



Start-Up Space

UPDATE ON INVESTMENT
IN COMMERCIAL SPACE
VENTURES

2022

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EXECUTIVE SUMMARY

Start-up space ventures attracted over \$15 billion in total financing during 2021, breaking the \$7.7 billion record set in 2020 (see Figure 1). In addition, 2021 was a recordsetting year for the number of start-up space deals (241, up 48% from 2020), recipients (212, up 46%), and average deal size (\$64 million, up 35%).

Three trends are shaping the start-up space environment in the 2020s.

1. Private investors continue to pour large amounts of capital into start-up space ven-

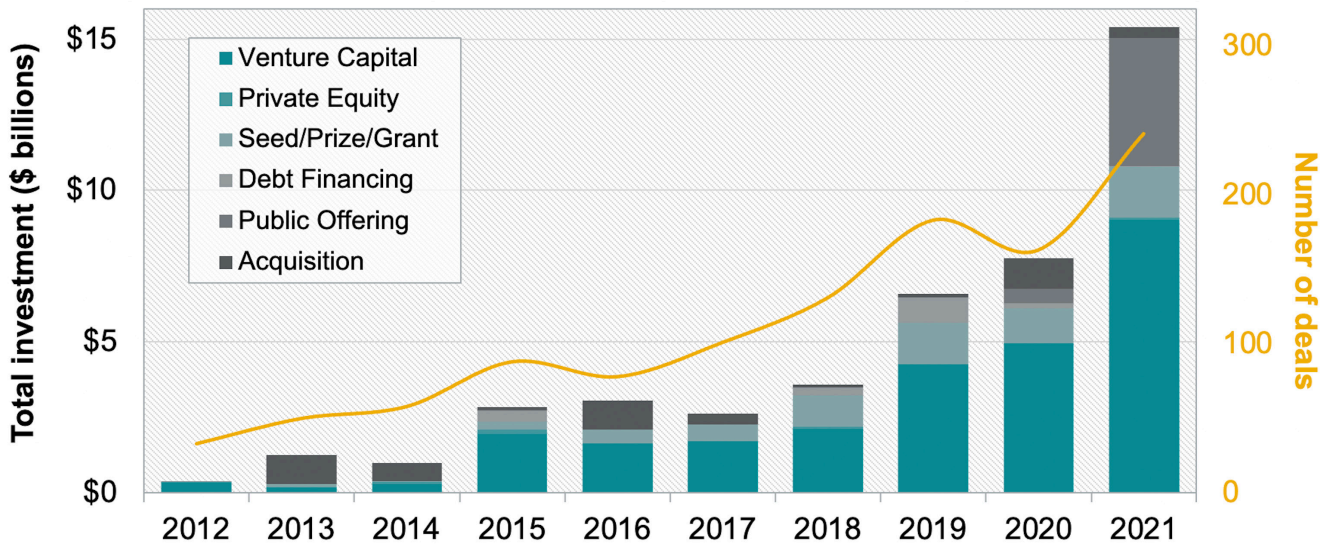
tures, shattering previous records as increasing numbers of investors fund more recipients with larger average deal sizes.

2. Public markets have emerged as a significant source of funding for companies across all space categories, from launch to in-space services.

3. A record number of mergers and acquisitions (M&A) occurred in 2021 for start-up space companies, driven by space-focused holding companies, recently public space companies, and legacy space incumbents.

Figure 1: \$15.4 billion invested in 2021 across 241 deals

Investment in Start-Up Space Companies 2012 to 2021, by Investment Type



Start-up space ventures attracted over \$15 billion in total financing during 2021, breaking the \$7.7 billion record set in 2020.

Record-Setting Venture Investment

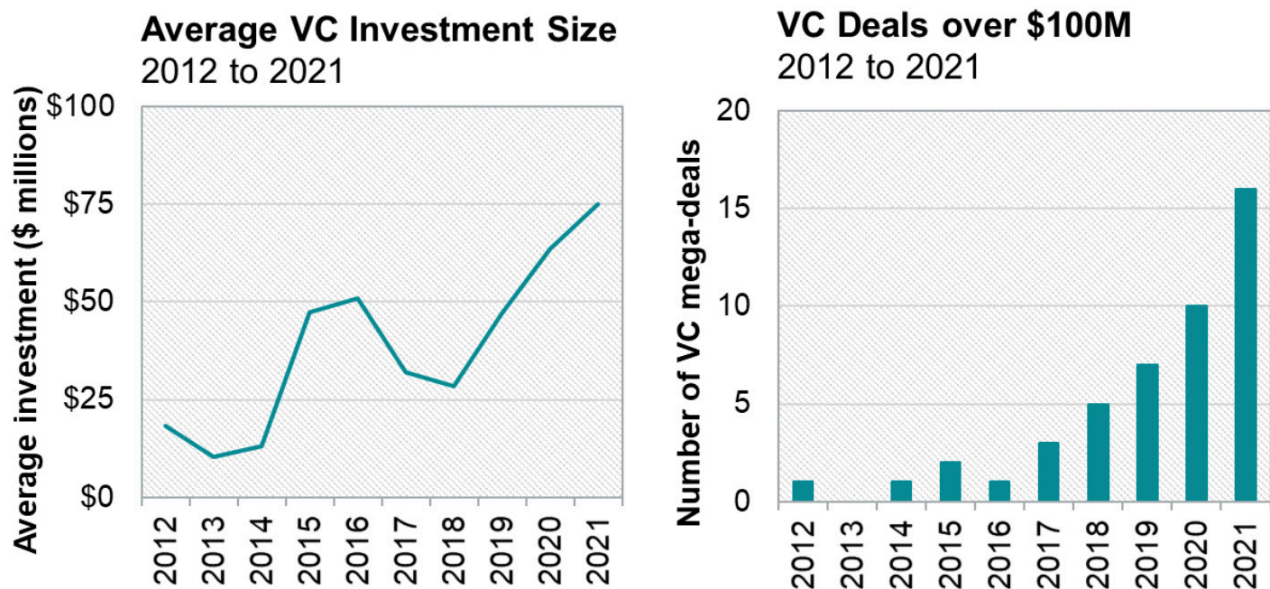
In 2021, the start-up space¹ ecosystem saw a significant increase in venture funding. Relative to 2020, venture capital (VC) investment grew 82%, from \$5 billion to \$9 billion, while the total number of VC deals grew 54%, from 78 to 120. Since 2016, average VC deal size in space has steadily increased. As shown in Figure 2, both average VC investment size and the number of ‘mega-rounds’ totalling over \$100 million have increased, particularly from 2018 to 2021.

SpaceX received an estimated \$1.8 billion in VC investment in 2021, the most by any single company. Reports from SpaceX’s most recent funding round estimate the company’s valuation exceeded \$100 billion.² OneWeb received \$1.5 billion in VC funding in 2021, largely supported by corporate venture activity from Bharti Enterprises and Eutelsat. Sierra Space, the space-focused spin-off of Sierra Nevada Corporation, raised \$1.4

billion in a venture round for the continued development of its reusable spaceplane, DreamChaser, as well as its large integrated flexible environment (LIFE) module, an inflatable habitat designed to support crewed on-orbit activities. Other companies attracting large infusions of venture capital during 2021 included small launch providers Relativity Space, raising \$650 million, and ABL Space Systems, raising \$370 million, respectively.

Record-breaking 2021 space VC investment was consistent with total U.S. VC investment trends. According to data from PitchBook, overall U.S. VC investment nearly doubled in 2021, rising from \$167 billion to \$330 billion, supported by continued low interest rates, increasing venture activity by ‘non-traditional’ investors such as private equity firms, hedge funds, and corporations, and an increasingly robust exit market.³ Looking forward, the availability of private funding will depend on several factors, including future interest rate levels.

Figure 2: VC investments in start-up space are increasing in average size and number



¹ A start-up space venture, as defined here, is a space company that has received and reported seed funding or venture capital at any stage in its development. See Methodology section for additional detail.

² CNBC, Elon Musk’s SpaceX hits \$100 billion valuation after secondary share sale, October 2021.

³ NVCA/PitchBook, Venture Monitor Q4 2021, January 2022.

The Rise of Public Offerings

The largest single start-up space investment category continues to be venture capital, representing \$9 billion of the \$15 billion raised during the year. In 2021 a significant source of start-up funding emerged in the form of public market capital. Space start-ups raised over \$4 billion in public market capital in 2021, representing 28% of total investment over the year.

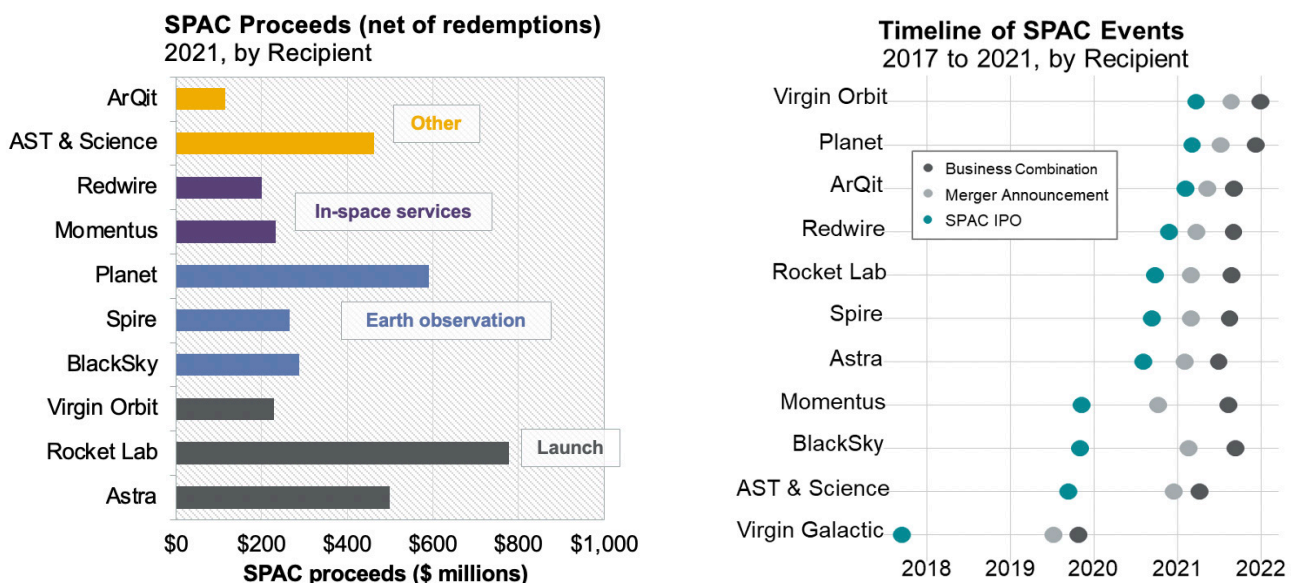
In 2021, 10 space start-ups went public via special purpose acquisition company (SPAC), raising nearly \$4 billion (net of shareholder redemptions).⁴ Three additional space start-ups (Satellogic, Terran Orbital, and Tomorrow.io) announced SPAC deals in 2021; of these, Satellogic completed its business combination in 2022, Terran Orbital still awaits final shareholder approval (expected to close in 2022), and Tomorrow.io's proposed deal was terminated (the company cited "market conditions" as the reason for termination). In addition to SPAC IPO funding in 2021, other notable public start-up space deals include Sidus Space raising \$15 million through the traditional IPO process, Mynaric raising roughly

\$76 million by offering shares publicly in the United States (previously company shares traded only in Germany), and publicly traded Virgin Galactic raising \$500 million through a secondary stock offering.

Figure 3 highlights SPAC funding raised by space start-ups in 2021 and shows the 11 completed space SPAC deals, ordered by date of merger announcement. While some space companies had gone public via SPAC in the past decades (Iridium in 2008, Avio in 2016), a surge occurred after Virgin Galactic completed the SPAC IPO process in 2019.

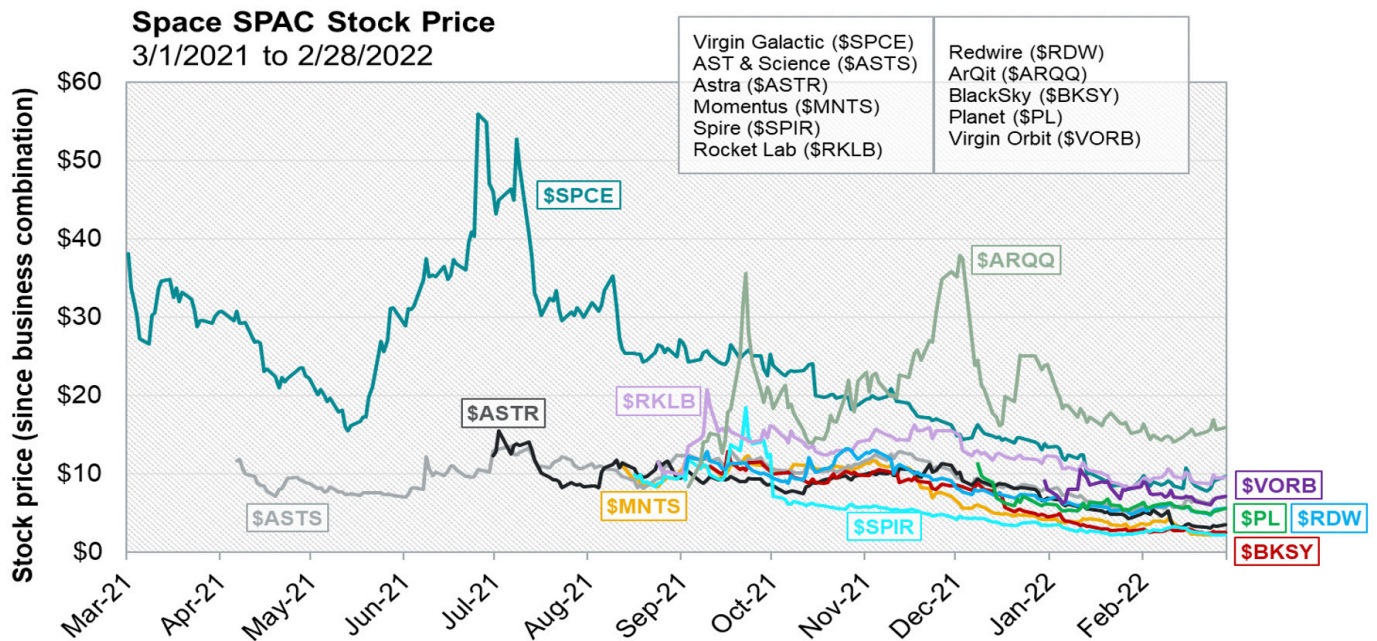
The stock prices of space companies that have merged with SPACs are shown in Figure 4. When a SPAC begins trading publicly, the initial price is typically set at \$10 per share. As of February 28, 2022, 10 of the 11 publicly-traded space SPAC companies were priced under \$10 per share. On average, space SPAC stocks have decreased 35% compared to their \$10 per share issue price. Poor or positive performance by SPACs that now trade publicly could affect the availability of funding for future such deals.

Figure 3: Significant start-up space funding raised via SPAC in 2021



⁴ The Start-Up Space Report considers actual SPAC proceeds (e.g., net of redemptions) only once the business combination is approved and the acquired company starts to trade as a newly merged company (under the new ticker symbol).

Figure 4: A record 13 start-up space acquisitions occurred in 2021



Increasing M&A Activity

A record number of M&A deals for companies occurred in 2021 with 13 start-up space acquisitions, compared to 11 in 2020 (see Figure 5). The year 2021 saw several space SPAC companies acquiring other space start-ups, with Redwire acquiring the most at 3 deals. Leveraging cash from the SPAC IPO process, these companies generally pursued acquisitions to further vertically integrate or to improve near-term revenues.

Redwire acquired Oakman Aerospace, Deployable Space Systems, and TechShot in 2021, having previously acquired Made In Space and ROCCOR in 2020. Other examples include Astra's acquisition of Apollo Fusion (electronic propulsion systems), Rocket Lab's acquisition of Advanced Solutions Inc. (flight software, simulation, and GNC systems) and Planetary Systems Corporation (mechanical separation systems and satellite dispensers), Planet's acquisition of VanderSat (Earth surface conditions), and Spire's acquisition of exactEarth (ship-tracking).

Voyager Space Holdings made three start-up space acquisitions in 2021. Voyager acquired The Launch Company, Valley Tech Systems, and Space Micro in 2021, adding to its portfolio which includes Altius Space Machines, Pioneer Astronautics, and XO Markets (the parent company of NanoRacks).

Several major space M&A deals occurred outside the defined start-up space ecosystem, generally because the neither the acquiring nor the acquired company had a publicly-reported seed or VC investment prior to the acquisition. Examples in 2021 include Providence Equity Partners' acquisition of Marlink, the maritime connectivity provider, GI Partners acquisition of satellite operator Orbcomm for \$1.1 billion, and Viasat's proposed acquisition of Inmarsat (anticipated to close in 2022).

