket Factory (RFA) has not published figures, but they are backed by OHB.[129] Vector Launch has raised over $103M, but entered bankruptcy in December 2019. However, operations were restarted at the end of 2020.[130]

Celestia Aerospace announced the raising of about $100 million in March 2022 but LinkedIn still shows only 2 employees as of September 2023.[131]

Virgin Orbit raised $228M in the SPAC merger, less than half of the amount it assumed when the deal was announced in August 2021.[132]

The minimum amount required to develop and launch an orbital class rocket seems to be at least tens of millions of dollars or more likely on the order of $100 million.[133] E. Berger reported in 2020 that "SpaceX spent about $100M on the Falcon 1 rocket from 2022 to May 2026. Peter Beck said Rocket Lab spent nearly $100M getting Electron rocket into space. Astra spent about the same on Rocket 3.0.

E. Berger also reported in 2020 that Virgin Orbit has not revealed how much it has spent to date, but estimation range between $500-$700M developing LauncherOne.[51] Virgin claims ~$1 billion of expenses in investor presentation.[134] That amounts to considerably more for similar capabilities, when compared to contemporary competitors.

Most of the launcher companies still have to keep fundraising to finish development and this separates serious competitors. It is also clear that the new companies after SpaceX have not been able to lower the development costs by much as of yet.

5.14 Launcher Stages

The number of rocket stages is categorized on Figure 15. Where available, the criteria has been the count of stages required to reach a circular polar orbit. 4 stages is typical with solid rockets and most of them are operational in the US and China. Many new launchers have 2 stages, but some require an additional third stage to circularize orbit. There are also four 1-stage SSTO launchers in development.

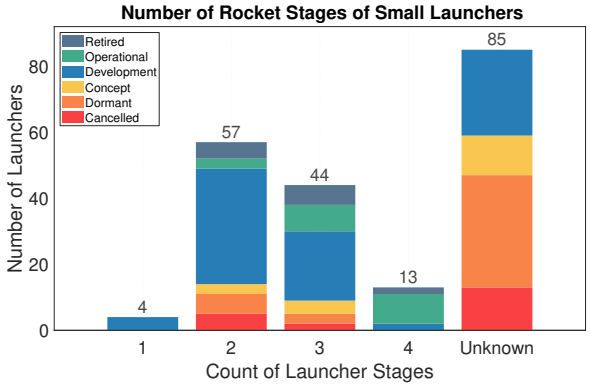

Figure 15: Small Launchers Stages

Some of the 4-stage launch vehicles include Galactic Energy's Ceres-1, iSpace's Hyperbola-1, China Rocket's Smart Dragon-1, CALT's Long March 11, Lockheed's Athena-2 and Northrop Grumman's Minotaur I and Minotaur C.

Rocket Lab is considered here to have 3 rocket stages, because circularizing orbit requires the Kick Stage and most mission have flown with it.

5.15 Propellant Types

Propellant or more accurately fuel types are shown on Figure 16. The criteria is defined by the propellant of the first and the largest stage or for the majority of the launcher stages.

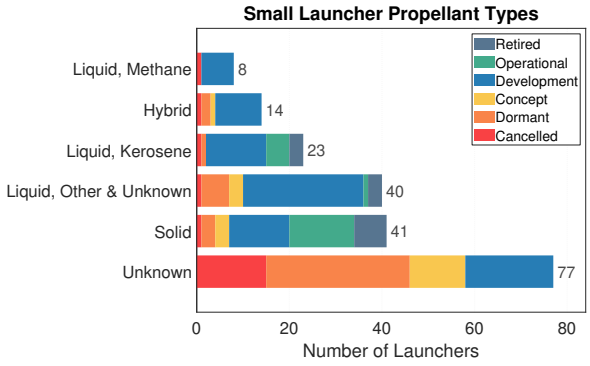

Figure 16: Small Launchers Propellant Types

Solid rockets are very common due to ICBM heritages and this matches with the previous list of 4 stage launchers. For example Galactic Energy's Ceres-1, iSpace's Hyperbola-1, China Rocket's Smart Dragon-1, One Space OS-M, Minotaur I and Minotaur C. Many solid launchers have 3 stages like JAXA's SS-520-4 and ExPace's Kuaizhou-11.

Kerosene and methane are the choice for many modern launchers. Many more small launch vehicles will likely use kerosene or methane, but only generic "liquid" has been announced. Small launch vehicles using kerosene include Falcon 1, Electron, Rocket 3, LauncherOne, Alpha, RS1.

Terran-1 used liquid natural gas (LNG) as propellant, which is mostly methane, but did not make it to orbit in March 2023.[135]

LandSpace's Zhuque-2 became the first methane-powered rocket to reach orbit in July 2023 but it is out of scope for current survey due to about 4000 kg payload to SSO orbit.[136]

Stoke Space fully reusable launch vehicle uses LNG for the first stage and liquid hydrogen (LH2) for the second stage.[137]

Hybrid is a promising technology in theory, but none have been demonstrated recently or yet on orbital-class rockets. Used by for example HyImpulse, Gilmour Space and Innospace.

