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Space Angels, Multiple Equilibria, and Financing the Space Economy

Chad Anderson had reason to be proud of his young space-focused investment firm, Space Angels. Since becoming CEO, Anderson had overseen growth along multiple dimensions: from practically zero annual revenue to $850,000; from zero investment capital under management to approximately $27 million; from 20 investor members to 250; and from no portfolio companies to 26. And if the first quarter of 2019 was any indication, this growth was set to continue. According to Dylan Taylor, an early Space Angels investor and prominent space financier, Space Angels was "the preeminent name in space finance" and was able to offer a unique seal of approval in the nascent space capital marketplace: "If we're in the deal, they [other space investors] are in, too."[1]

Space Angels was not alone, as high-profile rocket launches, rapid progress in satellite and other technology, and a wave of entrepreneurship had brought investors' attention to the commercialization of space. In the past decade, the space startup sector as a whole had enjoyed annual growth rates of 15-20%—and perhaps even greater—in both the size of investment inflows and the number of venture capital firms making investments. This growth came through not just space-focused investors, such as Space Angels and several newly announced sector-focused funds (see **Appendix C** for a list of announced and competing space funds), but also large generalists such as Draper Fisher Jurvetson, Shasta Ventures, and Bessemer Venture Partners. In 2015, the latter announced a $1.6 billion fund, BVP IX to "invest in innovative companies, to include the space sector."[2] Will Porteous, of the fund RRE Ventures, said in late 2018: "This is going to be looked back on as a golden period, from my standpoint, in terms of dollars flowing into the [space] sector."[3]

Anderson believed that Space Angels—along with these other investors—was vital to the development of the market for commercial space activities. He said, "We are the ones with the conviction to say 'There is a trend developing here, there is going to be a market!' If you live and breathe the space economy, all day every day, you're better positioned to identify the gaps in the market, and if you notice that customers are interested in paying for something, then you *have* a market. Our objective is to educate the market and to help the market be more sophisticated. To do so, we began by gathering data and intelligence." Moreover, Anderson was optimistic about Space Angels' role in that market: "It's a matter of continuously improving. We're already years ahead of the competition, and if we continue innovating, we can stay in front of the pack."

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But success was far from guaranteed, as decades of grand visions of space commerce had gone unrealized. Did Space Angels have the right strategy and model to build a space economy and prove space skeptics wrong? How should it evolve along with that sector to ensure its place in it?

Explore | Invest |Ascend

Founded in 2007 by Guillermo Söhnlein and Burton Lee, Space Angels Network began by facilitating a small group of space enthusiasts' investments in the nascent New Space sector. Over its first five years, it grew from four to 20 investing members, but its scale was limited by its informal structure. During that period, a well-known space entrepreneur purchased the Network (for a modest price) and subsequently split his ownership with Joe Landon (MBA '07), who had been involved with the Network from its early days and would remain involved over the next several years, for example as Chairman.

In 2012, Anderson connected with Landon, looking to get involved in the business of financing space startups, and he was offered the opportunity to lead the organization. Anderson, at the time an MBA student at Oxford University, became convinced that, although he didn't have any formal aerospace training, there was a growing need for businesspeople in the nascent space sector. Anderson moved to New York after graduation to take on the full-time role of CEO.

Anderson took the next six years to professionalize, grow, and transform Space Angels Network. Without financial resources, his strategy began with building the most comprehensive dataset on activity and trends in space investments. Space Angels would use this dataset to educate and inform the market, combat common misconceptions, and help investors new to space understand the early market developments that Space Angels was seeing. One advantage of this strategy was that data are free: in its early days Space Angels had no money. But the assembled dataset proved to be valuable: "We guarded this information very carefully for the first few years" Anderson said, "sharing confidentially with members and releasing only top-level figures on conference panels and in interviews with media." In October 2017, Space Angels launched the Space Investment Quarterly, based on this data, with the aim of uncovering insights about investing in the space economy **(see Exhibits 1-4)**. This approach was essential for this dynamic new market, Anderson said, because:

> "At the time, space investing was still a novel concept. Awareness of entrepreneurial space ventures was increasing, but investors still needed convincing. We had to help them understand the real risks and opportunities. We had to make this information free: give them access to the data first and then, only once they understood the magnitude of the opportunity, could we talk about compensation."