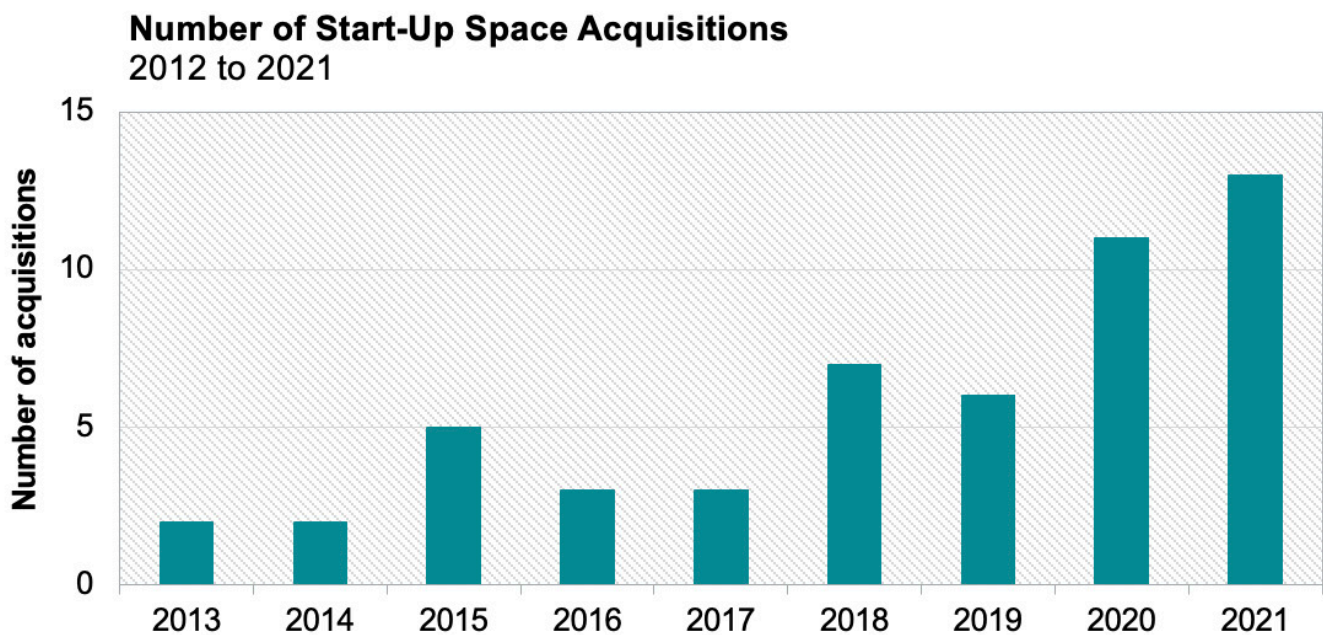
M&A activity is generally a positive indicator for both investors seeking exit opportunities and acquirers seeking to bolster competitiveness.

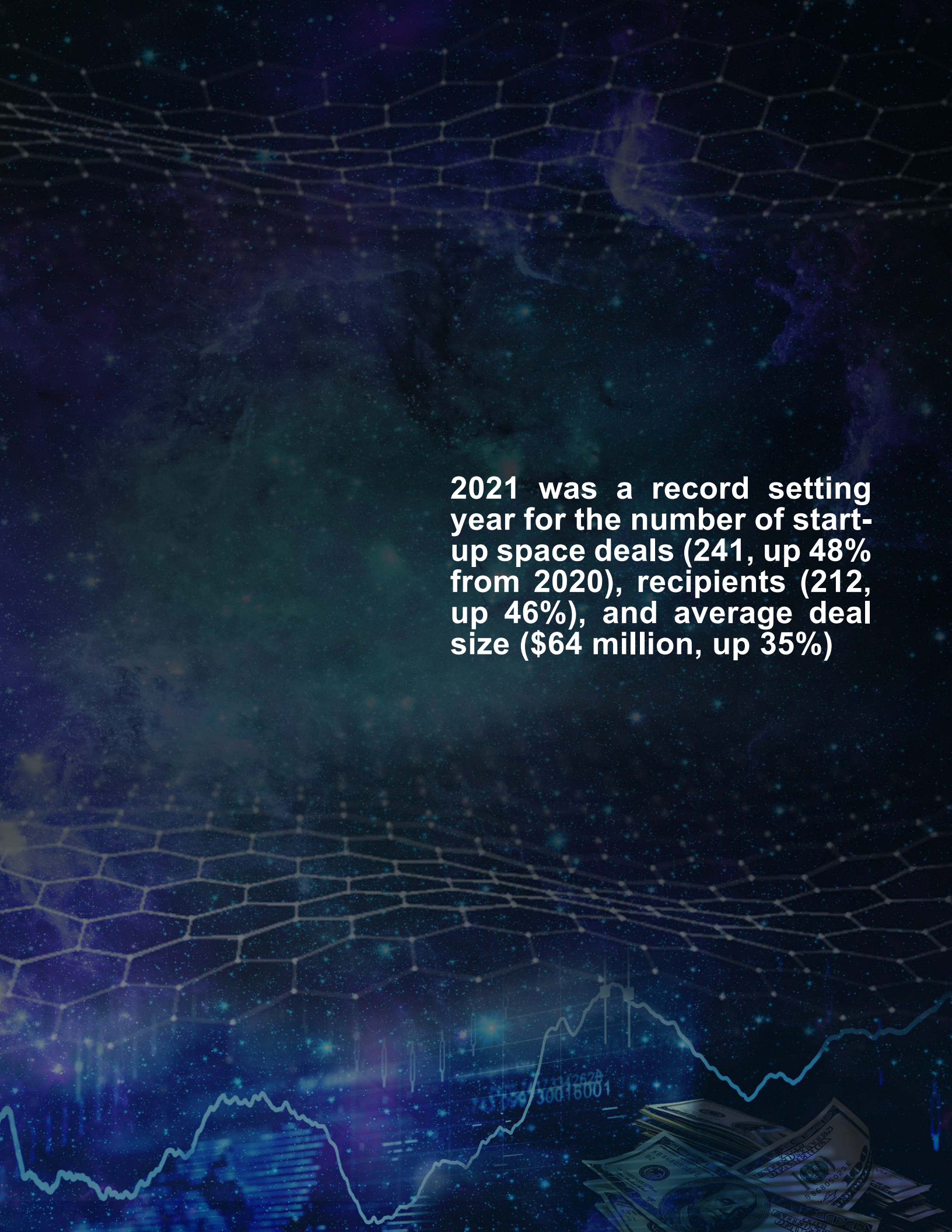
Looking Forward

2021 was a record-setting year for start-up space funding. Private investors poured historic amounts of capital into start-up space companies, and public markets emerged as a significant source of funding for start-ups across all space business areas. While start-up space remains well-supported by investors, future performance risks include

- uproven business models, uncertain customer
- bases, and typically lengthy time horizons for
- space businesses to mature. Newly public space
- companies, with requirements for quarterly
- financial reporting, face pressure to meet
- financial targets and may see stock price impacts
- for missing them.

Figure 5: A record 13 start-up space acquisitions occurred in 2021





2021 was a record setting year for the number of start-up space deals (241, up 48% from 2020), recipients (212, up 46%), and average deal size (\$64 million, up 35%)

INTRODUCTION

The Start-Up Space series examines space investment in the 21st century and analyzes investment trends, focusing on new companies that have attracted private financing.

Start-up space ventures are defined as space companies that began as angel- and venture capital-backed start-ups. This definition differentiates start-up space ventures from aerospace and defense government contractors and large, publicly traded space enterprises. Start-Up Space seeks to provide insight into the dynamics of this growing space industry segment and the investment driving it.

The report tracks seed, venture, and private equity investment in space start-ups as they grow and mature, from 2000 through the end of 2021. The report includes debt financing for these companies where applicable to provide a complete picture of the capital available to them. The report also highlights start-up space M&A and IPO activity.

Purpose and Background

BryceTech conducted the Start-Up Space study and produced this report, Start-Up Space 2022, the seventh in this series.

Capital that could be directed at any industry sector is flowing into space companies. This report seeks to inform investors, the aerospace industry, and the public about activity in this emerging space ecosystem. It reflects BryceTech's ongoing commitment to providing the space community with rigorous analyses of industry dynamics to support sound decision-making in industry, government, and academia.

Methodology

Our dataset includes a combination of: (a) publicly-reported investment transactions in start-up space companies as they mature, with details on investment level and investors where reported; (b) additional companies for which little or no transaction data was reported, but which we have identified as start-up space ventures; and, (c) qualitative data about investment trends and investor motivations. Bryce conducts ongoing interviews, surveys, and conversations throughout the global investment ecosystem, including at key nodes such as Silicon Valley/San Francisco, Southern California, Washington, D.C., Seattle, New York, Florida's Space Coast, Houston, Austin, Beijing, Brussels, Hong Kong, London, Luxembourg, Paris, Singapore, Sydney, and the United Arab Emirates.

Definition of Start-Up Space Venture

Our definition of a space company is a business entity that provides space products or services, specifically one that:

- Manufactures satellites, launch vehicles, or other space-based systems
- Manufactures satellite ground equipment
- Provides services that rely on these systems, such as satellite TV, radio, broadband, remote sensing, or on-orbit servicing, assembly, and manufacturing services
- Provides analytic services based on data collected extensively from space-based systems, either alone or in combination with terrestrial systems

Our criterion for a start-up venture is a space firm that has received and reported seed funding or venture capital. We term these firms start-up space ventures throughout this report, inclusive of all development stages.

Data Set

We include in our data set all firms that meet the start-up venture criteria at any time during the period 2000–2021. Analysis of investment magnitude (i.e., value), investors, and transactions throughout this report is based on data available as of January 31, 2022, covering transactions through December 31, 2021.

Types of Investor This analysis considers six categories of investor to aid in understanding trends in investment and investor motivation: angel investors, venture capital (VC) firms, private equity (PE) firms, banks (typically not strictly investors, but an important source of capital), corporations (as strategic partners and/or internal investors, or through corporate venture funds), and public markets. This typology conceptually groups some investor types that could be treated separately but share characteristics, such as sovereign wealth funds (included in venture capital category) and hedge funds (included in the venture capital firm category). While investor categories continue to shift and evolve, the typology here provides a useful (and generally accepted) broad description of groups of investors and their typical investment behaviors.

Types of Investment Our data set includes six key types of investment (seed, venture, private equity, acquisition, debt financing, and initial public offering) in the firms that fall within the definition of a start-up space venture. A firm that receives venture funding and then receives a significant investment from a private equity group would be considered a start-up space venture by our definition, and the investments of both the venture firm and the private equity group would be included. On the other hand, a long-standing aerospace firm that recapitalizes and receives an investment from the same private equity group would not be considered a start-up, and the private equity investment would not be included in this analysis. The focus of this analysis is ‘new’ start-up space ventures and the capital they are attracting.

Note that the seed category includes funding from prizes (such as business plan competitions or XPRIZE), foundations, and crowdfunding campaigns, as well as seed funding from angels and “space billionaire” super-angels.

We include debt financing for start-up space ventures to provide a complete picture of the capital available to the management team at these companies.

The data set includes only publicly reported transactions; it does not include proprietary investment information. In some cases, transaction value, funding round, or investors are undisclosed. Depending on available information, these are either estimated or excluded.

The data set generally excludes government funding, except for certain grants that mirror seed or venture funding (i.e., not contract awards), such as those provided by the Grand Duchy of Luxembourg. A few quasi-government corporations are included (e.g., Midland Development Corporation and The Valencian Institute of Finance), where they provide seed or venture investments with economic development objectives. Bryce also includes funding from publicly funded venture capital firms, such as the Central Intelligence Agency’s In-Q-Tel.

Sources Sources of data on companies and investments include BryceTech databases; company and investor press releases; annual reports, investor materials, and SEC filings; financial newsletters and databases, such as Crunchbase, PitchBook, Owler, and CB Insights; data provided by NewSpace Hub; news articles from major media outlets, investment publications, trade press, and business journals; and ongoing engagement with industry subject matter experts. Where possible, we confirmed the details of each investment using multiple sources. We further validate our data with venture capitalists, private equity investors, investment bankers, industry experts, management teams at space companies, and through targeted interviews.

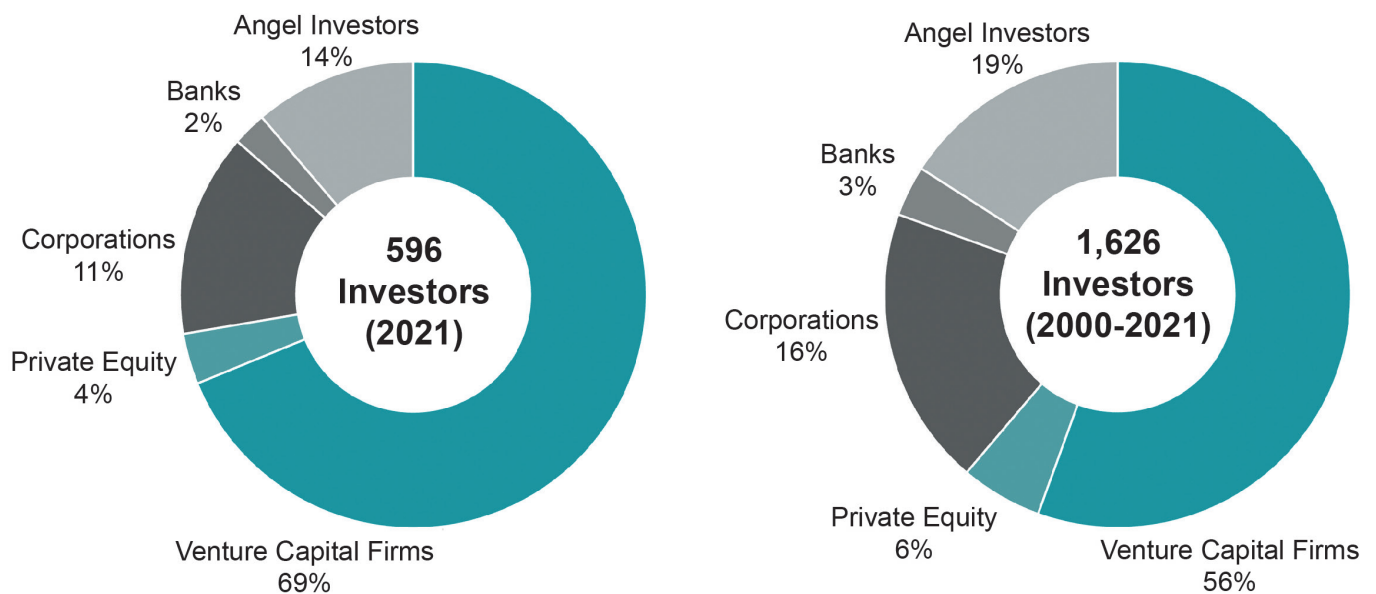
SPACE INVESTORS BY THE NUMBERS

Overall

In 2021, 596 investors (up from 374 in 2020) invested in 212 start-up space companies across 241 deals (up from 163 in 2020). Venture capital firms, angel investors, and corporations together

comprise roughly 90% of the 1,626 total investors identified in the start-up space database since 2000 (see Figure 6; since not all investors are disclosed, the total number of investors is higher). Private equity firms, and banks have played a comparatively smaller, less consistent, role in start-up space investment over this time horizon, active in 2010 and 2011, with relatively little activity until recent years.

Figure 6: 596 investors invested in 212 start-up space companies in 2021



Venture capital firms, angel investors, and corporations together comprise roughly 90% of the 1,626 total investors.

As shown in Figure 7, new investors continue to enter the start-up space ecosystem. Overall, 63% of start-up space investors in 2021 were first time investors in start-up space, including: 257 venture capital firms, 60 angel investors, and 35 corporations. Since 2017, the proportion of first-time investors has averaged roughly 65%, indicating continuous growth in the start-up space investor base.

Figure 8 shows the geographic distribution of start-up space investors. In 2021, 323 investors were based outside the United States (54%), compared to 273 in the United States (46%). Looking at all 1,626 investors since 2000, about 44% of investors in start-up space companies are from the United States, followed by China (12%),

Japan (8%), and the United Kingdom (8%). Within the United States, California and New York are home to the highest number of start-up space investors, representing 21% and 8% of the global total, respectively. The majority of investors being located outside of the United States is a recent development and due to increasing participation from international investors since 2018, primarily in China, Japan, and the United Kingdom.

We analyze each investor type in the next section, assessing their typical (1) role as a funding source, (2) general objectives in investing, and (3) participation in the start-up space ecosystem. For illustrative purposes, examples of select space deals are also provided.