There does not yet seem to exist a clear advantage between the launch costs and propellant types, and related economics would have to be proven.

5.16 Reusability

Figure 17 depicts the reusability status of small launchers. Partial reusability and full reusability has not been differentiated at this time.

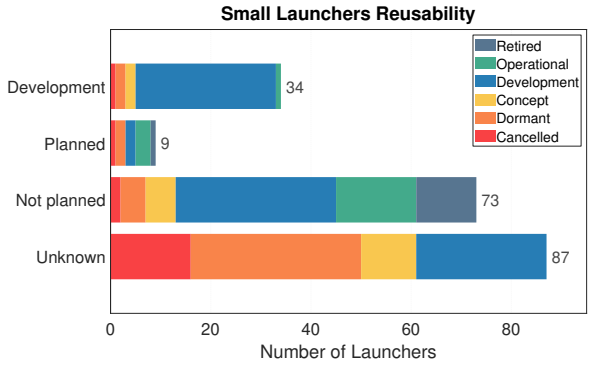

Figure 17: Small Launchers Reusability

Most small launchers are not planned to be reusable. Currently, 34 small launcher have reusability in development, an increase from 22 in 2021. Important to note that a large number of organizations have not announced plans about reusability.

Rocket Lab has been developing Electron's reusability. Mid-air catches by a helicopters were planned

to be the method as described in a 2022 paper by Shane Glynn et al "Reusable Electron: Analysis of progress toward the world's first reusable commercial small rocket."[138] However, the plan seems to have changed by early 2023, after the partially failed catches in May and November 2022,[139] in favour of splashdown and recovery from the ocean.[140,141] A pre-flown Rutherford engine was reused in August 2023, which launched in May 2022, and temporarily caught with a helicopter.[22]

9 organizations have announced plans to develop reusability in the future, which could and likely means new larger launch vehicles.

Stoke Space is developing a fully reusable launcher with a 24-hour turnaround.[19]

Virgin Orbit was evaluating parachute recovery of the first stage and an evolved rocket LauncherTwo, which could have included reusability.[134,142]

As of 2023, Astra is still betting that inexpensive, mass-produced and expendable small rocket can be successful in winning business.[99]

Compared to 2021, in 2023 the economic and competitive importance of re-usability is widely understood, but many small launchers have not announced changes to their approaches, perhaps attempting to get to orbit first.

5.17 Geographical Distribution

Distribution of the small launcher companies by the locations of legal headquarters is on Figure 18.

For companies that have presence in multiple countries, only the first primary location has been shown. Rocket Lab has a very large presence in New Zealand including the launch site, but the legal headquarters is in the United States.

Launch sites can be based elsewhere, which is the planned situation for many European launchers.

United States is where most of the entities are located followed by China, United Kingdom and India. Only USA, China, Russia and India have operational small launchers however.

UK has a relatively large number of developers including Orbex and Skyrora. Rocket Factory, HyImpulse and Isar Aerospace are located in Germany. France has for example Latitude, MaiaSpace, Sirius Space and Alpha Impulsion. India is home to Skyroot Aerospace, Agnikul Cosmos and Bellatrix. Avio and Sidereus are based in Italy. Gilmour Space is based in Australia.

Canada's small launch vehicle companies include SpaceRyde, C6 Launch Systems, NordSpace and Space Engine Systems. Spain has PLD Space, Zero 2 Infinity and Pangea Aerospace. Russia has for example SR Space, previously known as Success Rockets. IHI Aerospace, Interstellar, Honda and Space One are based in Japan.