By 2015, Space Angels began a gradual shift away from the decentralized investing model typical of an angel network, which Anderson claimed was "inefficient at best, dysfunctional at worst." Space Angels would start to take on a greater role in managing its members' investments with the launch of an Angel Fund. At the same time, membership had grown to 110 and Space Angels had raised $350,000 from a group of Founding Members to fund operations, hire staff, and organize its first fund investment (as a fund manager) of $500,000. Anderson disbanded the group of management team volunteers and began asking inactive members to leave the network so as to limit costs and build a more focused culture of investing.

In early 2017, Anderson rebranded the firm, dropping the word "Network" from its name, selecting a new logo, and adopting the motto: Explore | Invest |Ascend. Later in 2017, Space Angels completed the shift to what Anderson deemed a hybrid of "the best of traditional venture capital and angel investing." The firm would now offer two investment vehicles to investors. The first, named the "Angel Fund," was targeted at individual investors with more interest in active diligence and participation;

the second, named "Space Capital," was designed to appeal to institutional investors and individuals interested in a more traditional venture capital fund.

The Angel Fund sought to bring some of the economies of scale and efficiencies of a VC approach to the angel investing model. Anderson set up a series of Special Purpose Vehicles (SPVs) and began to raise capital from a limited pool of (approximately 250) investors under a standard "2 and 20" fee structure (in which the fund charges annual management fees of 2% of invested assets plus 20% of any realized profits on an investment). But, to continue educating the market and retain some of the appeal of the angel model, these investors would be given access to the data and information gathered by Space Angels as part of its due diligence process and, critically, make their own investment decisions on whether to invest in the deals. To facilitate this new model, Anderson explained, "Space Angels pioneered a new online investment platform to streamline the communication of investment opportunities, simplify legal documentation, and drive greater investor engagement. Our investment into the platform, particularly for an early-stage company, was significant. We're now on version 3.1 and have invested over $200,000 in its development." Angel Fund investors were, on average, in their mid-forties with net worth of approximately $10-50 million dollars, and the average amount invested per year per investor was $100,000. Each investor signed a membership agreement with Space Angels (primarily to protect confidential company information) which gave access to deals and asked investors to remain active (i.e., by investing at least $25,000 per year).

Space Capital LP was a traditional, albeit sector-focused, early-stage VC fund. It was a 10-year fund, with capital being deployed over the first four years and locked in for another six before "exit," when the initial investors would realize a return by liquidating their investment. Since its start in November 2017, Space Capital had raised $16 million (Anderson planned to cap it at $25 million) and had made investments in seven companies: GHGSat, Isotropic Systems, LeoLabs, NanoRacks, SpeQtral, Skywatch, and Totum Labs.

Justus Kilian, a Principal at Space Angels, and a Venture Partner at Space Capital, believed the two vehicles were strong complements: "The Angel and VC funds work together. The Angel Fund gives us the flexibility to invest in projects that the VC fund wouldn't, and the VC fund gives a stability and legitimacy to the company which reassure the Angels."

Space Angels proactively sourced deals through reputable partners such as NASA, DARPA, MIT Media Lab, Satellite Applications Catapult in the UK, and the ESA Business Incubation Centre at ETH Zürich, through student groups, incubators, and accelerators, and by simply leveraging the reputation of the company as a knowledgeable partner for space entrepreneurs. The set of Space Angels portfolio companies included many of the most prominent startups in the sector: Astrobotic Technology specialized in payload delivery and communications services to the Moon; Made in Space manufactured materials in orbit to be used in space and on Earth; NanoRacks manufactured hardware and provided hosting and other services in Low Earth Orbit; and Planet operated the largest constellation of Earth Observation satellites. (See **Appendix A** for a list of criteria that Space Angels used to select investments and **Appendix B** for its complete investment portfolio)