Figure 7: 375 (or 63%) of the 596 investors in 2021 were first-time start-up space investors

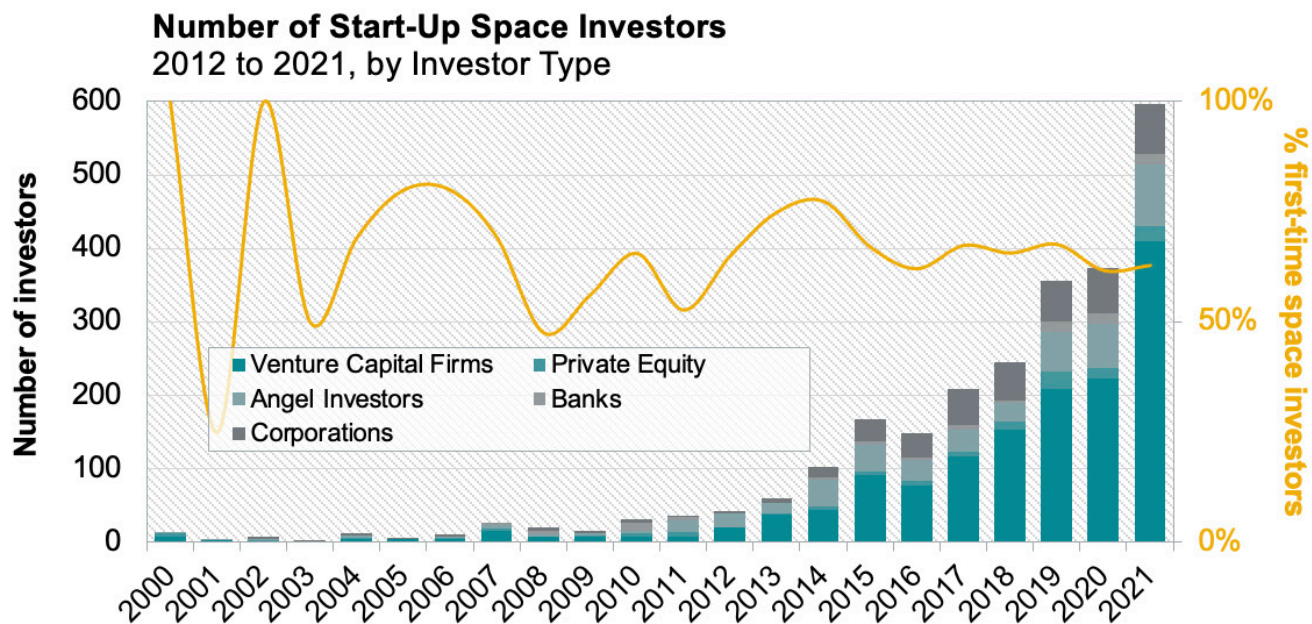
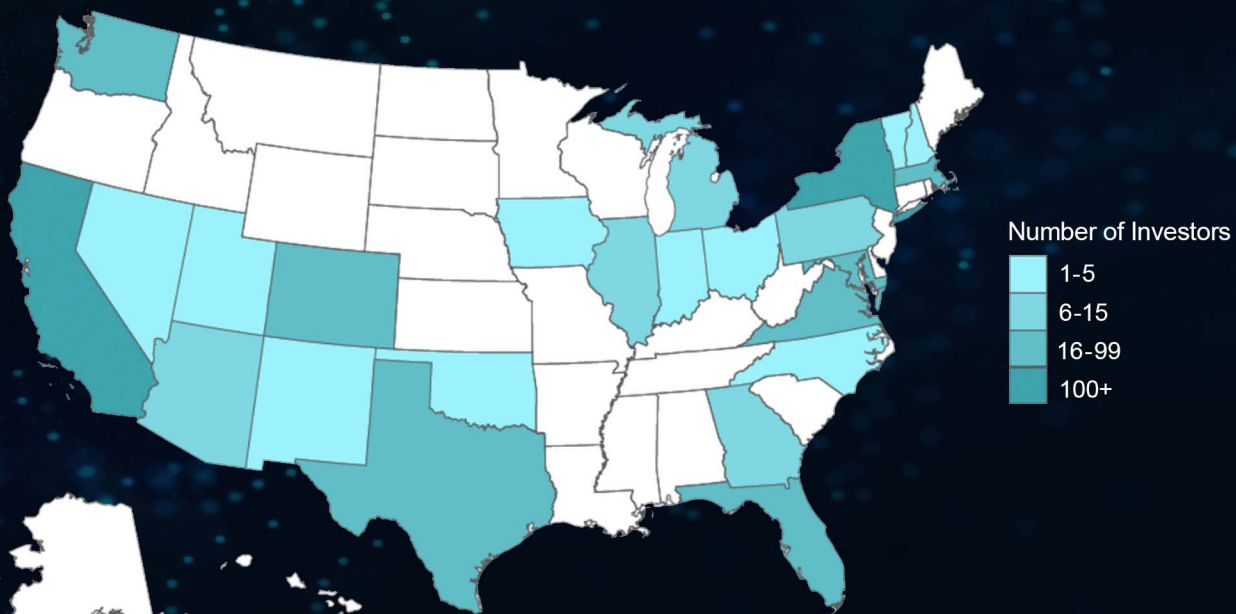
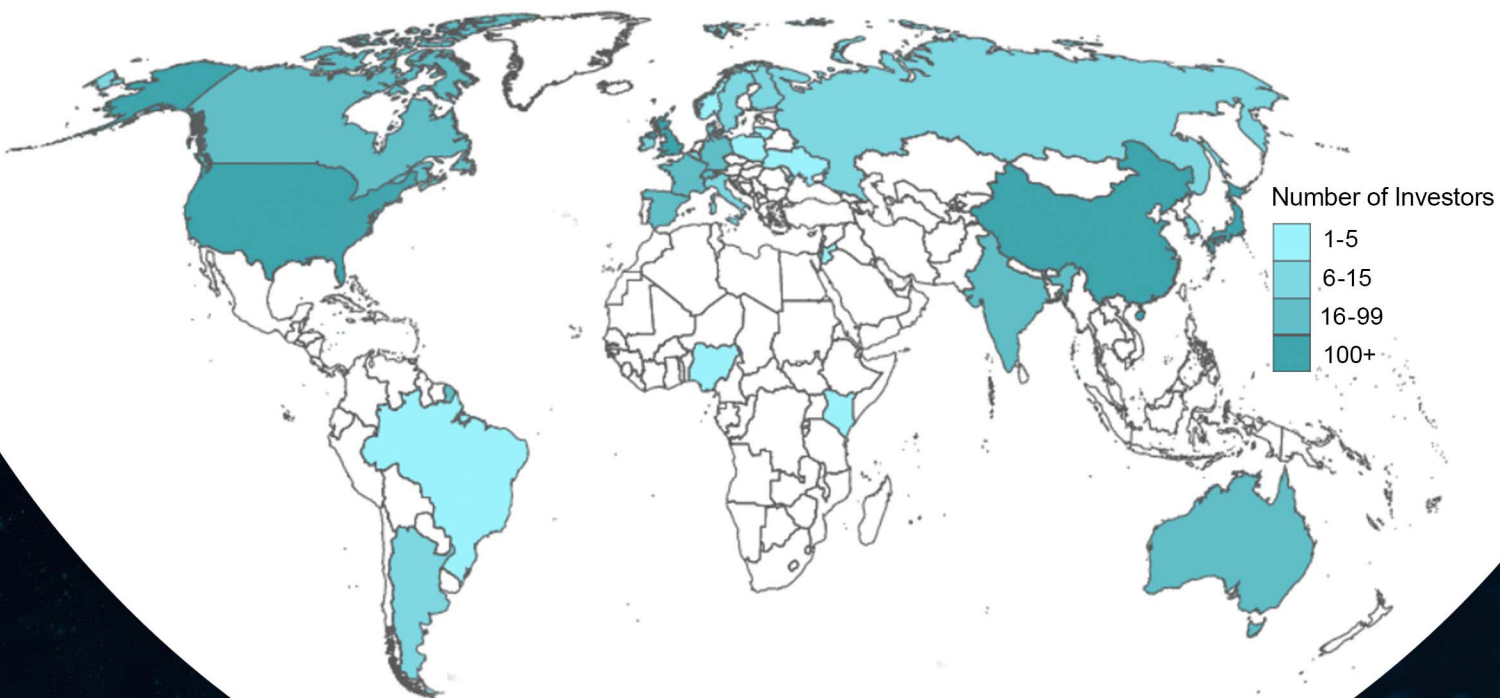


Figure 8: California, China, Japan, and the UK account for 49% of investors since 2000



Investors by Type

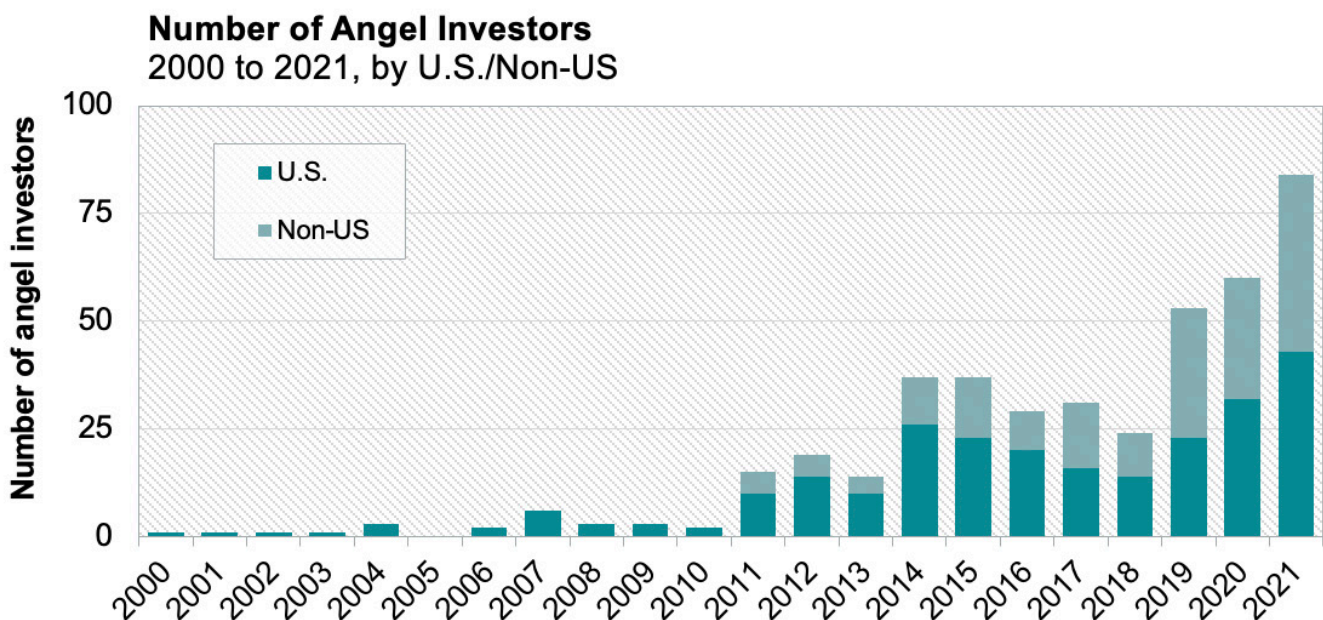
Angel Investors

Typically, angel investors are individuals or families (including family offices) that have accumulated a high level of wealth and seek potentially high returns by investing in ventures during their early stages. By getting in on the ground floor when a company is just starting development of its product or service, an angel investor can realize an attractive potential return, as the early investment will secure a significant foothold in the company. Angel investors typically seek to realize their return (i.e., exit) about 5 to 7 years from the date of investment. Angels may expect an equity stake in the company as high as 30 to 40% in return for their investment; however, angel stakes are often much lower, especially after subsequent, larger investors join the capital structure. In recent years, angels have also participated in syndicates, pooling investments with other angels and venture capital firms to provide more funding to start-ups. We include incubators and accelerators in this investor group because they provide equity as well as mentoring and networking at the pre-seed or seed stage of a start-up.

The most prominent angel investors are “space billionaires.” These billionaires have accrued their wealth through other successful businesses or investments and have either founded a space company or invested their own money in a space company. Several high-profile billionaires such as Jeff Bezos, Richard Branson, and Elon Musk are space investors. Other well-known billionaires, such as Bill Gates, Mark Zuckerberg, and the late Paul Allen, have been affiliated with space ventures. While angel investment typically ranges from \$50,000 to a few million dollars, the investment level by space billionaires far exceeds typical angel levels, often hundreds of millions of dollars to over \$1 billion per funding event.

Angel activity has continued to increase in recent years, and a record 84 angel investors reported investing in start-up space ventures in 2021, with roughly 51% based in the United States (see Figure 9). Most angel investments are not made public, so the actual number of angel investors is likely higher. Since 2000, 315 unique angel investors have invested in start-up space companies. Angels are still predominately based in the United States, comprising 56% of the global total since 2000. Of the U.S.-based angels investing

Figure 9: A record 84 angel investors reported investing in start-up space ventures in 2021



in start-up space companies since 2000, 54% are based in California, 13% in New York, and 6% in Washington. The remaining 27% of U.S.-based angels are spread across 19 other states. Outside of the United States, 24% of non-U.S. angels are based in India, 15% are based in Japan, and 13% are based in the United Kingdom. The remaining non-U.S. angels are from 16 other non-U.S. countries.

Venture Capital Firms

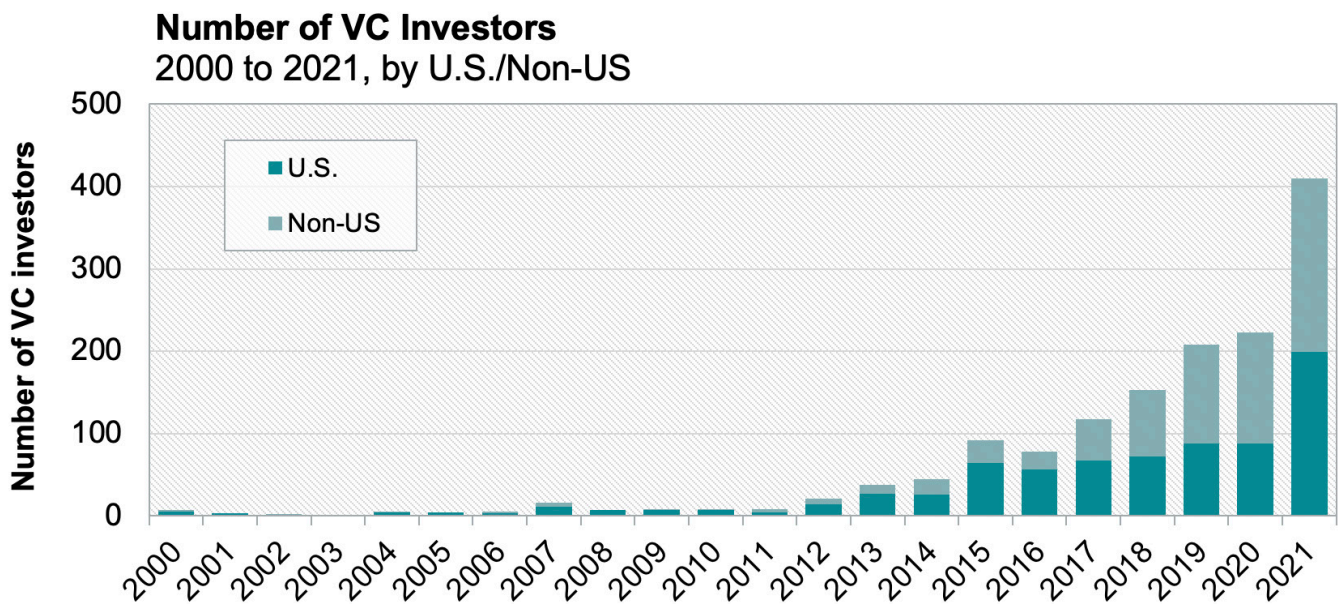
Venture capital firms are groups of investors that invest in start-up, early stage, and growth companies with high growth potential. These firms accept a significant degree of risk in trade for potential high returns. The inherent risk of venture investment results in a high failure rate. A 2012 research study by Shikhar Ghosh, senior lecturer at Harvard Business School, finds that, “About three-quarters of venture-backed firms in the United States don’t return investors’ capital.” VC funding has traditionally come in stages (or rounds), generally designated Series A, Series B, Series C, etc. The form of investment is equity; specifically, the instrument is usually preferred stock. Consequently, the VC firm has an equity ownership stake in the company, but at a higher priority (or preference) than investors at common equity (e.g., founders, employees,

and angels) and a lower priority than any holders of company debt. The preferred shares are usually convertible to common stock in the instance of an initial public offering (IPO; see “Public Markets”) or sale of the company, which are the typical instances of a VC’s exit.

Several space-oriented VC funds have emerged from this class of investors. Examples include Space Angels (operating a venture capital fund, Space Capital, focused on early-stage companies), London-based Seraphim Capital (offering several platforms including the Seraphim Space Fund focused on early-stage space investments), Starburst Aerospace (a space-oriented VC firm and accelerator for start-ups), and SpaceFund (with a blockchain-oriented method of soliciting investor capital for start-up space companies), among several other VC firms with varying degrees of space activity.

The number of VC firms investing in start-up space increased to 410 in 2021 from 223 firms in 2020 (see Figure 10). Of those 410, 153 (37%) had previously reported investment in start-up space companies, while 257 (63%) appear to be new entrants to the start-up space ecosystem.