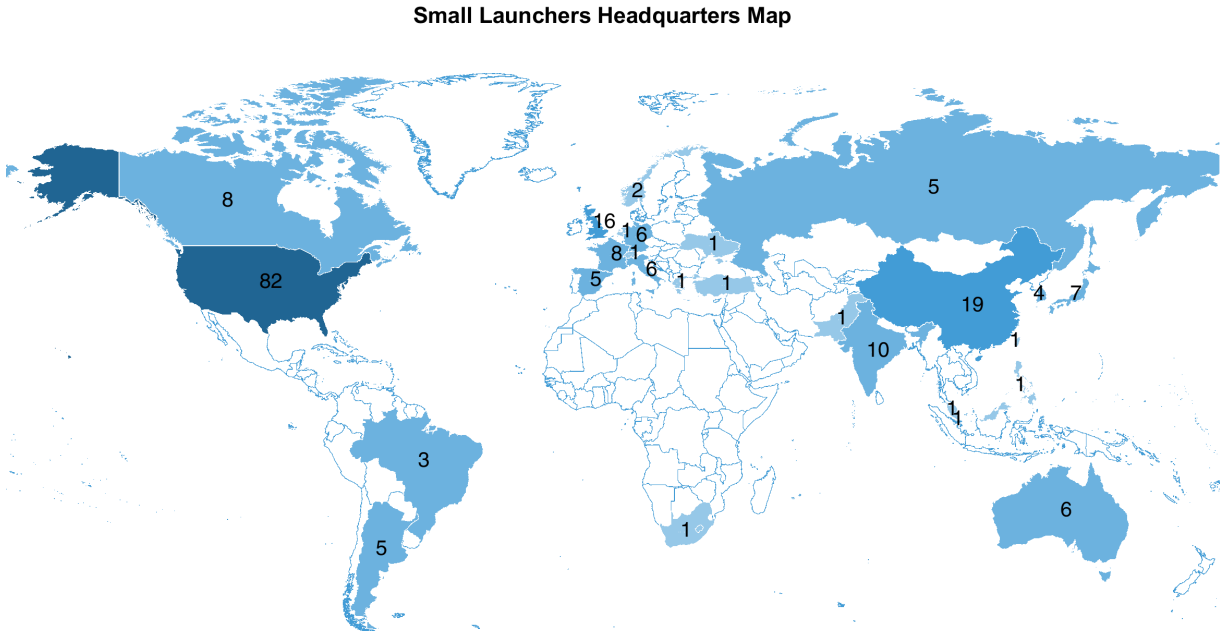

Figure 18: Headquarters Locations of Small Launcher Organizations

6. MARKET ANALYSIS

This section presents an overview of market context, competition, and revenues of small launchers.

6.1 Market Overview

Compared to most new emerging space industries, space launch is an existing market, and it is straightforward to add up the yearly commercial and institutional revenues.

This was a longer section in the previous 2021 survey but most of the content about launch market size estimations and forecasts has not been repeated.

Most studies estimated the 2020 launch market revenue between $5-9 billion. With 114 orbital launches performed in 2020, 26 of them by SpaceX,[143] and many small launchers with costs less than $100 million, the lower numbers could be more realistic. In 2021, there were 146 orbital launch attempts of which 31 were by SpaceX.[144] In 2022, there were 186 orbital launch attempts of which 61 were by SpaceX.[144] According to Bryce Tech, the 186 launches divide into 66 commercial launch vehicles with commercial spacecraft, 34 launches that were government-procured commercial launch services and 86 were government-operated launch vehicles.[145]

According to Bryce Tech, commercial launch vehicles had $5.3B of revenues in 2020, when adding up the 94 commercially procured launches with $2.1B of that in the US.[146] The same report from 2021 states $5.7B of revenues in 2021, when adding up the 113 commercially procured launches with $2.0B of that in the US.[147]

ResearchAndMarkets estimated space launch services market at $12.86 billion in 2020 and reaching $14.92 billion in 2021 and $31.84 billion by 2026.[148] In 2022, they estimated the space launch services market at $16.9 billion and projected to reach $29.6 billion by by 2027.[149]

Studies tracking smallsat launches and forecasting the future demand rarely mention the sizes of obtainable markets. Graphs show large increase in launched smallsats, but majority are SpaceX's Starlink, which are launched on SpaceX rockets and thus not part of the serviceable available markets. OneWeb had been using Sojuz rockets until the last few.[150] Rocket Lab is planning their constellation,[151] very likely launched on own rockets. European megaconstellation will possibly use European rockets. Unknown how many will be left for open competition.

Big constellations are moving to larger satellites.[152] Starlink V2-Mini are about 800 kg and Starlink V2 are about 1250-2000 kg but neither are part of the accessible market.[153] OneWeb Gen2 is expected to be about 500 kg.[152]

Telesat awarded 14 launches of up to 18 satellites to SpaceX in September 2023 starting from 2026.[154] Rivada contracted 12 Falcon 9 launches for 2025-2026.[155] Terran Orbital is building 300 satellites for Rivada, each about 500 kg.[156]

In April 2022, Amazon announced 83 launches dividing into 38 Vulcan launches from ULA, 18 launches from Ariane 6 and 12 New Glenn launches from Kuiper with option for 15 more. This is in addition to 9 Atlas 5 launches it has purchased previously.[157] All those vehicles are experiencing delays but said in Sept 2023 they can meet the schedule.[158]

Market is growing, but in addition, constellation economics is challenging and almost none has been proven including Starlink. There is no guarantee that most of the announced approximately 200-300 constellations will happen.[75] They may include dozens, hundreds, or even thousands of satellites, which would amount to a large number of potential launches, which then may or may not happen. Constellations are also more economical to launch in larger batches.

In addition, many of the constellations that have higher probability of success, like Starlink, use in-house launchers, because it is a major competitive advantage due to lower cost and flexibility. There are also geographical considerations. For example, Chinese constellations will almost certainly use Chinese launch vehicles and Europe's IRIS2 is assumed to launch on European rockets.

6.2 Small Launcher Benefits Claims

Small launchers have benefits over larger rideshare missions in on-demand flexibility, specific orbits, and in some cases, shorter time to orbit from contracting. The previous 2021 survey had a long section on these themes, but they will not be repeated at length due to lack of notable updates.