As the company's model evolved, so too did its relationship with (and the makeup of) its investors. In the early years, Space Angels Network investors were space enthusiasts for whom return on capital was arguably of secondary importance. As Dylan Taylor explained: "It wasn't about the money. It was about: How do you build the appropriate capital infrastructure for the space startup sector?" Investors in the Angel Fund and Space Capital were, in contrast, "not any different from non-space investors in terms of the return/impact tradeoff. It's a spectrum. On one end, it's all about impact, with investors focused on helping humanity go to Mars; on the other, investors are focused solely on financial return…Previously, with the majority of investors being enthusiasts, skepticism was a common sentiment among finance-first investors. But as the space economy matures, the spectrum is becoming more balanced with more mainstream investors becoming aware of the opportunity," said Anderson.

Competition in Space Finance

The growth of Space Angels was part of a broader increase in the allocation of attention and capital to entrepreneurial ventures in the space sector. Competitors to Space Angels were also partners in building the financial markets' acceptance of space as a worthwhile investment target. And their collective efforts seemed to be working: in an interview with BNN Bloomberg in late 2018, Anderson noted "back then [2012] there wasn't a whole lot of entrepreneurial activity in space, but today it's a much different story. It seems like every top VC has a space company in their portfolio and they're looking to do more."[4] "Venture capital investment in space is now a generally accepted theme," he said, adding that 41 of the 100 largest VC firms have invested in at least one space startup.[5] In addition to venture capital, large banks were also entering the market, with Morgan Stanley hosting a 'Space Summit' in New York City[6] and investing, through its alternative investment fund, in a small launch company's Series B financing.[7] In late 2018, Will Porteous, of RRE Ventures, said of the funding surge: "I don't see it slowing down. I see the flows continuing. And, frankly, it's a pleasant surprise."[8]

Bryce Space and Technology—the industry's leading consultancy—catalogued the growth in space startup financing through a variety of indicators.[9] Space Angels' own data on the industry offered another, generally consistent, view of its status and growth.

The sheer number of investors in space had grown dramatically in recent years **(see Exhibit 1)**. Bryce catalogued an average of four VC firms investing in space each year from 2000 through 2005, only 9 per year from 2006 through 2011, but an average of 60 investing each year from 2012 through 2017 (and 87 in 2017). Moreover, new investors made up nearly half of these VC firms, with 43 of the 87 investors in 2017 not having made previous investments in the start-up space ecosystem. Space Angels catalogued 587 venture capital funds with at least one space investment in their portfolio as of Q1 2019, compared to a mere dozen VC funds back in 2009. It also noted that, in addition to returning investors Kleiner Perkins, Data Collective, Spark Capital, Khosla Ventures, RRE, Canaan Partners, and GV (Google Ventures), a number of top VCs entered the space economy in 2018—including Greylock Ventures, Andreessen Horowitz, Accel Partners, and Playground Ventures. This growth went beyond venture capitalists, extending to angel investors. Bryce calculated that only one angel investor funded a venture in space on average in each year from 2000 through 2005, only five per year from 2006 through 2011, but an average of 25 in each year from 2012 through 2017. Overall, Bryce identified 164 investors in 2017 compared to just eight on average between 2000 and 2005.

These investors were bringing more capital with them over time, as well (see **Exhibits 2** and **3**). According to Bryce, of the total $18.4 billion invested since 2000 in space startups, $2.5 billion came in 2017 alone, and more than 80% of the $6.3 billion in VC funding since 2000 was invested from 2015 through 2017. Investments since 2000 had also included $2.3 billion in seed funding, $1.7 billion in private equity, and $4.5 billion in debt financing. Similarly, Space Angels reported that of the total $20.4 billion invested in private space companies since 2009, $16.3 billion (or 80%) had come in just the last four years (2015-1Q2019). The mix of funding sources included corporate investors (39%), VC funds (22%), angels (21%), and others (18%). Both Bryce and Space Angels showed that the majority of funding went to U.S.-based companies. According to Bryce, 75% of global investment in space startups went to U.S.-based firms along with 90% of all angel and seed investment in earlier stage startups. According to Space Angels, 53% of funding went to US-based companies, while the rest went to UK (26%), France (7%), China (5%), Singapore (1%), Canada (1%), and other countries (7%).