Figure 10: A record 410 VC firms invested in start-up space ventures in 2021



Since 2000, 903 unique VC firms have invested in space start-ups, 46% of which are headquartered in the United States. Of the U.S. firms, 51% are based in California and 18% in New York. Massachusetts, Maryland, Virginia, Texas, and Pennsylvania lead the remaining states hosting U.S.-based VCs investing in space. Outside the United States, VCs investing in start-up space ventures have headquarters in 34 countries, led by China hosting 28% of the non-U.S. total, the United Kingdom with 15%, and Japan with 10%. Germany, Australia, France, Canada, Russia, and Singapore are also each home to ten or more VCs investing in space companies.

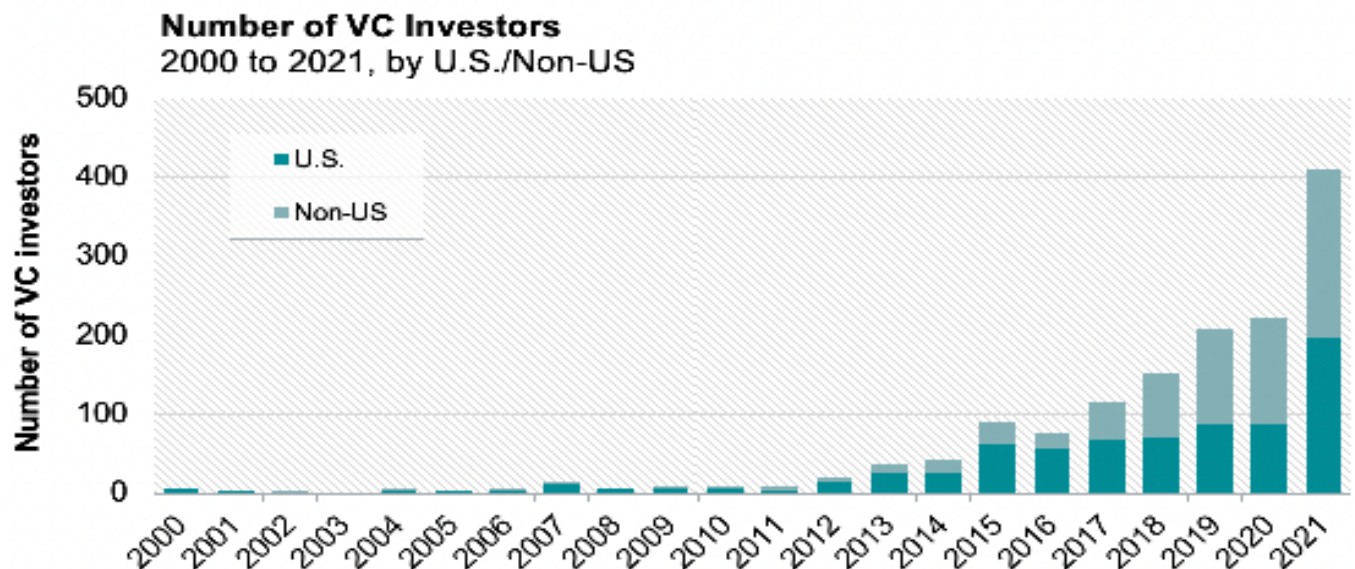
Most Active Space VCs

Twenty-eight venture capital firms invested in five or more start-up space companies in 2021.⁵ Seraphim Capital and TechStars have invested in sixteen; Space Capital has invested in thirteen; Sparx Space Frontier Fund has invested in twelve;

Data Collective has invested in eleven; Promus Ventures has invested in ten; Founders Fund, In-Q-Tel, and Y Combinator have invested in nine; Khosla Ventures, Liquid 2 Ventures, and Matrix Partners have invested in eight; SpaceFund has invested in seven; Horizons Ventures, Lux Capital, and SOMA Capital have invested in six; and 12 other companies have invested in five start-up space companies. In addition, 58 venture capital firms have invested in three or four start-up space companies (see Figure 11).

Fifty-two start-up space companies have attracted investment from two or more of the most active space VC firms shown above (that is, fifty-two start-up space companies have received investment from at least two of the 28 VC firms shown in Figure 11, indicating a preference to invest in common with each other). This relationship is diagrammed in Figure 12.

Figure 11: VCs investing in five or more space companies



⁵ We consider publicly-reported seed and venture investments by traditional VC firms only; the analysis excludes 1) investments by non-traditional VC firms (e.g., PE firms, corporations, etc.), and 2) prizes awarded to start-up space companies by VC firms through accelerators and business competitions

Figure 12: Common investments among highly space-focused VCs

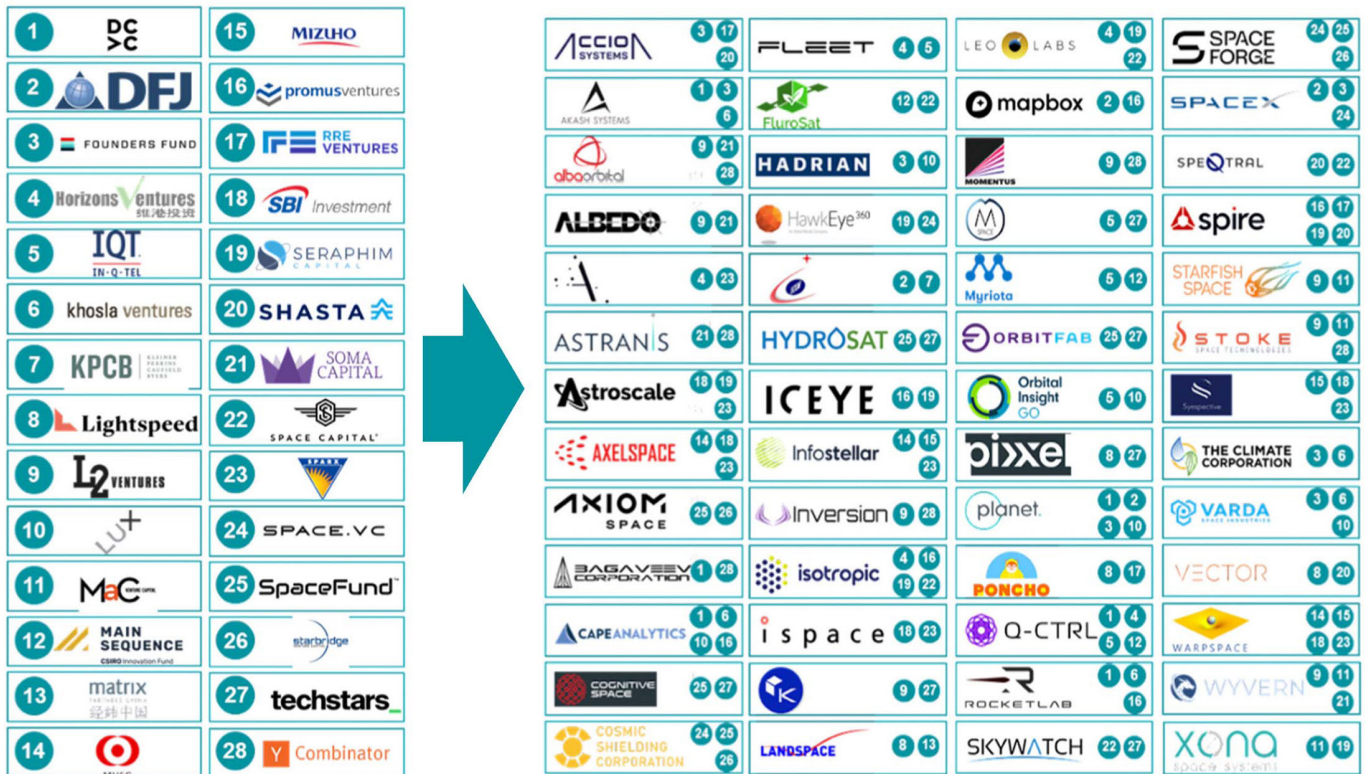


Figure 13: VCs that have participated in multiple space start-up deals since 2000



Since 2000, Sixty-three VCs have participated in at least five start-up space deals, multiple investment rounds or other specific transactions, which may include more than one investment in a single company. Seraphim Capital lead this group, having participated in 26 start-up space deals since 2000. It is followed by TechStars (23), Khosla Ventures (20), Data Collective (17), Space Capital (17), Founders Fund (16), Lux Capital (16), Promus Ventures (15), Draper Fisher Jurveston (13), Matrix Partners (13), Y Combinator (13), RRE Ventures (12), In-Q-Tel (11), Horizons Ventures (10), KPCB (10), Liquid 2 Ventures (10), Sequoia Capital (10), Bessemer (9), SpaceFund (8), Starbridge Venture Capital (8), and 43 other VCs with at least five start-up space deals since 2000. See Figure 13.

Private Equity Firms

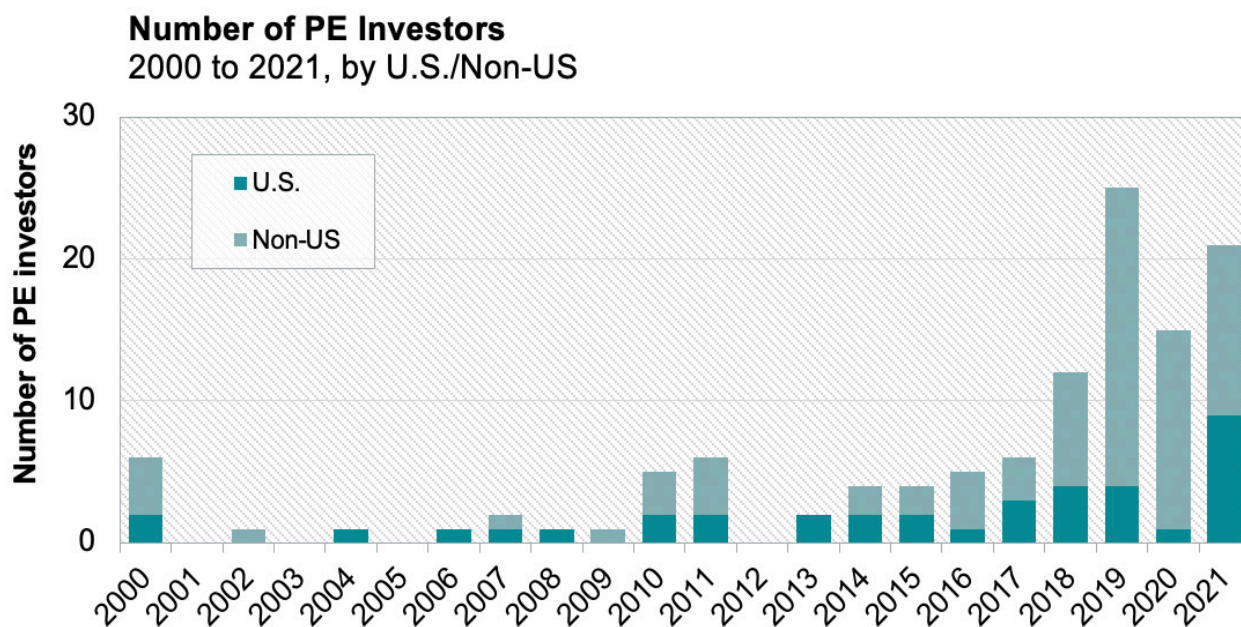
PE firms manage funds of capital on behalf of limited partner investors. The funds primarily consist of capital commitments made by institutional investors, such as sovereign wealth funds, pension funds, and family offices. Large PE firms tend to invest magnitudes over \$100 million, usually in companies that are ideal candidates for debt restructuring or leveraged buyouts. They

traditionally invest in established companies rather than start-ups and using significant leverage, often acquire an entire company or a group of related companies that can merge. In recent years, many PE managers are making equity investments at earlier stages of companies' maturity—on a minority basis, and with longer expected exit time-horizons. These investors may also invest in other types of funds, for example venture capital, as well as directly into private companies.

Given their use of leverage to finance acquisitions, traditional PE firms generally seek companies with stable cash flows, and thus PE activity has generally been limited in the start-up space ecosystem. Historically, their appetite for space investment has been limited to the telecommunications industry or government contracting.

The number of PE firms investing in start-up space increased to 21 in 2021 from 15 firms in 2020. Of these 21 PE firms, 6 had previously reported investment in start-up space companies, while 15 appear to be new entrants to the start-up space ecosystem. The number of PE firms investing in space start-ups has varied over the study period as shown in Figure 14. Since 2000, 92 unique PE firms have invested in start-up space compa-

Figure 14: Number of PE firms investing in space start-ups has varied over the study period



nies. About 31% of PE firms are headquartered within the United States. New York accounts for 39% of the U.S. total, followed by California (21%) and Maryland (11%). Non-U.S. PE firms have headquarters in 15 countries. 32% of non-U.S. PE firms are based in China with an additional 19% based in the United Kingdom. France, Israel, Canada, and Australia are each home to four or more PE firms with start-up space investments.

Corporations

Corporations invest internally, in R&D, in manufacturing, in operations and processes, and in many other areas to enhance capabilities to create or strengthen an existing expertise or advantage. Some large companies also invest through a corporate venture fund or acquire firms to bolster their competitiveness. When a corporation provides funding for a venture, it is usually in the form of straight equity or sometimes in the form of debt, often with the option to convert the instrument into equity of the investee company.

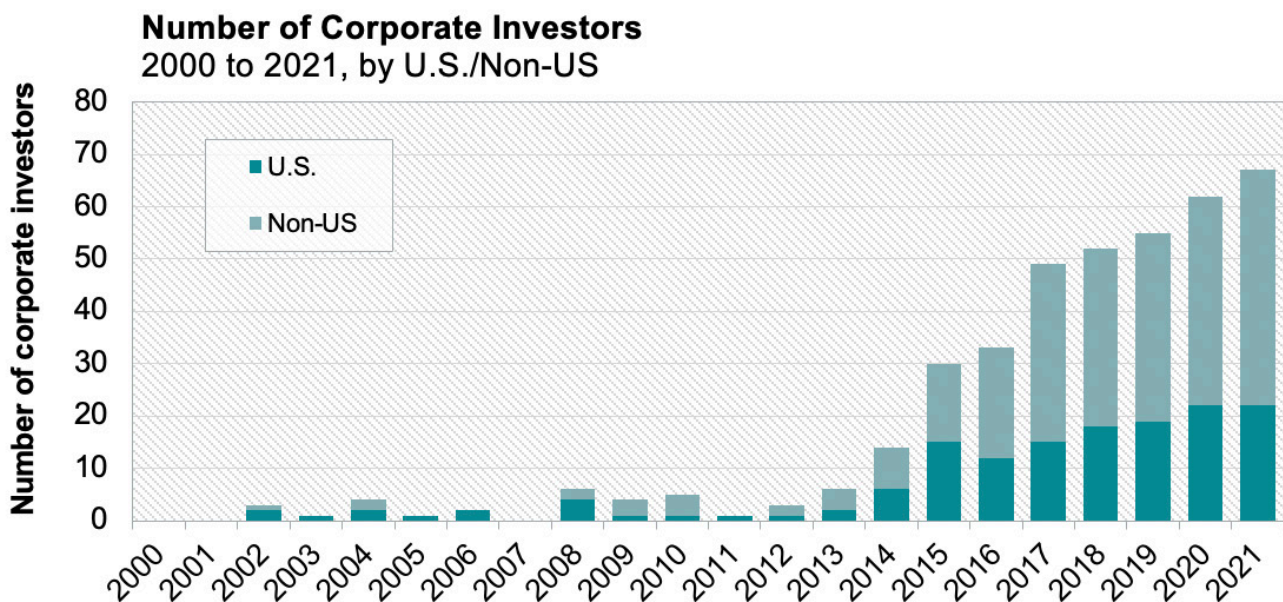
The most active corporate investors in the start-up space ecosystem are Airbus (24 deals via Airbus

Ventures or Airbus Group), Boeing (14 deals via Boeing or Boeing HorizonX), Google (12 deals via Google Ventures or Google), Lockheed Martin (8 deals via LM Ventures), SoftBank (8), and Tencent (8). Not all corporate investments and acquisitions satisfy the definition of a start-up space deal as they represent deals between companies that have not received seed or venture investment. Examples include Intelsat’s acquisition of Gogo, Northrop Grumman’s acquisition of Orbital ATK, and more recently, Viasat’s planned acquisition of Inmarsat.

We also include space-focused holding company Voyager Space Holdings in the corporations category. Voyager has said it aims to facilitate synergies between its portfolio of space companies by providing shared resources, in addition to capital.

As shown in Figure 15, the number of corporations investing in start-up space ventures rose by 8% from 2020 (62) to 2021 (67). Since 2000, 259 corporations have reported investing in start-up space companies. Participation from corporations was low in the first fifteen years of

Figure 15: 259 corporations have reported investing in start-up space companies since 2000



the study period, but increased significantly in recent years. Of the corporations investing in start-up space ventures, 33% are headquartered in the United States, about 34% of which are based in California (11% of the global total). The remaining U.S. portion of the global total is distributed across the United States, with New York, Illinois, Maryland, Texas, and Virginia leading. Non-U.S. corporate investors comprise 67% of the global total, 31% of which are based in Japan, 15% in China, and 9% in the United Kingdom. Others include Canada and Spain, each of which is home to ten corporations investing in start-up space companies.