These advantages remain true and some market opportunity always exists due to these benefits as for example evidenced by new customers for Rocket Lab. However, majority of the customers prefer lower prices and/or use larger rockets to fly batches of satellites to an orbital plane.

With many of the recent retirements, cancellations, delays and launch failures, it will take at least 2-3 years to observe how launch cadences for other providers such as Firefly, ABL, Astra and SSLV will scale up, and by how much the total market changes, and how many will choose dedicated launches over cheaper rideshare missions.

6.3 Competitive Advantages

Amongst small launchers, many competitive advantages have been claimed. For example 3D printing (additive manufacturing), engine efficiency, propellant types, launch methods (airlaunch), number of stages, reusability etc.

Reusability is becoming a clear advantage because propellant costs are low. Everything else is unproven, however, and bigger challenge seems to be achieving the first orbital launch and then scaling up manufacturing and launch rates from there. Most of those claimed advantages can also be weakened by other factors. Long-term, lowest cost and highest margins should result in winning strategy.

6.4 Wider Market Competition

Small launchers are not only competing between themselves for customers. Rideshare or piggyback launches, space tugs, deployment from space stations, and on-board propulsion, can all achieve the same goal of putting a spacecraft into the preferred orbit. In the previous 2021 survey, this was also a longer chapter, but there have been few changes.

SpaceX added a 50 kg rideshare option for $275k, which further captures customers directly. Before that, one would have to purchase the 200 kg slot for $1 million or use third-party launch brokering services. There is a possibility to pay per additional kilograms, which is $5.5k per kilogram.[26] SpaceX Transporter rideshare missions now also launch regularly 3-4 times per year.[27] Separate mid-inclination orbit launches will be added to the manifest. The Bandwagon missions will deliver payloads at altitudes of 550-605 kilometres and inclinations of approximately 45 degrees.[27]

The SpaceX rideshare price will be increasing annually by $500 per kilogram. Customers can lock in a lower price if they pay in full on contract signature, even if the mission is launching years later.[27]

6.5 Revenues

SPAC revenue predictions were indeed optimistic and have not come to fruition. In this section, only launch services revenues are presented if available.

Astra Astra's revenue estimation from February 2021: $4M and 3 launches in 2021; $47M and 15 launches in 2022; $206M and 55 launches in 2023; $619M and 165 launches in 2024; $1125M and 300 launches in 2025.[50]

Astra's first paid commercial launch was in February 2022, followed by subsequent paid commercial launches in March 2022 and June 2022. In August 2022, Astra discontinued Rocket 3, also known as Launch System 1.[159]

In reality, Astra reported launch service revenues of $5.899M in 2022 plus revenues for space products.[159] There have been no launch revenues reported before 2022 or in 2023, after Rocket 3 was retired and Rocket 4 has yet to launch.

Virgin Orbit Virgin Orbit was projecting $15M in revenue for 2021, $70M for 2022, $331M for 2023, $914M for 2024, $1554M for 2025 and $2063M revenue in 2026. Subtracting revenue from space solutions gives $766M in 2024, $1240M in 2025 and $1627M in 2026 for space launches.[134]

In reality, Virgin Orbit had 2 launches in 2021, 2 in 2022 and one in 2023.[160]

Virgin reported revenues of $3.84M in 2020 and $7.385M in 2021.[161] Virgin did not generate any revenue from launch services during the year ended December 31, 2020.[161] Revenue increased by $3.5 million for the year ended December 31, 2021, compared to the year before primarily due to launch services revenue of $6.0 million from two launches.

In 2022, the revenues were $33.1M. Revenue increased by $25.7 million for the year ended December 31, 2022 compared to the year before primarily due to an increase of $26.7 million related to launch service revenue from two launches and other launch-related services.[162] Virgin was not able to file 2023 Q1 report by the deadline.[163]

Rocket Lab Rocket Lab's historical and estimated revenues from 2021 March are (launch revenues in parenthesis): $13.5M in 2018; $48M in 2019; $35M ($33M) in 2020; $69M ($49M) in 2021; $176M ($115M) in 2022; $267M ($141M) in 2023; $450M ($232M) in 2024; $749M ($399M) in 2025; $1159M ($658M) in 2026; $1571M ($915M) in 2027.[164]

In reality, Rocket Lab reported launch service revenues of $39M in 2021 and $60.7M in 2022. Nine missions were completed in the year ended December 31, 2022, versus six launch mission completed in the year ended December 31, 2021.[165]

The total launch revenue for Q1 and Q2 of 2023 is $42.1M for 6 launches, coming to $7M per launch.[166] Notably, the cost of revenue in the 2023 Q2 report seems to be lower than revenue for the first time.[167]

Compared to others, Rocket Lab has been performing closest to their forecasts.