Finally, this growth in the number of investors and scale of resources funded the growth of more space startups (see **Exhibits 2** and **3**). Again, according to Bryce, over 180 new angel- and venture-backed space companies were started and funded in the period 2000 to 2017, the vast majority since

2012. Fully 73 of these companies reported receiving new funding in 2017, including 44 VC deals. Space Angels reported that $20.4 billion had been invested into 435 private companies since 2009, 90% of which received their first outside investment since 2012; up from a mere two dozen in 2009.

Most relevant to Space Angels was the seed funding (or angel investing) sub-sector of space finance. The $2.3 billion in seed investments since 2000 was dominated by the "super angel" investors—in Bryce's terminology—of Jeff Bezos, Elon Musk, and Richard Branson, each of whom had their own startup. More conventional seed financing was relatively small in magnitude, at $46.5 million in 2017, but it had increased 150 percent since 2015, and a number of new space funds had recently been launched (see a list of such funds, compiled by Space Angels, in **Appendix C**). Among the many funds launched, those that were funded and operational by late 2018 included Seraphim Capital, a U.K.-based public-private "$95 million space-focused fund" launched in 2016 with funding from the British Business Bank, and the country of Luxembourg's public venture capital fund, which reports said was funded with approximately 100 million euros ($116 million).[10]

Anderson expressed confidence that Space Angels occupied a valuable niche within the broad space financing market, concentrating on investments in companies too small and too early for generalist venture capitalists' tastes. "We want to stay focused on what we know and do best, stay in our lane and keep improving our offering. The traditional funds tend not to invest early, they typically invest in series B and later, for a number of reasons" Anderson said. Taylor agreed: "If anything, the capital markets are going later, with most Angel investors moving to [series] A and most VCs to later stage."[11] Anderson also suggested that Space Angels was well-positioned relative to other angel investors, "Developing a reputation for deal sourcing takes a long time and it is difficult to replicate."

Multiple equilibria and equilibrium selection

Key to Space Angels' strategy was the idea that it would have to help create at least two markets: a capital market for investments in early-stage space startups, and a broader market for the products those space startups would produce.

In particular, longer-horizon space investments were difficult to market to investors, even those such as university endowments, Sovereign Wealth Funds, and pension funds for whom long-horizon investments were essential components of a balanced portfolio, "unless it was something transformational, with 1000x returns" according to Dylan Taylor. Some sovereign wealth funds and nations, including the United Arab Emirates and Luxembourg, had invested in long-term, high-risk ventures, but they were the exceptions.

Anderson believed the Angel Fund and Space Capital brought attention to early-stage startups ignored by the broader investment community: "The sector hasn't been taken seriously because, until now, there haven't been many serious players. But they're coming and we're looking to find them and fund them." Since 2015, Space Angels had made 33 investments (37 counting Space Capital) in 26 portfolio companies, less than 2% of the companies it evaluated (over 500 per year as of 2018). As a sector-focused investor, Anderson claimed, "our investments serve as a signal to other investors that they are quality opportunities. This is evidenced by our graduation rate (number of portfolio companies that have secured additional outside capital), 72%[12] as of the end of 2018.[13] By educating the market and the investors, we help to create the demand… While companies in existing markets, like satellites or launch, are easier to sell to investors because they don't need as much convincing that customers exists, for new markets such as space situational awareness, deep space platforms, or space manufacturing, it's up to us to get the deal rolling."