Banks

Banks are less likely to have a major role in providing financing for start-up ventures. The basic model is that equity investors provide a substantial “cushion” (e.g., 30% of the total capital expense or CapEx required for a certain program, such as deployment of a satellite or satellites). The remainder of CapEx (or other types of programmatic expenditure) is financed by debt, sometimes in the form of “convertible debt,” meaning that the initial

instrument is in the form of debt. At certain trigger points, the debt can be converted, in whole or in part, into an equity stake in the financed company. Commercial banks based in the United States, such as Wachovia, Wells Fargo, and Citibank, and non-U.S.-based banks, such as Deutsche Bank, BNP Paribas, and ABN AMRO, in Europe, have provided debt financing at a magnitude of \$100 million to \$1 billion (sometimes exceeding \$1 billion) per funding event. Most of the companies financed are companies with stable cash flows and large satellite CapEx requirements, such as GEO satellite operators. In addition, government-backed banks (i.e., export credit agencies), such as U.S. Export-Import (Ex-Im) Bank and COFACE of France, have provided debt funding (or guaranteed third-party debt funding) for several satellite systems. In the start-up space ecosystem, the most active banks are the Scottish Investment Bank (9 deals), the Business Development Bank of Canada (6 deals), HSBC Holdings (6 deals), and the European Investment Bank (3 deals).

Of the corporations investing in start-up space ventures, 33% are headquartered in the United States; about 1/3 of those are based in California.

As shown in Figure 16, the number of banks investing in start-up space ventures in 2021 (14) is relatively consistent with levels of bank participation observed in 2019 and 2020. Of the 14 banks that invested in 2021, 6 had previously reported investment in start-up space companies, while 8 appear to be new entrants to the start-up space ecosystem. Since 2000, 57 unique banks have invested in space start-ups. 19% of those banks are headquartered within the United States with New York accounting for 40% of the U.S. total. Non-U.S. banks are primarily based in Japan (24% of non-U.S. total) and the United Kingdom (12%), with China, France, Germany, Luxembourg, Spain, and Switzerland each home to three or more banks with start-up space investments.

Investment Banks

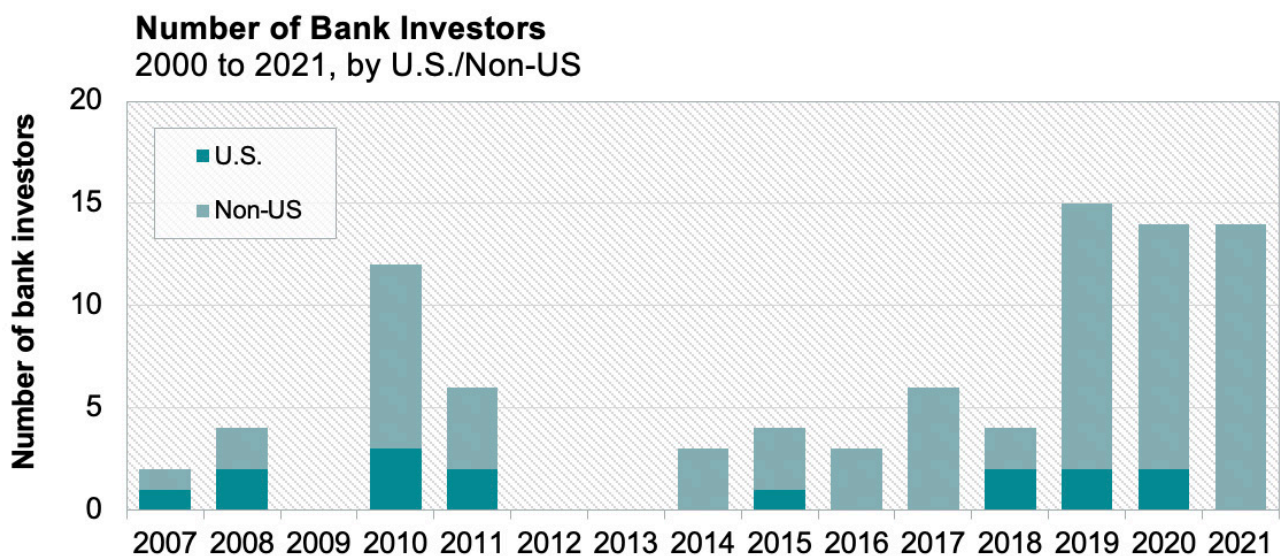
Investment banks and investment bankers—often-visible actors in complex investment transactions typically involving private equity, corporations, and/or public markets—often act as brokers arranging and facilitating these transactions, rather than as the principal lenders or investors.

Investment banks play a variety of roles, including advising on capital raising approaches and more strategic transactions such as mergers and acquisitions, as well as underwriting a capital raising event (e.g., an IPO). Investment banks often focus on large transactions (typically in the multi-hundred million-dollar to over \$1 billion range), and large space/satellite communications companies work with investment banks as financial advisors. These institutions will usually take the role of “lead managers” of a financing transaction, often with several fulfilling that position. For example, J.P. Morgan, Lehman Brothers, and UBS acted as joint lead managers for a \$500 million capital raise in 2007 for fledgling mobile satellite services operator TerreStar (now owned by DISH Network).

Public Markets

Toward the later stages of a company’s funding trajectory, there can be an initial public offering (IPO), or public sale of the company’s equity (common stock). The IPO enables additional capital to be raised to supplement prior funding rounds and

Figure 16: 259 corporations have reported investing in start-up space companies since 2000



provide previous investors an exit mechanism for their investments (i.e., sell their equity shares in the public marketplace). In a customary process for an IPO, an issuer selects an underwriter that helps with regulatory issues, marketing, pricing, and post-deal price stabilization. In return, the issuer pays an underwriting fee and agrees to a lockup that prevents certain shareholders from selling for a specified time.

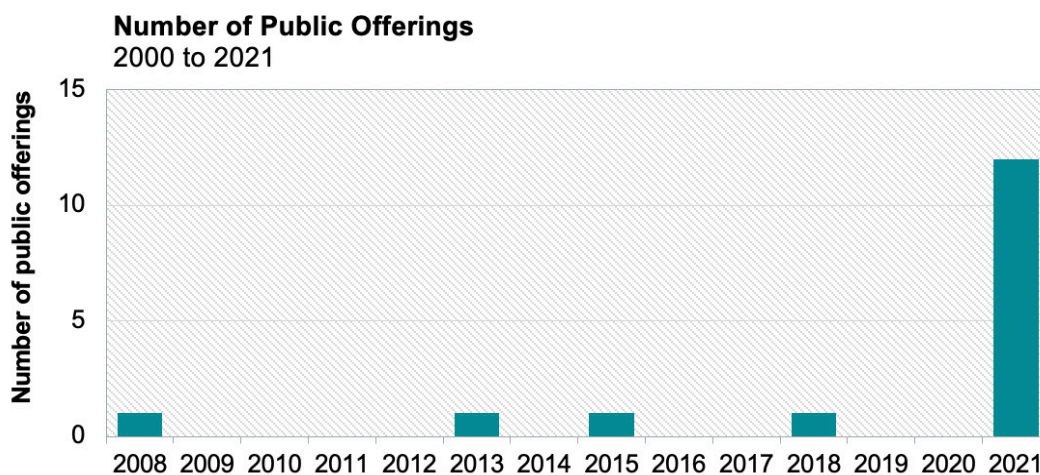
SPACs

In recent years, alternatives to this IPO process have been more common, including a direct listing or sale to a special purpose acquisition company (SPAC). A direct listing allows shareholders to sell existing shares on an exchange for whatever the market was willing to pay, but no new shares are issued. Alternatively, a SPAC can act as a shell company that goes public with the purpose of using the proceeds to acquire a private company, in effect making it publicly listed. SPAC deals typically involve negotiation only between the SPAC sponsor and the target. As a result, the transaction is perceived to be more straightforward and transparent for a private company seeking to become publicly listed. In some cases, going public via SPAC IPO enables the sponsor and target company to bypass the need for large due-diligence and transaction costs commonly associated with traditional IPOs.

This report includes SPAC proceeds only once the business combination is approved and the acquired company starts to trade as a newly merged company (under the new ticker symbol). Since public shareholders have the option to redeem their shares prior to merger completion, our dataset considers actual SPAC funding (e.g., net of redemptions) counted within the public offering investment category. Lastly, SPAC sponsors frequently invite private investment in public equity (PIPE) as a part of the business combination to provide an additional cash buffer in case of high redemptions; for simplicity, we also include PIPE investments within the public offering investment category.

While many established space companies and government contractors have long since had their IPOs and continue to trade publicly (e.g., Boeing, Lockheed Martin, Northrop Grumman, L3 Harris), IPOs of space start-ups had historically been limited (e.g., UrtheCast in 2013, Kleos Space in 2018, Virgin Galactic in 2019). However, a record 12 start-up space IPOs occurred in 2021 (see Figure 17). SPAC IPOs represented 10 of the 12 deals. In addition to the SPAC IPOs, Sidus Space went public via traditional IPO and Mynaric, a company developing laser technology for optical inter-satellite links, began trading publicly on the U.S. stock exchange in 2021 after previously only trading publicly in Germany.

Figure 17: A record number of IPOs occurred in 2021



Conclusion

The start-up space ecosystem continues to attract record numbers of investors, both recurring and first time, across an increasingly diverse geography. While the aggregate investor base remains largely comprised by VC firms and angel investors, consistent with historical trends, 2021 saw increased participation from corporations and public market investors.

As shown in Table 1, the typical investment size of corporations and public markets is typically much larger than earlier stage investors. By garnering participation from corporations and public markets, the start-up space ecosystem will broaden both the pool of potential investors and the magnitude of available capital for start-up space recipients.

Table 1: Different types of investors pursue different investment objectives

Type of Investor	Characterization of Investor	Typical Space Investment	Investment Type	Examples of Transactions	Expected Returns/ Exit Horizons
Angel Investors	High net worth individuals, families, or groups of angels	\$50K – \$1M	Equity	York Space Systems with \$250K of angel investment from Dylan Taylor in 2015	5-10X investment/5-7 years
Venture Capital Firms	Groups of investors focusing on early stage, high growth ventures and accepting a significant degree of risk	\$2M – \$75M	Equity preferred stock in several tranches (e.g., Series A, B, C)	Kymeta with \$218M of venture capital from multiple (2012–present)	5X investment/5 years
Private Equity Firms	Large investment houses that have multi-billion dollar investment funds—focus on established companies	\$100M – \$1B	Equity	Virgin Galactic with \$490M of investment from Aabar Investments (2009 and 2011)	3-5X investment/3-5 years
Corporations	Large companies providing strategic investments to support large CapEx space projects Internal R&D for special projects Independent R&D as government contractor Merger and acquisition Venture investing	\$100M – \$1B	Equity and sometimes debt	OneWeb with \$3.0B of investment from SoftBank, Airbus, Intelsat, and other corporations (2015-2019)	Significantly less returns than for PE firms/horizon is over a long term
Banks	Private and government backed banks providing substantial debt financing layered over equity	\$100M – \$1B	Debt, sometimes convertible into equity	O3b with \$184M of debt financing from COFACE in 2015	Straightline interest rates (e.g., 5–10%)
Public Markets	Later stage funding vehicle for supplementary fundings	\$100M – \$1B	Equity	Iridium raising \$170M in an IPO	Serves as a vehicle to allow the earlier investors to exit

The start-up space ecosystem continues to attract record numbers of investors, both recurring and first time, across an increasingly diverse geography.

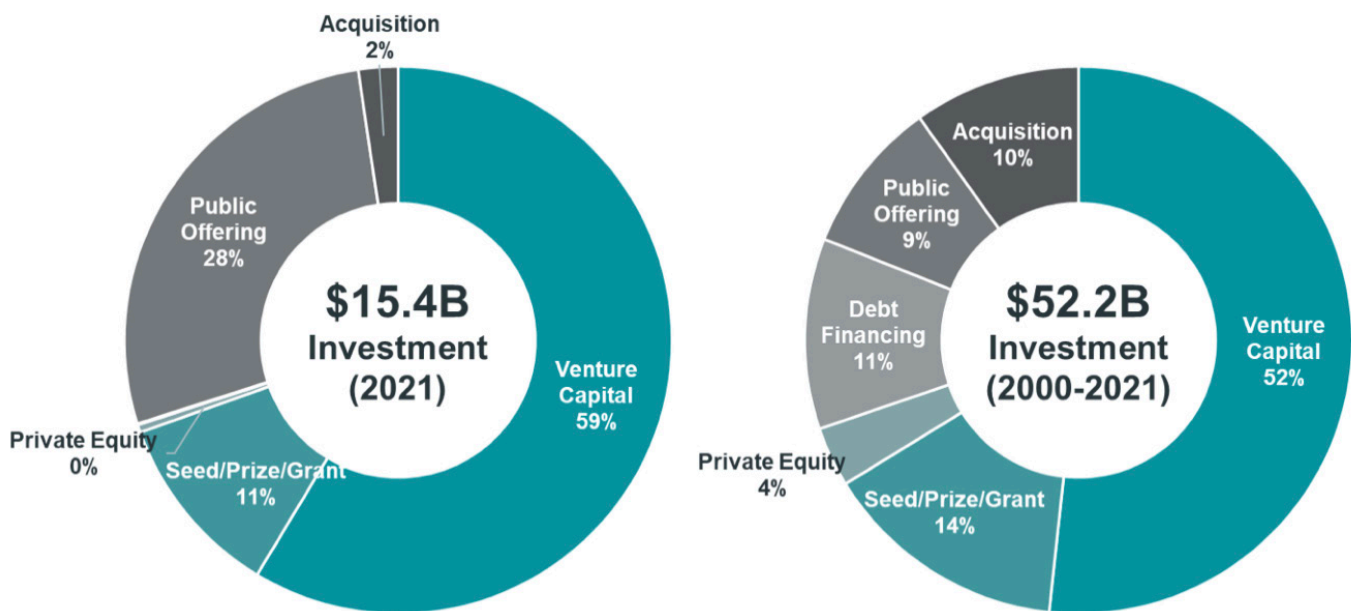
SPACE INVESTMENT BY THE NUMBERS

Overall

A record \$15.4 billion was invested in start-up space companies in 2021, nearly double the investment raised in 2020, the previous record year (see Figure 18). This difference is primarily driven by an increased number of large venture rounds and the \$4.2 billion in funding raised through public offerings (\$3.7 billion via SPAC). In 2021, capital raised via public offerings represents 28% of total investment on the year, a significant departure from years past (6% in 2020 was the previous high).

Cumulative investment in start-up space ventures since 2000 totals \$52 billion with 69% occurring within the last five years. As shown in Figure 19, the mix of investment types has evolved over the last 20 years. In the last five years, the majority of investment has been seed and venture capital - about \$28 billion (or 77%). Seed funding is evident in most years, most notably Jeff Bezos's super-angel investments in Blue Origin. Venture capital has increased significantly in recent years in both frequency and magnitude, while debt financing and private equity were more prominent in the middle years of this timeframe. Acquisitions and public offerings comprise \$10 billion (or 19%) of total start-up space investment since 2000, roughly \$6 billion of which occurred in the past two years.

Figure 18: Public funding comprises 28% of the \$15.4 billion invested in 2021



The number of start-up space deals in 2021 was 241, increasing from 163 in 2020. The number of U.S. deals exceeded the number of non-U.S. deals, making up 52% of the 2021 total (see Figure 19). In terms of magnitude, total investment in U.S. space start-ups in 2021 was \$12 billion (78% of total investment), compared to \$3.4 billion (22%) for non-U.S. space start-ups (see Figure 19). California-based recipients collected 54% of the U.S. total in 2021, followed by Washington and Colorado with 14% and 13% of the U.S. total, respectively. Outside the United States, the United Kingdom solicited 50% of the non-U.S. total magnitude invested (driven primarily by OneWeb), followed by 15% attributable to China-based recipients.