6.6 Backlogs

It is interesting how small launch companies that once announced significant backlogs, some over $100 million, have now retired those launchers (e.g., Rocket 3, Terran 1) or went bankrupt (Virgin Orbit). Focusing and freeing up the workforce are valid reasons when developing the next larger rockets, especially if the cost of revenue would have been higher than the launch prices, but in NewSpace, iteration and learning and any revenue from continued manufacturing and launch campaigns seems equally important. As history shows from possibly every launch company, increasing the cadences takes years, even when customers are waiting.

Astra Astra's launch services backlog as of August 2021 was $150M and pipeline was $1.2B.[168] The backlog increased to $160 million by the end of 2021.[169] No further launch services backlog figures have been found.

Virgin Orbit Backlog grew from $86 million at the end of 2020 to $575 million at the end of 2021, although only $152 million of that was in the form of binding agreements.[132]

In 2021, Virgin claimed ∼$300 million in active contracts and ∼$1.3 billion in active proposals.[134]

In November 2022 in the Q3 results filing, backlog of binding contracts decreased from the previous quarter, down 12% to $143 million.[170]

No further backlog figures have been found.

Rocket Lab Rocket Lab's backlog as of June 2021 was $141.4 million.[171]

As of December 31, 2022, backlog totalled $503.6 million, of which $116.2 million is related to launch.[165]

As of June 2023, backlog increased from $534.3 million as of June 30, 2023, of which $161.9 million is related to Launch Services.[167]

ABL ABL had a backlog of 75 launches in 2021, but 58 are likely from Lockheed Martin, who is also an investor.[172]

In November 2021, Amazon booked ABL for first Kuiper satellite launches to take place in 2022.[173] However in October 2022, Amazon switched first KuiperSat launch to ULA.[174]

Relativity Space In 2019, Relativity's backlog for Terran 1 included undisclosed number for Telesat, one satellite for mu Space, rideshare missions for Spaceflight and a contract with Momentus.[175,176] As of 2023, these customers launched on other (cheaper) launchers or have not yet launched.

In June 2022, a multi-launch deal was signed for OneWeb's second-gen broadband satellites starting in 2025 using its fully reusable 3D-printed rocket Terran R. This was the fifth customer for Terran R, and the only one that had been publicly named, bringing the total value of all binding launch agreements for that rocket to more than $1.2 billion.

In July 2022, Relativity and Impulse Space announced first commercial mission to Mars in 2026.[177]

By April 2023, Terran R had won launch deals from seven customers worth over $1.6 billion.[178]

M. Sheetz wrote in June 2023 that Jefferies analysts noted the Terran R rocket has an implied price of $55M per launch, although early customers "signed at a discounted rate" of $45M.[179] This would make the backlog of $1.6B about 29-35 launches.

After cancelling Terran 1 in 2023, Relativity Space was negotiating with NASA to move their one launch (VCLS Demonstration 2) onto another rocket.[180]

6.7 Valuations

Current valuations for most launch companies are not known because there have not been recent funding rounds or the valuations have not been made public, such as for Isar Aerospace.

First some context, SpaceX was estimated to be worth $4.8 billion in 2012 after the first Dragon capsule docked with the ISS plus billions of dollars in awarded NASA and private contracts. By that time, SpaceX had performed 2 successful launches of Falcon 1 and 3 of Falcon 9.[181] Before the Dragon COTS Demo Flight 2, other estimates put SpaceX valuation at $1.3B and NASA funding at $400-500M.[182]

Rocket Lab Rocket Lab went public in August 2021 at $4.8 billion valuation, providing it with $777M in capital.[183] Before SPAC in March 2021, the valuation was $4.1B.[16] On 2023 September 19th, the valuation is about $2.1B.

Astra Astra went public in July 2021 at about $2.1B valuation[184] and raised nearly $464 million.[168,185] However, as of September 19th 2023, the valuation is only $41 million.

Virgin Orbit Virgin Orbit announced in August 2021 that it will go public at $3.2 billion valuation, while raising $483M including $100M private round.[134,186,187] However, the merger provided just $228M, with only $68 million coming from SPAC proceeds due to high redemption rate.[188]

Firefly Firefly's latest round of $75M was announced in May 2021 and it valued the company at just over $1B. Firefly planned to raise $300M more later in 2021.[189]

Relativity Space Relativity Space's latest funding round announced in June 2021 was $650M and it valued the company at about $4.2B. Previous $500M round in Nov 2020 valued the company at $2.3B. Total amount raised is currently over $1.3B.[190]

ABL ABL announced $170M round at $1.3B valuation in March 2021.[191] In Oct 2021, ABL raised $200M at $2.4B valuation.[105]

6.8 Sustainability

Winners will likely depend on who can decrease the cost while keeping reliability. Although, with very low mission costs, there may not be enough cadence to cover companies fixed costs. Some small launch market will always exist for prototypes, governments, and for constellations that need to pick orbits and launch replenishments. Government subsidies will further enable some small launch vehicles to be developed, skewing the commercial market. Increasing small satellite market will also stimulate more dedicated rideshares. Rideshare is lower cost and piggyback missions will launch in any case, while the dedicated launchers need to make profit from theirs. Thoughts from industry have been mixed.[192,193]

Peter Beck, CEO of Rocket Lab, is not convinced there exists sufficient market demand for new launch services. "Launch is not a great business, because it makes up just 4% of the overall space market and is rarely, if ever, profitable. SpaceX own satellite internet constellation, Starlink, is in part an attempt by the firm to enter a more profitable market."[194] Which is what Rocket Lab is aiming to do also.