Technology and access to information played an important role in this effort, especially for the Angel Fund investors. The Angel Fund's online platform, secure and restricted to members, contained detailed information on the active investments Space Angels has chosen. Each deal had a full set of financial statements, a due-diligence memo, videos, and investor calls. A curated "deal room" had information on new investment opportunities," while an "invest button" fully automated the execution of legal documents and funding. Of course, this technology came with risks: "This platform has a lot of proprietary information, so obviously it's important to protect it from industry insiders seeking competitive intelligence and bad faith usage." Additionally, Anderson organized an annual Expedition, an experience for 20 of the most active Angel Fund investors to get a first-hand look at the nascent private space industry. The event aimed to make space investments "more tangible" and foster their desire to invest in the sector.[14]

Space Angels also deployed marketing and public relations tools to build these markets. Christina Mannatt, head of marketing, explained:

> "We have a responsibility to explain complex things in a way, through a more reliable language, without dumbing it down. The majority of the population is not fluent in rocket science, but all have a relation to space, either emotionally through nostalgia or technologically through the GPS on their phones. It is important for people to understand what it takes to power that economy. ... So, we are putting content out into the world for the general space ecosystem. Because potential members could be anywhere."

Upon investing, Space Angels' efforts turned to helping their portfolio companies build and manage their businesses, many of which became interlinked and thus part of the space economy's broader development. Space Angels routinely helped portfolio companies connect to each other and other strategic partners, reviewed quarterly reports, checked in on operations monthly, and occasionally joined the company's board. (See **Appendix A** for a list of activities)

Creating these new markets would require risk-taking. Anderson expected half of the companies Space Angels invested in to fail. As of 2018, however, only one of Space Angels' 26 portfolio companies had missed a further funding round (Planetary Resources[15]), while over half had reached Series B funding. As Anderson said, "As a team, it's important to continuously remind ourselves that we have to be willing to take risks."

Academic research had suggested that over-heated investment cycles, in which risk became underpriced and a "bubble" formed, could have beneficial effects in nascent, technology-dependent industries. Economists Ramana Nanda and Matthew Rhodes-Kropf, both of Harvard Business School, wrote in 2013: "We find that firms that are funded in hot times are more likely to fail but simultaneously create more value if they succeed… We find that in addition to being valued higher on the day of their IPO, successful firms that are funded in hot markets had more patents and received more citations in the initial years following their first funding than firms funded in less heady times."[16]

Anderson sounded a cautionary note, however, about feeding a space investment bubble:

> "'Hype' without substance is a disservice to everyone involved. You want people to get behind good business plans. There is a lot of momentum in the market right now and we don't want it to stop. So, we need to avoid leaving investors with a bad taste in their mouth. We aim to be transparent about the companies which are doing well and those which aren't."

Space Angels was, in other words, concerned not only with its own success but with that of the broader space sector. As Justus Kilian put it: "Investing in space is more than investing in a handful of companies, it is investing in an entire ecosystem, a new economy."

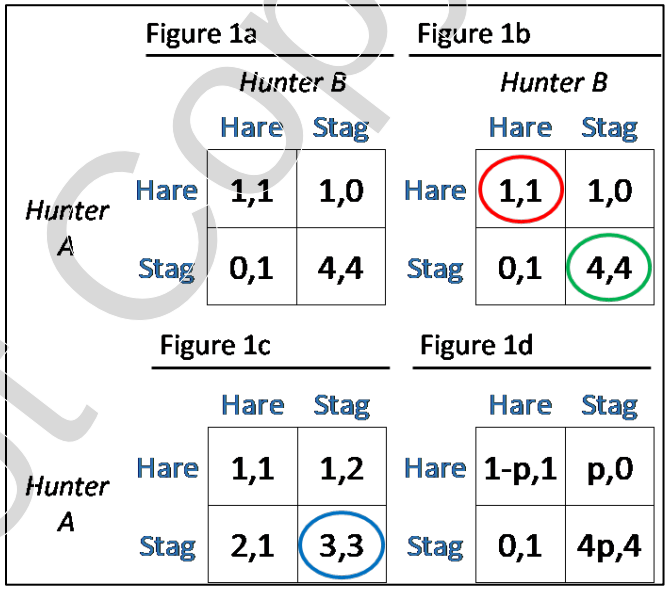
Big Game Hunting in Space

Interdependencies such as those among the space businesses that Space Angels was trying to nurture were of great interest to economists because they involved effects, called externalities or complementarities, poorly priced in the marketplace. Finding mechanisms by which companies, and thus society, could realize the value of those complementarities could deliver gains to all parties.