Figure 20 illustrates investment magnitude by recipient category. In 2021, 81% of total investment magnitude was attributable to launch, satellite communications, and Earth observation categories (84% of total investment since 2017). In-space services solicited \$1.1 billion in 2021 (or

Figure 19: \$15.4 billion invested in 2021 across 241 deals

**Investment in Start-Up Space Companies
2012 to 2021, by Investment Type**

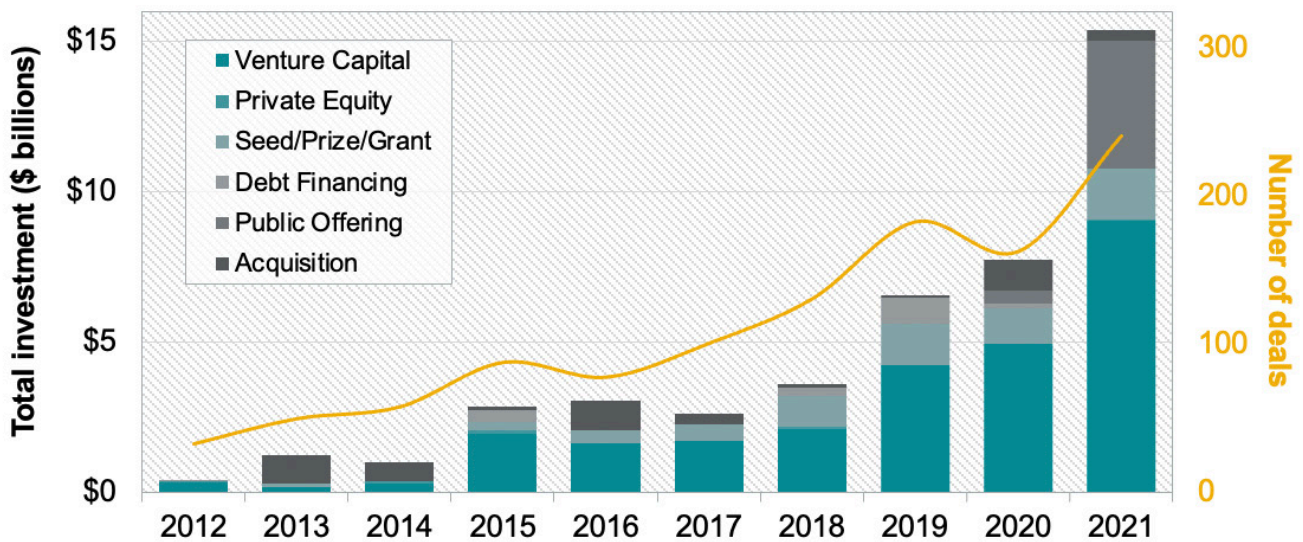
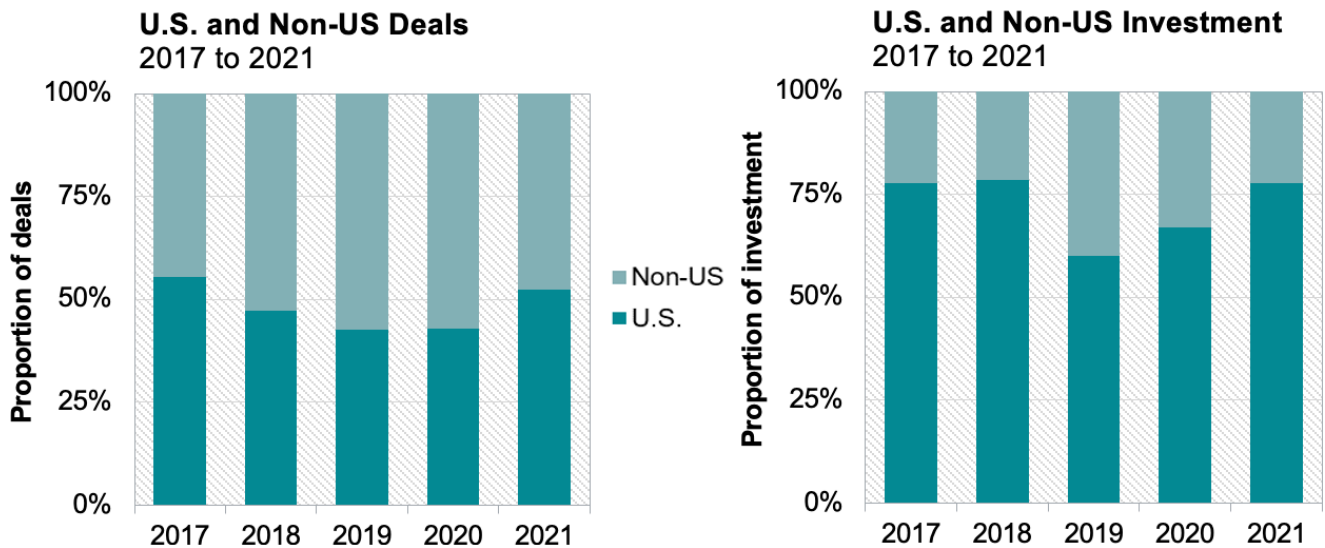


Figure 20: Deal frequency and magnitude greater for U.S. recipients in 2021

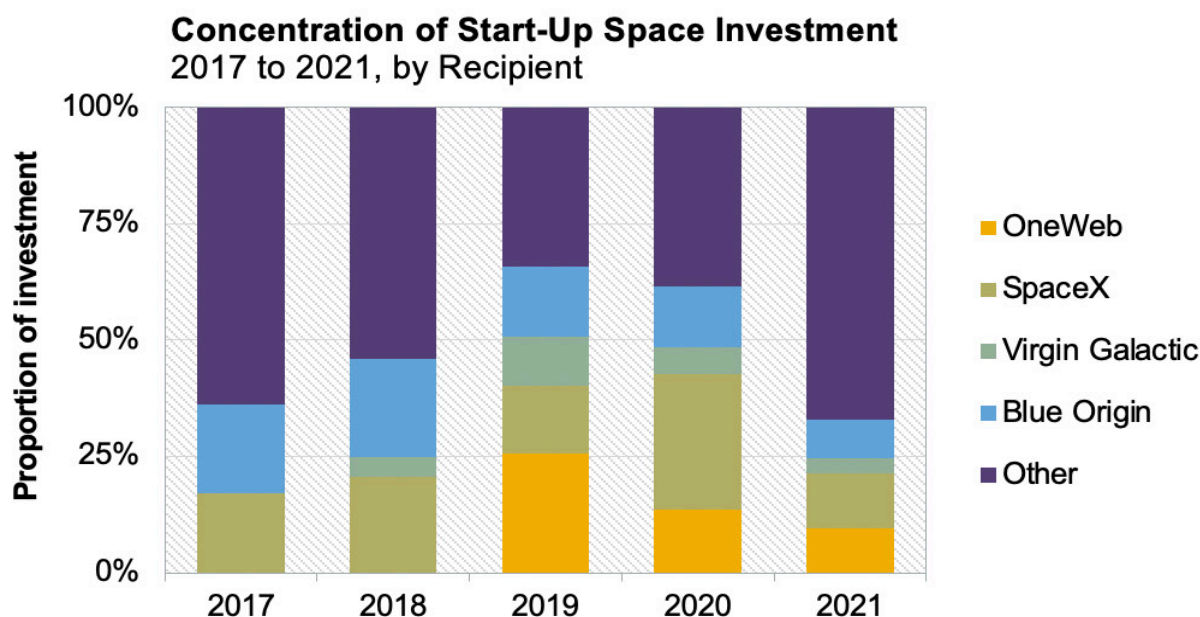


7% of total investment), the fourth largest recipient category. This is a significant increase from recent years; in-space services captured only 2% of total investment from 2017 to 2020. The largest in-space services deals in 2021 include \$233 million to Momentus, \$200 million to Redwire, \$140 million to Loft Orbital, \$130 million to Axiom Space, and \$109 million to Astroscale. In discussing the value proposition of in-space services with investors, factors cited for the increased interest include the potential return relative to more mature alternative markets (e.g., launch, satellite communications), potential for technology to be applied both in-space and terrestrially, and a general perception of expanding in-space markets (particularly LEO) with numerous products. Alternatively, inhibiting factors included long time horizons, uncertain total addressable

market, and general tail end risks, particularly as related to human spaceflight.

Figure 21 depicts the concentration of start-up space investment by company since 2017. After peaking in 2019, the concentration of investment in SpaceX, Blue Origin, OneWeb, and Virgin Galactic has steadily declined. These four companies solicited 66% of total investment in 2019, falling to 33% in 2021. Sustained private investor appetite for space companies, and new funding options offered by SPACs, have supported continued diversification. For example, as of 2020, only SpaceX, Blue Origin, OneWeb, and Virgin Galactic had attracted aggregate funding above \$1 billion.⁶ In 2021, three additional start-up space companies joined the list of \$1 billion recipients: Sierra Space, Relativity Space, and Rocket Lab.

Figure 21: 84% of total investment since 2017 attributable to launch, satellite communications, and Earth observation



⁶ Excluding investment associated with acquisitions.

Investment by Type

Seed Funding

Overall, seed investment rose by 46% in 2021, from \$1.2 billion to \$1.7 billion (see Figure 22). Similar to prior years, seed funding in 2021 was dominated by an estimated \$1.25 billion from Jeff Bezos to Blue Origin.⁷ Excluding investment from super-angels, total seed investment in 2021 was \$433 million, an increase from \$153 million in 2020; the number of seed deals also increased,

from 64 in 2020 to 92 in 2021.

Since 2000, total seed funding is \$7.6 billion. As shown in Figure 23, seed funding is dominated by a few super-angel seed investments, primarily Jeff Bezos in Blue Origin (\$5.6 billion since 2000), Elon Musk in SpaceX (\$100 million in 2006), Richard Branson in Virgin Galactic (\$157 million in 2018 and \$162 million in 2019), and Robert Bigelow in Bigelow Aerospace (\$250 million between 2010 and 2013 - however, the timing of these commitments is not public, and were spread over the period).

Figure 22: Seed investment rose by 46% in 2021

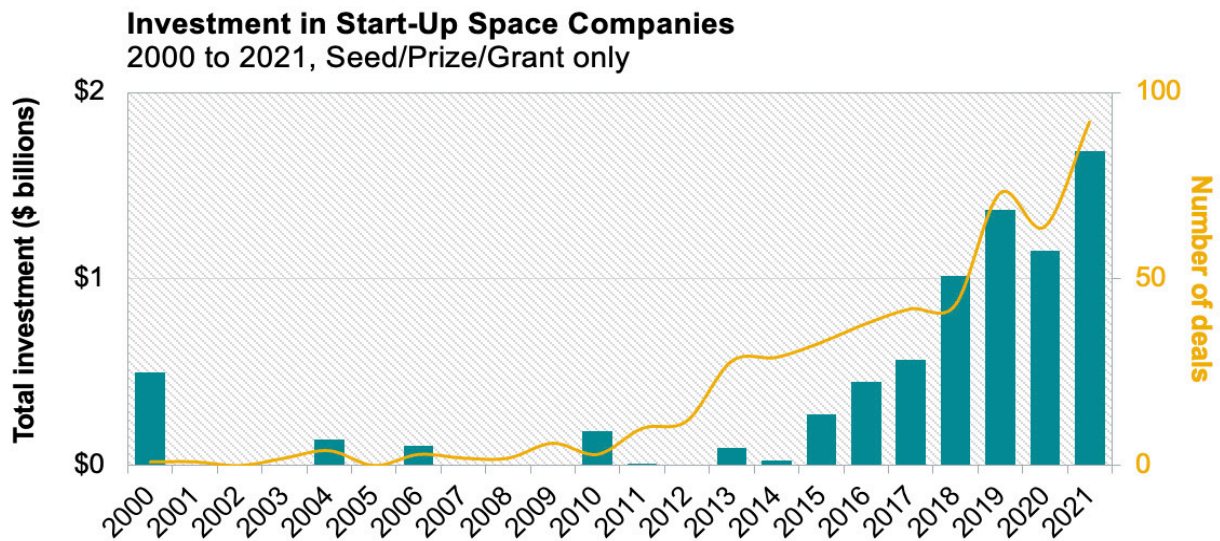
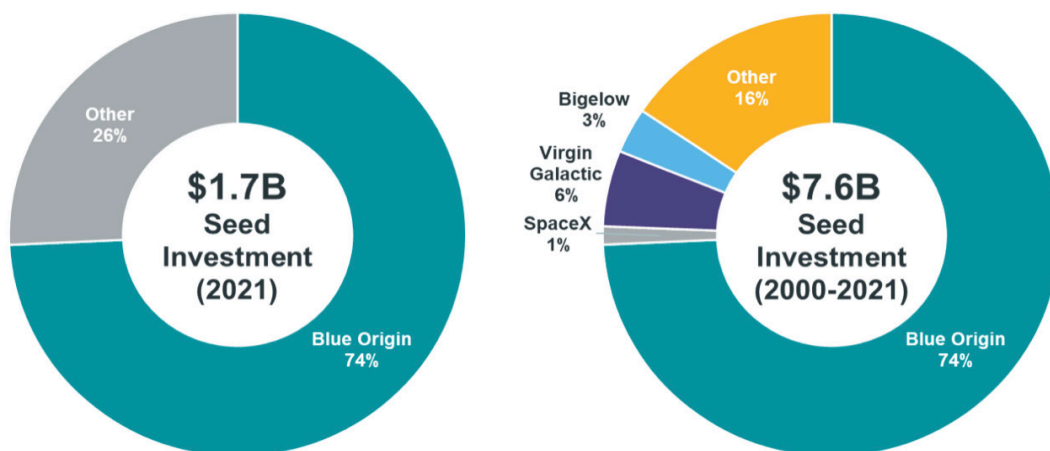


Figure 23: Super-angels represent 84% of total seed investment since 2000



⁷ This estimate represents an increase from assumed Bezos' seed funding in 2020 (\$1 billion) as Blue Origin continues to scale up operations. According to CNBC, Blue Origin's employee count increased from roughly 3,500 in Q4 2020 to nearly 4,000 employees in Q4 2021.

Venture Capital

In 2021, the start-up space ecosystem saw a significant increase in venture funding (see Figure 24). Relative to 2020, venture capital (VC) investment grew 82%, from \$5 billion to \$9 billion, while

the total number of VC deals grew 54%, from 78 to 120. Since 2000, VC investment in start-up space companies totals \$27 billion, with 82% invested in the last five years. As shown in Figure 25, both average VC investment size and the number of 'mega-rounds' over \$100 million have increased, particularly from 2018 to 2021.

Figure 24: A record \$9 billion of venture capital funding in 2021

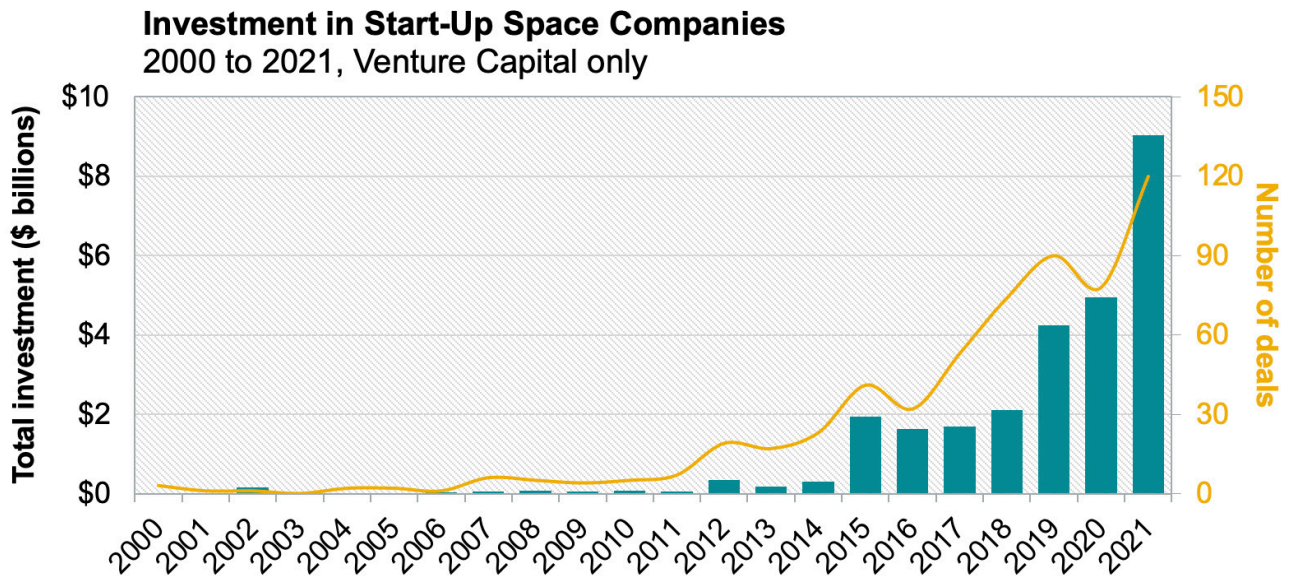


Figure 25: VC investment in start-up space is increasing in number and average magnitude