J. Foust reported in 2021 that small launch companies appear to be increasingly turning to government customers, who are more willing to pay a premium for dedicated launch services, to close their business case.[195] Firefly's Les Kovacs said in 2019, "Of the 100-plus companies, my assessment is that you'll probably have five, six, maybe seven survive". US military will likely only support 2 vehicles.[196]

Roland Berger expects 5-7 microlauncher players to reach commercial scale in the next 10 years, and are confident at least one will be European.[197]

Chris Kemp, CEO or Astra, is likely correct in saying that the problem today is not a lack of demand but a shortage of operational vehicles.[198] As of 2023, many companies are still 1-3 years away from achieving that regular operational status.

Charles Beames, chairman of York Space Systems, wrote well in SpaceNews op-ed in 2021, "In a growth phase, unsuspecting investors can be led astray by opportunistic huckster salesmen, thereby creating an artificially inflated market – the so called "bubble" that people keep talking about. This is not what we are witnessing in today's space industry, though. Instead, private capital is being invested to explore hundreds of different technical and business approaches to better address current and future space launch needs."[199] However, as seen on Figure 8 and others, most small launchers are similar. Thus, small launch likely still was a bubble based on very high valuations and market forecasts.

6.9 Future Plans & Alternative Revenues

Most launcher organizations are looking beyond expandable small launch vehicles to reusability, larger rockets and many other revenue sources. Some of them have been estimated to generate significant revenue.[50,134,164] Expanding the range of activities is likely the smart step in long-term, similar to for example SpaceX and Blue Origin. The following descriptions are non-exhaustive.

6.9.1 Reusability

Reusability seems to be vital to stay competitive in the long-term. Rocket Lab CEO Peter Beck warned that anybody developing a launch vehicle that is not reusable is making a dead end product. "I think reusability is absolutely fundamental".[198]

Some companies seem to be transitioning to larger reusable rockets and it is unknown who will fully develop and keep operating reusable small launchers.

However, most small launch vehicles are continuing on the same expendable paths when compared to 2 years ago. For many of them, it is perhaps more important to get to orbit at least once and only afterwards potentially announce the development of next larger reusable launch vehicles.

6.9.2 Larger Rockets

Rocket Lab CEO Peter Beck noted in 2021 that the demand is veering from small rockets toward larger vehicles that can launch bigger payloads.[198]

Notable trend is that numerous launcher startups are developing larger rockets after their repeated claims about the big increase in small satellite market and dedicated launch advantages. Yet, most are responding to partially reusable Falcon 9 and not

Starship, seemingly competing with what SpaceX is already doing, instead of developing now.

U.S. Space Force said in 2023 that in its latest strategy to procure launch services, it is taking a calculated risk that new players in the industry will deliver on their ambitious plans after companies shared their roadmaps to expand into the medium-class market.[200]

Rocket Lab unveiled plans for its Neutron rocket in March 2021, a 8-ton payload class launch vehicle. "We've listened to our customers and the message is clear - biggest doesn't always mean best when it comes to constellation deployment." Efficiently building the mega-constellations of the future requires launching multiple satellites in batches to different orbital planes.[201] Neutron will enable significantly higher revenue per launch with its capability to deploy larger spacecraft and greater numbers of satellites per launch and will also be capable of supporting crewed flight and cargo resupply.[202]

Rocket Lab targets $50 million launch price for Neutron rocket to challenge SpaceX's Falcon 9. It also expects to fly the reusable Neutron boosters "10 to 20 times" each, in range with the current reuse performance of a Falcon 9 booster. They "ultimately expect the margins to be in around the 50% range" for Neutron launches. The cost of goods for each Neutron should be at $20-$25M, with about half of that coming from the non-reusable second stage.[203]

Relativity announced fully reusable Terran-R in Feb 2021.[204] It was designed to place more than 20 tons into LEO, comparable to Falcon 9.[205] Relativity retired Terran 1 after the first failed launch to focus on Terran R.[206] At the same time, Terran R was redesigned towards a more conventional approach by making second stage expendable, reducing additive manufacturing and increasing payload to 23,500 kg to LEO when the first stage is recovered.[206]

Around 2021, Firefly Aerospace had plans for a larger vehicle called Beta, but work was only starting.[205] As of 2023, Firefly together with Northrop Grumman is developing two-stage launcher capable of over 16,000 kg to LEO, to be able to challenge Neutron and Terran-R. It is called "Next Generation Medium-Lift Vehicle," or MLV, and is aiming first flight in 2025.[207]

Astra has announced Rocket 4 with increased size and performance, and Rocket 5, which could also be used for point-to-point transportation.[208,209] As of August 2022, Astra retired Rocket 3 to focus on the enlarged Rocket 4.[210]

Virgin Orbit was studying LauncherTwo as part of long-term development.[134] One challenge with air-launch is scalability, because the limitations of the plane and both may need to be upgraded.

Gilmour Space was planning a larger Eris-400 (Eris-L) in 2018, but current status is unknown.[211]

LandSpace has likely retired Zhuque-1 after the first failed launch and focused on Zhuque-2, which made maiden flight in 2023.[212]

One Space is planning larger OS-M rockets.[213] iSpace is working on reusable Hyperbola-2.[214] Deep Blue Aerospace is also developing Nebula-2.[215]

Initially, Interstellar engineers were designing a rocket to loft 100 kilograms to LEO starting in 2020. After surveying the market and finding little demand for vehicles of that size, Interstellar began planning for a larger rocket with 1000 kg payload.[91] However, in the news from late September and on the website, Zero is stated to be capable of 800 kg to LEO and 250 kg to SSO, and as a future max capability.[120]

Galactic Energy is working on Pallas-1, scheduled for 2023 and capable of about 3000 kg to SSO.[29]

Well-funded and larger European small launcher startups have not yet announced medium-class launch vehicles but some likely will in the future.

6.9.3 Satellite & Constellation Programs

Multiple small launch providers are working on in-house spacecraft development programs.

Rocket Lab's Photon is used by Varda Space as a satellite platform and first spacecraft was launched on Falcon 9 in 2023.[216] Cheaper cost of rideshare was the primary reason of choosing Falcon 9 over Electron's flexibility in orbit and dates.[217]

Rocket Lab has announced intentions to develop their own constellations.[151]

Astra is, or perhaps was as of 2023, developing a disc-shaped modular spacecraft platform,[218] by the looks similar to Orbcomm-OG1.

Gilmour has a satellite program.[219] Virgin Orbit was working with strategic partners on spacecraft constellations.[134]

Phantom Space is also developing spacecraft and constellations for customers.[220]

6.9.4 Orbital Transfer Vehicles (Space Tugs)

Space tugs have considerable technological overlap with upper stages and satellite programs.

Rocket Lab's Photon (Kick Stage) can also serve as a space tug. It flew CAPSTONE to the Moon in 2022[221] and planning a Venus mission.[222]

Skyrora is developing a space tug.[223]

Firefly Aerospace announced acquisition of Spaceflight Inc in June 2023 to help offer end-to-end space transportation services, despite already developing Space Utility Vehicle transfer vehicle.[224]

In 2021, Virgin Orbit was studying third stage and space tugs to enable orbits beyond LEO.[134]

SmallSpark pivoted from a small launcher called Frost-1 to a lunar space tug in about early 2023. The S4-Space Logistic Vehicle (S4-SLV) is due to perform its first mission in 2024.[225]

Launcher flew first Orbiter space tug in January 2023 and second mission in June 2023.[226,227] Their small launcher Launcher Light program was cancelled after being acquired by Vast in early 2023.[228]

Before bankruptcy in early 2023, SpaceRyde was developing upper stages that would remain operational in space and could be refuelled.[62,229]

6.9.5 Spacecraft Subsystems & Miscellaneous

Rocket Lab is also selling spacecraft components and scaling up their manufacturing.[230]

Astra acquired Apollo Fusion in June 2021 for $30 million in stock and $20 million in cash plus earn-outs and incentives.[231] Selling spacecraft propulsion systems has become the primary revenue source for Astra after the retirement of Rocket 3, selling hundreds at great margins.[99,232]

Virgin Orbit had been investing in constellation companies such as Arqit, Sky and Space and SatRev, which were then buying launch services, but it is unclear what happened to the stakes after bankruptcy.

Firefly is also developing Blue Ghost lunar lander and received a $93.3M contract from NASA.[233]

Relativity wants to build an industrial base on Mars and is also looking into point-to-point space transportation on Earth.[234,235]

6.9.6 Rocket Engines

Ursa Major was founded in 2015 as a rocket engine manufacturer.[236] In October 2022, they were reported to have closed $100 million Series D for a total of about $234 million raised at a $400 million valuation.[237] Alternatively, according to Pitchbook, the round was $150 million at a $550 million valuation.[238] Their small launch customers include Phantom Space, which ordered over 200 engines in May 2022.[239,240] In April 2023, Astra Space selected Ursa's Hadley liquid engine to power the upper stage of its new Rocket 4 launch vehicle.[241] M. Sheetz reported in early June 2023 that Ursa Major laid off 27% or 80 employees.[238]