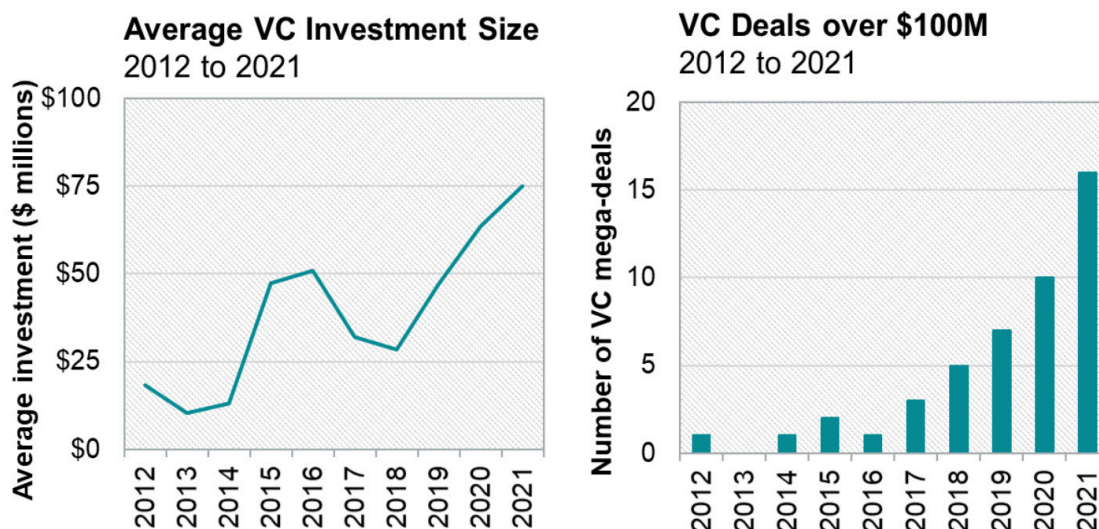
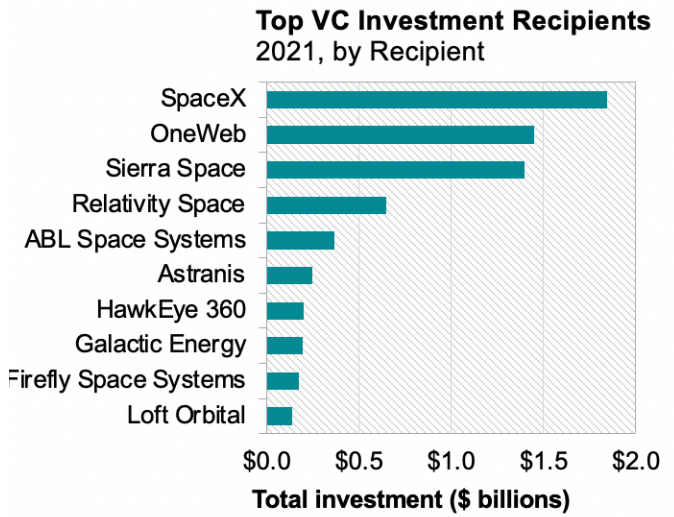


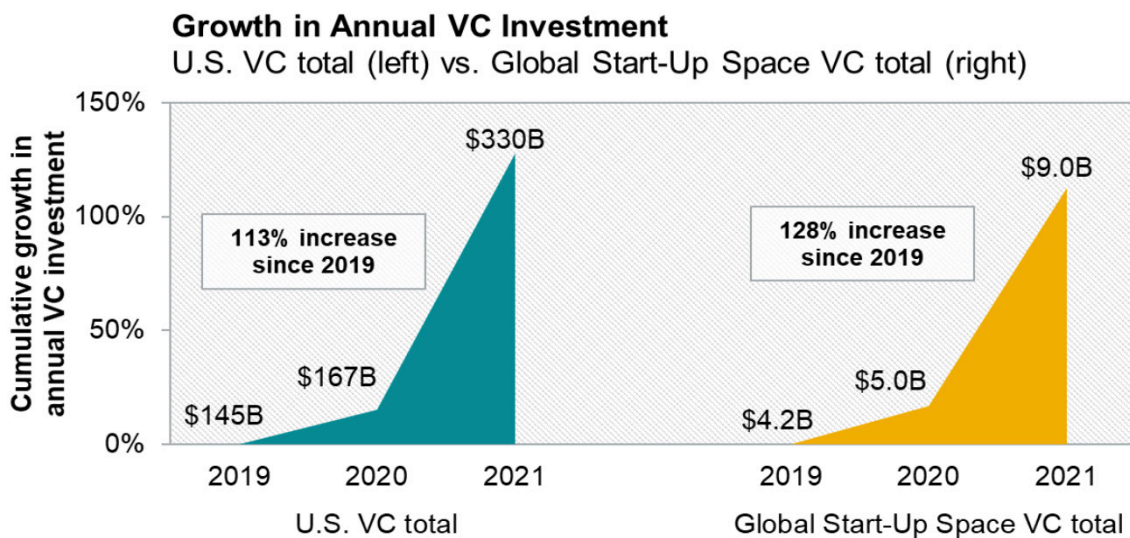
Figure 26 shows the top ten recipients of venture funding in 2021. SpaceX received an estimated \$1.8 billion in VC investment in 2021, the most by any single company. Reports from SpaceX's most recent funding round estimate the company's valuation exceeded \$100 billion. OneWeb received \$1.5 billion in VC funding in 2021, largely supported by corporate venture activity from Bharti Enterprises and Eutelsat. Sierra Space, the space-focused spin-off of Sierra Nevada Corporation, raised \$1.4 billion in a venture round for the continued development of its reusable spaceplane, DreamChaser, as well as its large integrated flexible environment (LIFE) module, an inflatable habitat designed to support crewed on-orbit activities. Other companies attracting large infusions of venture capital during 2021 included small launch providers Relativity Space, raising \$650 million, and ABL Space Systems, raising \$370 million. Record-breaking 2021 space VC investment was consistent with total U.S. VC investment trends. Figure 27 compares start-up space VC funding to the broader U.S. VC market. According to data from PitchBook, total U.S. VC investment rose 128% from \$145 billion in 2019 to \$330 billion in

Figure 26: Top ten recipients of venture funding in 2021



2021, supported by continued low interest rates, increasing venture activity by 'non-traditional' investors such as private equity firms, hedge funds, and corporations, and an increasingly robust exit market.⁹ Over the same period, the start-up space ecosystem has seen annual VC investment rise from \$4.2 billion in 2019 to \$9 billion in 2021 (an increase of 113%).

Figure 27: Record-setting VC investment in 2021 across many industries including space



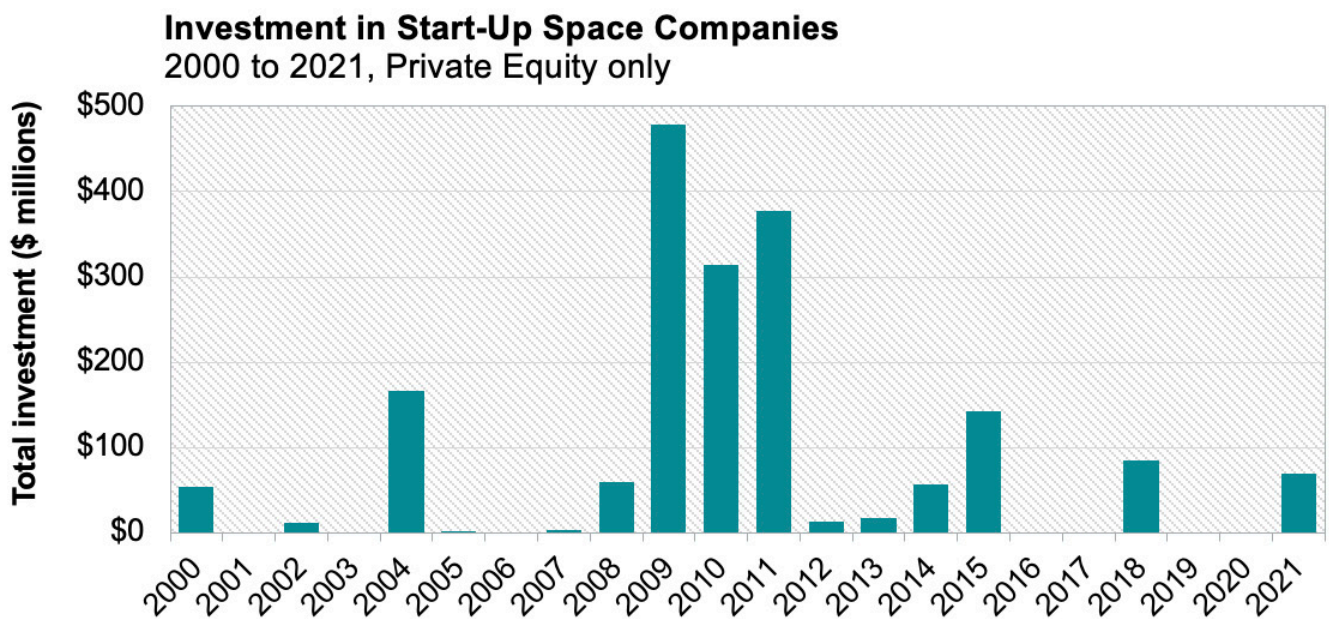
⁹ NVCA/PitchBook, Venture Monitor Q4 2021, January 2022.

Private Equity

The year 2021 marked the first time since 2018 that publicly disclosed PE funding was invested in a start-up space venture. In this context, PE funding represents minority-stake investments in start-up space companies (e.g., the PE firm does not take control of the recipient company). We include majority-stake investments, which are more typical in the PE ecosystem, within the acquisition section. In 2021, two PE deals occurred totaling \$69 million. The largest deal went to Omnispace, a company developing a hybrid space and ground network to provide 5G and internet of things services, soliciting \$60 million in a PE deal led by Fortress Investment Group. The other PE deal is attributable to Kleos Space, a Luxembourg-based start-up developing a radio frequency constella-

tion for reconnaissance, soliciting \$9 million from a team of PE firms. PE investment in space start-ups has totaled \$1.9 billion since 2000. Historically, the appetite for such investment has been limited to investment in the telecommunications industry or government contracting. Previous notable private equity transactions since 2000 include Aabar Investments' \$380 million to Virgin Galactic in 2009 and another \$110 million in 2011. Additionally, O3b received investment of \$230 million in 2010 from a group of investors including Google, North Bridge Venture Partners, Allen & Company, SES, Liberty Global, HSBC Holdings, Development Bank of Southern Africa, Sofina, and Satya Capital. In 2011, Ligado Networks raised \$265 million from Harbinger Capital Partners, Spectrum Equity Management, and other undisclosed investors.

Figure 28: Two PE deals occurred in 2021 totaling \$69 million

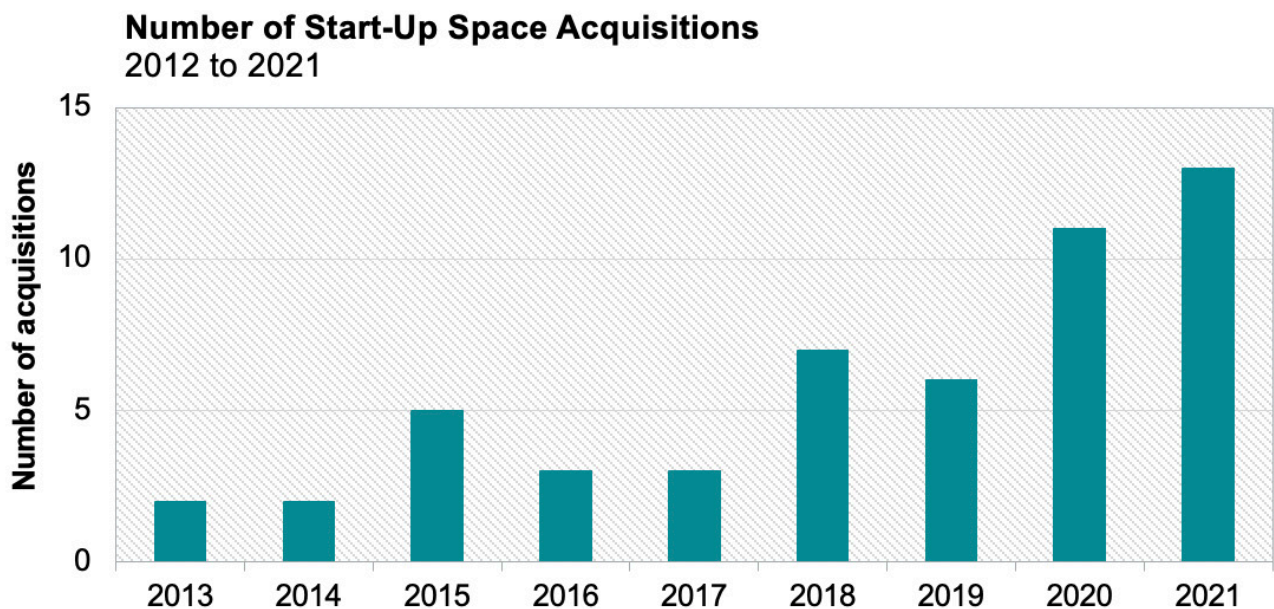


Mergers and Acquisitions

A record number of M&A deals for start-up space companies occurred in 2021. 13 start-up space acquisitions occurred in 2021 totaling \$0.4 billion, compared to 11 in 2020 totaling \$1 billion (see Figure 29).¹⁰ 14 In 2021, space-focused holding companies (Voyager Space Holdings, Redwire) acquired a bevy of emerging technologies with

the goal of supporting operational synergies. In addition to increased acquisition activity by these holding companies, 2021 saw several space SPAC companies acquiring other space start-ups. Leveraging cash from the SPAC IPO process, these companies generally pursued acquisitions to further vertically integrate or to improve near-term revenues. Since 2000, acquisitions of start-up space ventures total \$5.2 billion across 55 deals.

Figure 29: Start-up space acquisitions have increased in frequency



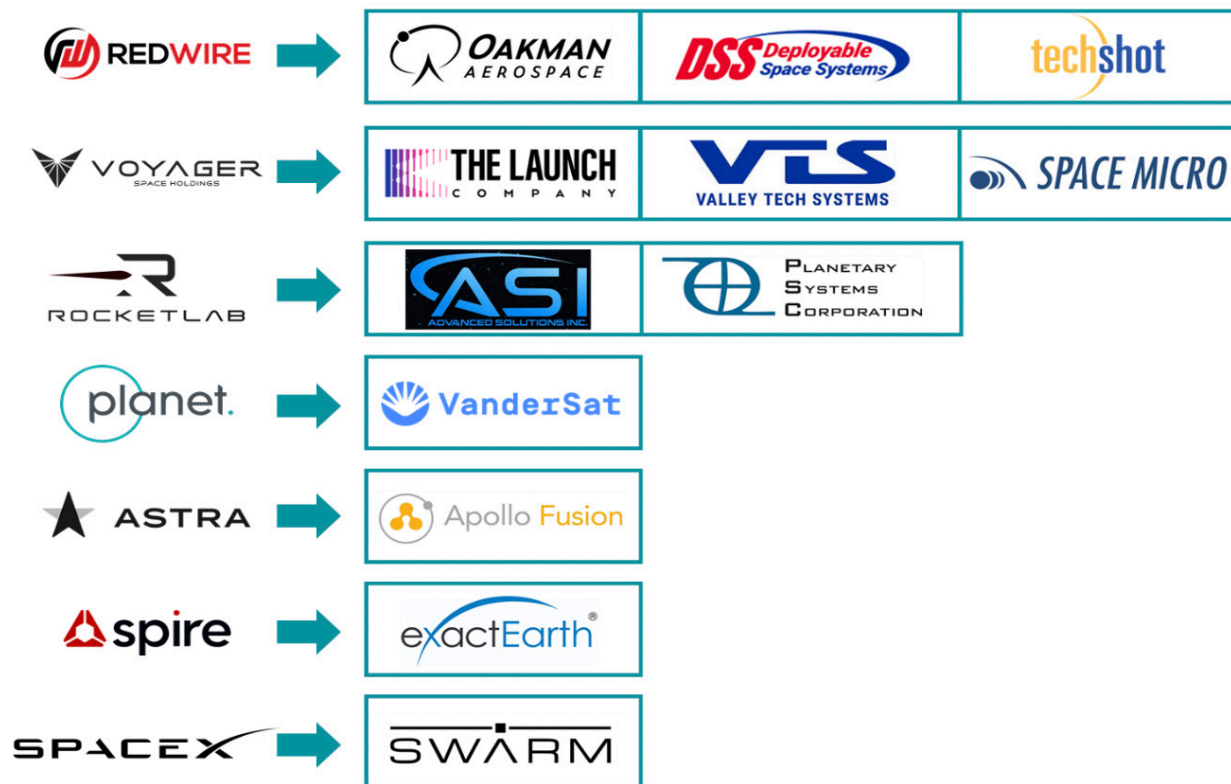
¹⁰ The magnitude of several M&A transactions was undisclosed.

Figure 30 details start-up space acquisitions in 2021, including acquirer and target company. Voyager Space Holdings and Redwire were the entities responsible for the highest number of start-up space acquisitions in 2021 with 3 deals each. Voyager acquired The Launch Company, Valley Tech Systems, and Space Micro in 2021, adding to their portfolio which includes Altius Space Machines, Pioneer Astronautics, and XO Markets (the parent company of NanoRacks). Redwire acquired Oakman Aerospace, Deployable Space Systems, and TechShot in 2021, having previously acquired Made In Space and ROCCOR in 2020. Other examples include Astra's acquisition of Apollo Fusion (electronic propulsion systems), Rocket Lab's acquisition of Advanced Solutions Inc. (flight software, simulation, and GNC systems) and Plan-

etary Systems Corporation (mechanical separation systems and satellite dispensers), Planet's acquisition of VanderSat (Earth surface conditions), and Spire's acquisition of exactEarth (ship-tracking).

Several major space M&A deals occurred outside the defined start-up space ecosystem, generally because the neither the acquiring nor the acquired company had a publicly-reported seed or VC investment prior to the acquisition. Examples in 2021 include Providence Equity Partners' acquisition of Marlink, the maritime connectivity provider, GI Partners acquisition of satellite operator Orbcomm. Prior to 2021, examples include Intelsat's acquisition of Gogo in 2020, Viasat's acquisition of RigNet in 2020, and Northrop Grumman's acquisition of Orbital ATK in 2017.