Pangea Aerospace was founded in 2018 and was developing a small launcher called Meso after raising approximately $7 million by 2021.[242] Around 2023, they pivoted to (aerospike) rocket engines and satellite propulsion systems.[243] In April 2023, Pangea announced a deal to supply aerospike engines to Tehiru Space, which could generate up to €50M revenue in the next five years and overall targeting €300 million in turnover in 2030.[244]

In 2021, The Verge reported that Astra and Firefly signed a deal to manufacture Firefly's Reaver engines in-house.[245] However, in an interview from August 2023, Astra's CEO Chris Kemp could not comment on the contractual relationship but said that Rocket 4's Chiron engines have a lot of Astra parts, engineering and testing.[99]

Launcher, which was acquired by Vast, cancelled their small launch vehicle development but is still planning to continue developing the E-2 rocket engine in order to sell it.[228]

6.9.7 Hypersonics

Hypersonic testbeds are a new revenue source for some of small launch companies.

HASTE (Hypersonic Accelerator Suborbital Test Electron) is a suborbital testbed launch vehicle derived from Rocket Lab's Electron rocket. HASTE provides reliable, high-cadence flight test opportunities needed to advance hypersonic and suborbital system technology development. HASTE employs the same carbon composite structure and 3D printed Rutherford engines as Electron, but has a modified third stage for suborbital payload deployment, a larger payload capacity of up to 700 kg, and options for tailored fairings to accommodate larger payloads.[246]

Rocket Lab launched first HASTE suborbital mission in June 2023.[247] In September 2023, a deal was signed with Leidos for four more HASTE missions scheduled for 2024-2025.[248]

In March 2022, Virgin Orbit was discussing roles the company could play in hypersonics to increase revenue and concluded a study for the U.S. Missile Defense Agency.[249] After bankruptcy in May 2023, Stratolaunch bought the Boeing 747 "Cosmic Girl" plane and its associated launch equipment to be used for hypersonics testing. Once a spacelaunch company, Stratolaunch pivoted to the hypersonics test-launch business in 2020 after the cessation of financial support from the Allen family.[250]

Ursa Major's first contract in 2017 from the Air Force Research Laboratory was to supply the Hadley rocket engine for X-60A, a hypersonic test vehicle.[251]

7. CONCLUSIONS

Statistical overview of 203 small launch vehicles with payloads up to 1500 kg has been presented. As an update to the previous survey from 2 years ago, which had 180 entries, changes and trends have also been noted. For a better overview, it is recommended to view the 2021 survey[1] because many facts, discussions and findings are not repeated.

- Years 2021-2023 saw notable :
  - retirements (e.g. Rocket 3, Terran 1);
  - bankruptcies (e.g. Virgin Orbit,SpaceRyde);
  - cancellations and pivots to space tugs (e.g. Launcher, SmallSpark) or engines (Pangea);
  - cancellations and pivots to larger launchers (e.g. Rocket 4) and others beyond the scope of small launchers (e.g. Terran R);
  - continued delays for maiden launches.
- 13 or 6.4% of 203 small launchers are retired, 20 or 10% are operational, 88 or 43% are in development, and 76 or 37% are either have concept, dormant or cancelled status.
- None of the very small launchers with payloads up to 50 kg have performed maiden launches.
- None of the operational small launchers offer dedicated mission prices of less than $4 million.
- Prices per kilogram of dedicated rockets continues to be much higher than rideshare missions, but some upcoming launchers are promising to reduce the gap.
- The future of air launch from horizontal spaceports is now unclear.
- Development times can be as low as 2-3 years, but some have taken more than 10 years.
- Development delays in the range of 1-3 years are very common, but can be much longer.
- Revenue and launch cadence forecasts in the SPAC presentations were very overestimated.
- About 40 launcher organizations have announced funding of over $10 million. It was about 30 in 2021. Majority of the 203 small launchers do not have the funding to finish development and will likely become defunct.
- Re-usability continues to be less common for small launchers with about 17% of rockets in development and 5% planned for the future. The ones in development have increased since 2021. However, there are many which have not announced reusability plans (yet).

From the market analysis side, revenues, backlogs and valuations were updated, and many claims were discussed in a wider context.

- Small launch excitement is cooling as both launcher and constellation delays have shown that the small launch market size for the near future is not as large as forecasted 2-3 years ago.
- Rocket Lab's launch cadence is waiting behind customer readiness, which is related to market demand, and it is not behind rocket readiness.
- Many small launch organizations have started developing larger rockets, but also satellite platforms, orbital transfer vehicles and pursuing various other revenue sources. A recent new direction is hypersonics.
- Launch market elasticity is difficult to forecast, but currently the gap between the $1M SpaceX 200 kg rideshare and $7.5M Electron launch is likely large for most space startups.
- It will be interesting to observe how large the market demand would be for a lower absolute price and price per kilogram launch vehicle, when compared Rocket Lab's Electron.

The aim is to keep repeating this written study about every two years, but the online database and accompanying figures will continue to be updated multiple times per year.

With numerous bankruptcies, cancellations and pivots, who will take the lead in offering more affordable and reliable small satellite launches?

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