Figure 30: Acquisition activity in 2021 by acquirer and target company



Public Offering

In 2021 a significant source of start-up funding emerged in the form of public market capital. Space start-ups raised over \$4 billion in public market capital in 2021, representing 28% of total investment over the year.

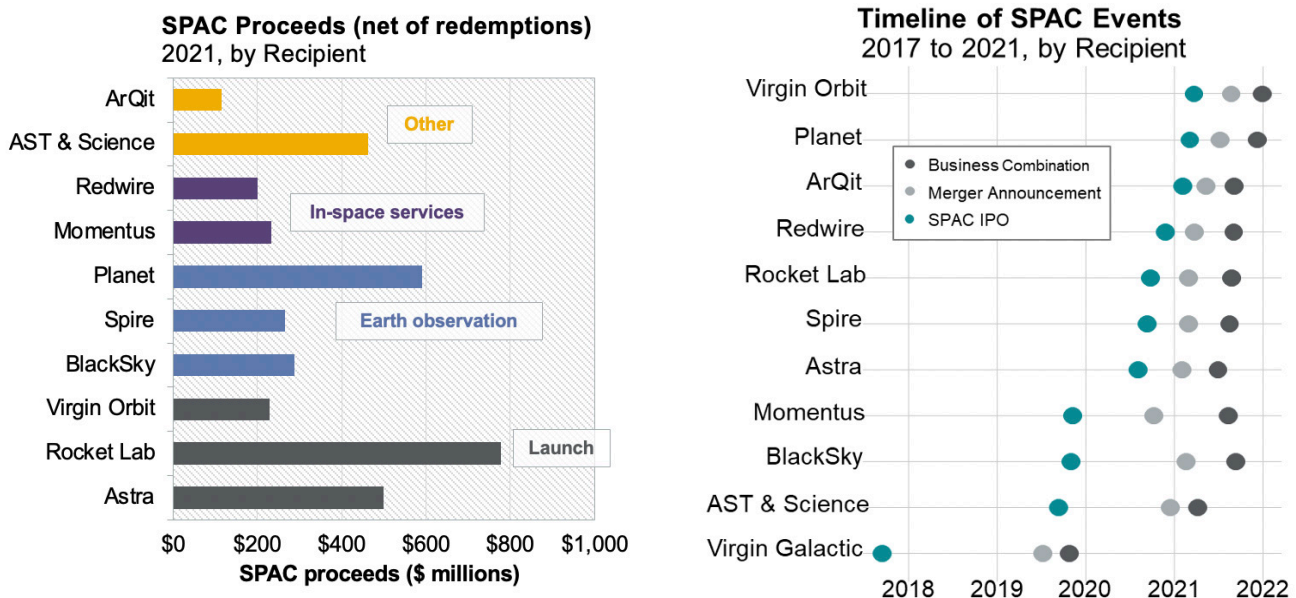
In 2021, ten space start-ups went public via special purpose acquisition company (SPAC), raising nearly \$4 billion (net of shareholder redemptions).¹¹ Three additional space start-ups (Satellogic, Terran Orbital, and Tomorrow.io) announced SPAC deals in 2021; of these, Satellogic completed its business combination in 2022, Terran Orbital still awaits final shareholder approval (expected to close in 2022), and Tomorrow.io's proposed deal was terminated (the company cited "market conditions" as the reason for termination). In addition to SPAC IPO funding in 2021, other notable public start-up space deals include Sidus Space raising \$15 million through the traditional IPO process, Mynaric raising roughly \$76 million by offering shares publicly in the United States

(previously only trading in Germany), and publicly-traded Virgin Galactic raising \$500 million through a secondary stock offering.

Figure 31 highlights SPAC funding raised by space start-ups in 2021 and shows the 11 completed space SPACs, ordered by date of merger announcement. While some space companies had gone public via SPAC in the past decades (Iridium in 2008, Avio in 2016), a surge occurred after Virgin Galactic completed the SPAC IPO process in 2019.

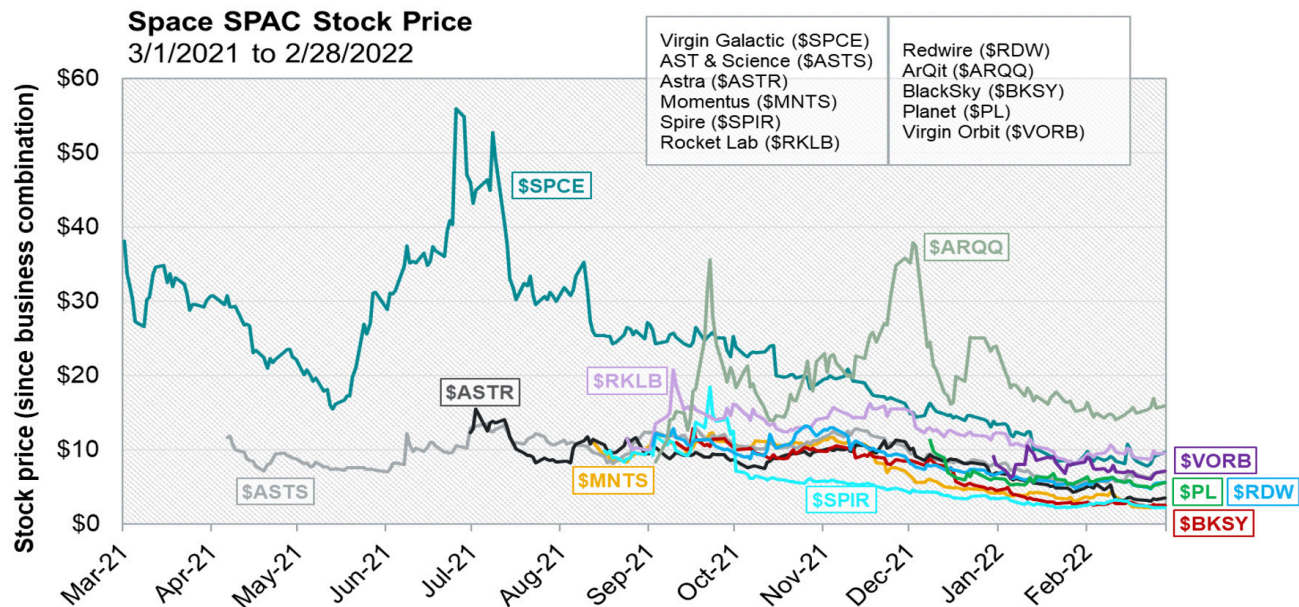
The stock prices of space companies that have merged with SPACs are shown in Figure 32. When a SPAC begins trading publicly, the initial price is typically set at \$10 per share. As of February 28, 2022, ten of the eleven publicly-traded space SPAC companies were priced under \$10 per share. On average, space SPAC stocks have decreased 35% compared to their \$10 per share issue price. Poor or positive performance by space SPACs that now trade publicly could affect the availability of funding for future space deals.

Figure 31: Significant start-up space funding raised via SPAC in 2021



¹¹ The Start-Up Space Report considers actual SPAC proceeds (e.g., net of redemptions) only once the business combination is approved and the acquired company starts to trade as a newly merged company (under the new ticker symbol).

Figure 32: Publicly-traded space SPAC stock prices



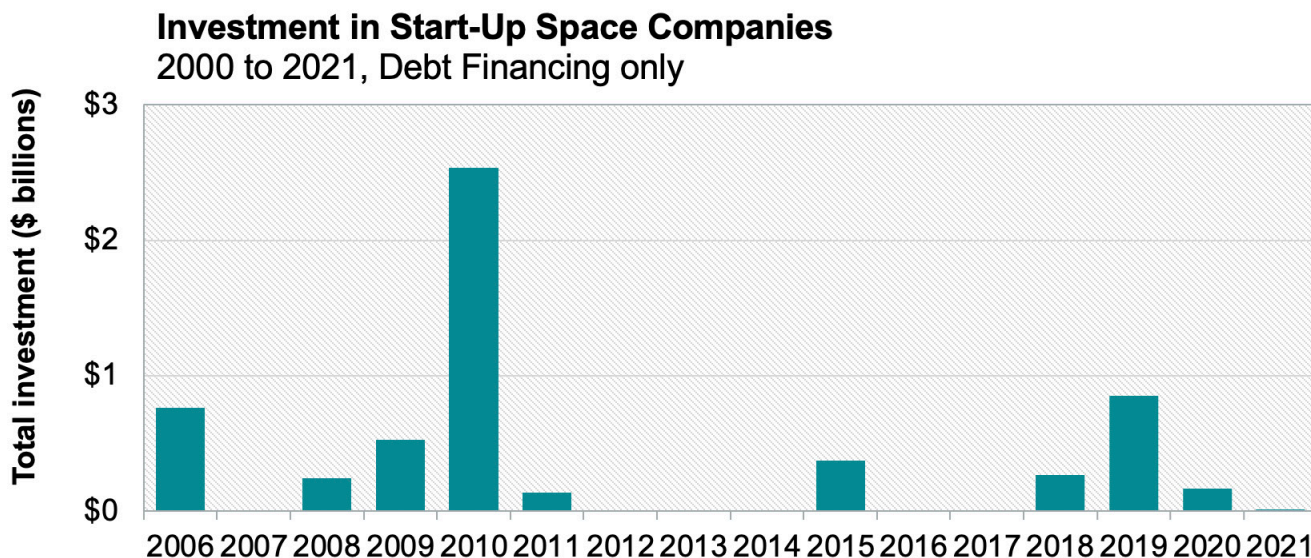
Debt Financing

Only 1 debt financing round occurred in 2021, roughly \$12 million to EnduroSat from the European Investment Bank (see Figure 31). This is a decline from the 9 reported debt financing rounds in 2020 totaling \$166 million (Astranis and One-Web each raised \$50 million debt financing deals in 2020).

Since 2000, debt financing for start-up space ventures totals \$5.9 billion. Several debt financing

transactions occurred between 2006 and 2010, attributable to companies such as Protostar (2006, 2008), WildBlue (2006), O3b (2009, 2010), and Ligado Networks (2010). The spike in 2015 represents debt financing deals for O3b, Planet, and UrtheCast. Debt financing rose again in 2018 and 2019, largely driven by transactions reported by SpaceX, Audacy, Kacific Broadband Satellites, and BlackSky. For example, in 2019, Kacific raised a \$160 million debt round from the Asian Development Bank and Blacksky raised \$50 million from Intelsat.

Figure 33: One debt financing round occurred in 2021 for roughly \$12 million



Conclusion

As detailed throughout the report, 2021 was a record-setting year for start-up space funding. Private investors poured a historic magnitude of capital into start-up space companies, and public markets emerged as a significant source of funding for start-ups across all space categories.

To sustain levels of investment seen in 2021, space start-ups will need to assuage investor concerns related to unproven business models, uncertain customer bases, and the lengthy time horizons needed to achieve profitability. For some of the newly public space companies, the transparency afforded by quarterly financial reporting will create significant pressure to achieve the financial projections presented upon SPAC announcement. For privately funded space companies, the runway

to achieve profitability may be relatively longer and more forgiving given the risk tolerance typical of any venture capital-funded industry. However, the availability of private funding could be negatively impacted by macroeconomic factors such as inflation.

In either case, the next few years will undoubtedly see several space start-ups attempt to pivot from investment-supported development and deployment to business-supported operations while navigating an abundance of technical, regulatory, and economic challenges.



Private investors poured a historic magnitude of capital into start-up space companies, and public markets emerged as a significant source of funding for start-ups across all space categories.

START-UP SPACE: WHAT'S NEXT?

2021 was another record-setting year for start-up space, with more than \$15 billion in investment reported. Several companies are planning important technical demonstrations for 2022 and beyond, and others are promising an expansion of operations. The revenue dynamics and operational performance of maturing start-up space firms are important trends to watch in start-up space.

Large LEO Constellations

Deployment of SpaceX and OneWeb's large LEO telecommunications constellations, which began in 2019, has continued steadily in 2020 and 2021. At the time of writing, SpaceX has deployed over 2,000 operational Starlink satellites, currently offering beta service (up to 150 Mbps) for select users in 29 countries, with pending regulatory approval in many more. SpaceX recently announced a premium service with speeds up to 500 Mbps targeted towards enterprise customers. Similarly, OneWeb has deployed over 300 satellites and rolled out initial commercial service in 2021 to select northern regions including Alaska, the United Kingdom, Greenland, and Iceland. OneWeb plans to extend coverage by the end of 2022. Tens of thousands of additional smallsats are planned for the next several years with other communications constellations scheduled to deploy (e.g., Amazon Kuiper and Telesat LightSpeed).

The year 2021 was also important for Earth observation satellite start-ups. Several operators received substantial private and public funding for the development and deployment of new constellations. In addition, government agencies like the National Reconnaissance Office (NRO) and NASA have signaled increasing interest in purchasing commercial imagery by awarding new contracts. These contracts, coupled with increasing investment, are indicators of continuing growth in Earth observation small satellites.

Both Earth observation and telecommunications smallsat business ventures face significant hurdles in proving their business models. Earth observation satellite operators seek to expand markets for data analytics to new types of users, while telecom constellations will face strong competition from terrestrial competitors, price pressure on bandwidth, and have still not solved the core problem of convenient and price-appropriate ground infrastructure.

Smallsat Launch Ventures

Dozens of new small launch vehicles are in varying phases of development and operation, many receiving significant investment in the past few years. Rocket Lab, Astra, and Virgin Orbit each conducted successful operational launches and completed SPAC mergers in 2021, receiving considerable investment in the process. In addition, small launch providers Relativity Space and ABL Space Systems raised the 4th and 5th largest venture capital rounds in 2021, \$650 million and \$370 million, respectively.

Small launch ventures are of interest to national security customers. U.S. government small launch programs include contracts to start-up space firms Virgin Orbit, Rocket Lab, and Astra, among others. The NRO is deepening its ties with Rocket Lab through smallsat launches and the U.S. Air Force has awarded multiple small launch contracts through expedited mechanisms. The small launch industry is dynamic and could likely experience significant changes as companies mature business plans or leave the market.

While governments are interested in small launch vehicles, competition with larger vehicles and business case uncertainty will shape the commercial market. With 100+ prospective small launch vehicles in some stage of planning or development, many not progressing beyond paper and lacking significant investment, a shakeout of the market is inevitable as it matures.

Space Tourism (Commercial Human Spaceflight)

Long awaited commercial suborbital human spaceflights began in 2021. Virgin Galactic and Blue Origin both conducted crewed launches with their respective founders. Blue Origin has since conducted 3 additional suborbital flights, while Virgin Galactic delayed further flights until the end of 2022 to refurbish its VSS Unity spacecraft and VMS Eve carrier aircraft. Further, SpaceX successfully completed three human spaceflight missions in 2021, two for NASA and its first all-civilian flight on the Inspiration4 mission. SpaceX has additional commercial human spaceflight contracts with Axiom, Space Adventures, and the recently announced Polaris program, which will consist of up to three human spaceflight missions ultimately culminating with the first crewed Starship flight.

The year 2021 ended with NASA selecting three U.S. companies to develop designs for space stations and other commercial space destinations including two start up space companies Blue Origin and Nanoracks, and Northrop Grumman. The companies will share over \$400 million in funding allocated to the program. These companies join Axiom Space in the race to develop a commercial space station, with Axiom previously awarded \$140 million from NASA in 2020 for a private module to be attached to the ISS.

On-Orbit Servicing, Assembly, and Manufacturing

Following Northrop Grumman's successful mission extension vehicle missions in 2019 and 2020, there is increasing interest in commercial on-orbit servicing, assembly, and manufacturing (OSAM) technologies and markets, including life extension, debris removal, and in-space transportation. Companies are designing and in some cases developing spacecraft capable of debris removal, orbital transfers, satellite deployments, satellite refueling, and other life extension services. Other OSAM services under development

include robotic assembly and manufacturing of industrial and medical products that benefit from microgravity environments. OSAM activities have potential to expand the on-orbit ecosystem; they face significant technology and business barriers.

Exploration

NASA's Artemis program, which seeks to return humans to the moon by 2025, creates significant opportunities for start-up companies. Several major missions to the moon are expected to take place in 2022 including Artemis I, and others supported by start-up companies including Intuitive Machines, Astrobotic, ispace, Orbit Beyond, Rocket Lab, and Redwire. Fourteen companies in total are engaging in NASA's Commercial Lunar Payload Services (CLPS) program, competing for task orders to fly specific research payloads or instruments to the moon. Start-up companies can also increase readiness of their technologies through lunar-focused Small Business Innovation Research awards and other initiatives. NASA's Artemis program will continue to provide on-ramps and opportunities throughout the decade as NASA aims to create a sustainable lunar presence. Governments, particularly NASA, are likely to remain the primary source of demand for these activities.

National Security

The Space Development Agency awarded several contracts to start-ups to support the national defense space architecture. NRO awarded study contracts to commercial Earth observation companies to expand suppliers of commercial data. U.S. government small launch programs include contracts to start-up space firms Virgin Orbit, Rocket Lab, and Astra, among others. Governments other than the U.S. are also increasingly aiming to leverage domestic start-up space capabilities. Government stakeholders are an important element of the potential success of many venture-funded space start-ups.

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