One way in which economists analyzed markets characterized by complementarities was through a game called the Stag Hunt.[17] In a Stag Hunt game, there are two hunters, A and B. Each hunter chooses whether to hunt a hare or a stag. Hares can be hunted individually, while stags must be hunted together, and stags are worth much more than hares to the hunters. Of course, the hares and stags are metaphors for possible strategies in a wide range of settings, including an industry like the space sector. One might readily imagine which activities in space better fit under the categories of hares—modest and unilaterally achievable—and stags—big, bold and necessarily team efforts.

Below, **Figure 1a** shows a Stag Hunt game as typically presented, with hunter A's choices in the rows and hunter B's choices in the columns. Within each cell of the two-by-two matrix summarizing the game, the first number represents the payoff to A and the second number the payoff to B.

Figure 1 A Stag Hunt game



Source: Casewriter. This figure also appears in the HBS publication: https://digital.hbs.edu/digital-infrastructure/hunting-big-game-in-commercial-space/.

Figure 1b shows the *two* equilibria of the Stag Hunt game.[18] To find them, consider the strategies each hunter should adopt given the other hunter's play. Suppose hunter A expects hunter B to hunt the hare: then it will be better for A to hunt a hare (and earn 1) than to hunt a stag (and earn 0). The same logic holds for hunter B, so one equilibrium of the game is for both A and B to hunt the hare, as outlined in red in the figure. But now suppose that hunter A expects hunter B to hunt the stag. Then it will be better for A to hunt the stag (and earn 4) than to hunt the hare (and earn 1), and the same logic

holds for hunter B. Therefore, a second equilibrium holds in which both A and B hunt the stag, outlined in green in the figure, and this equilibrium is substantially better for each of the hunters.

The power of the Stag Hunt game is to capture the all-too-common situation in which complementarities not rewarded by the market can leave an industry (or a society) stuck in an inferior equilibrium. Everyone in the Stag Hunt would agree that cooperatively hunting the stag is a superior equilibrium, but no individual has the incentive to unilaterally pursue a stag once the players find themselves hunting hares. To see this explicitly, note that starting from the upper left corner of **Figure 1b**, either individual would lose by unilaterally pursuing the stag.

Economists have identified at least two ways to overcome this risk in the Stag Hunt: public (or private) intervention in payoffs, and private coordination through reputation and repeated play of the game. Both of these strategies were directly relevant to the space sector and Space Angels' strategy.

For example, consider what a government (or large investor) might do to change incentives. It might subsidize (fund) unsuccessful stag hunting and tax (retain a share of the returns to) successful stag hunting, producing payoffs like those shown in **Figure 1c**. In this situation, the *only* equilibrium is to hunt the stag together. Everyone wins, because the government (or large investor) has used its tools to manage the complementarities. In the context of space, some of the current efforts of commercial space companies can be thought of as hares, with the bigger, bolder visions—the stags—left unpursued.

Space Angels' efforts could be understood as an example of this approach to solving the Stag Hunt, an approach adopted by the VC sector in general. Skeptical of the government's ability to solve such an incentives problem, Chad Anderson and his team were stepping in: "Governments are not good at determining what can be done commercially. They are good at determining the tech they need to achieve their goals but they're not great at understanding the market, what the market needs. In commercial terms, timing is everything, and they don't understand the market dynamics well enough to know when to put the money in."

An alternative solution to the Stag Hunt is for reputation and repeated play to support cooperation. Suppose, starting from a hare-hunting equilibrium, hunter A unilaterally announces that he will hunt a stag. If this announcement is believed by hunter B with probability p, hunter A will find it better to abide by his announcement and hunt the stag whenever $p>0.25$ (see **Figure 1d**). How can such trust be established? By repeated play and the building up of credibility. Among new commercial space companies, where the players are few and the key decision-makers even fewer, establishing such reputations was a plausible approach. In fact, Space Angels' broader strategy of encouraging more risk-taking and bolder ventures in space, as well as its serving as a focal point for a network of repeated interactions among the leaders of the space sector, could be seen as contributing to this possible solution of the Stag Hunt.

Conclusion

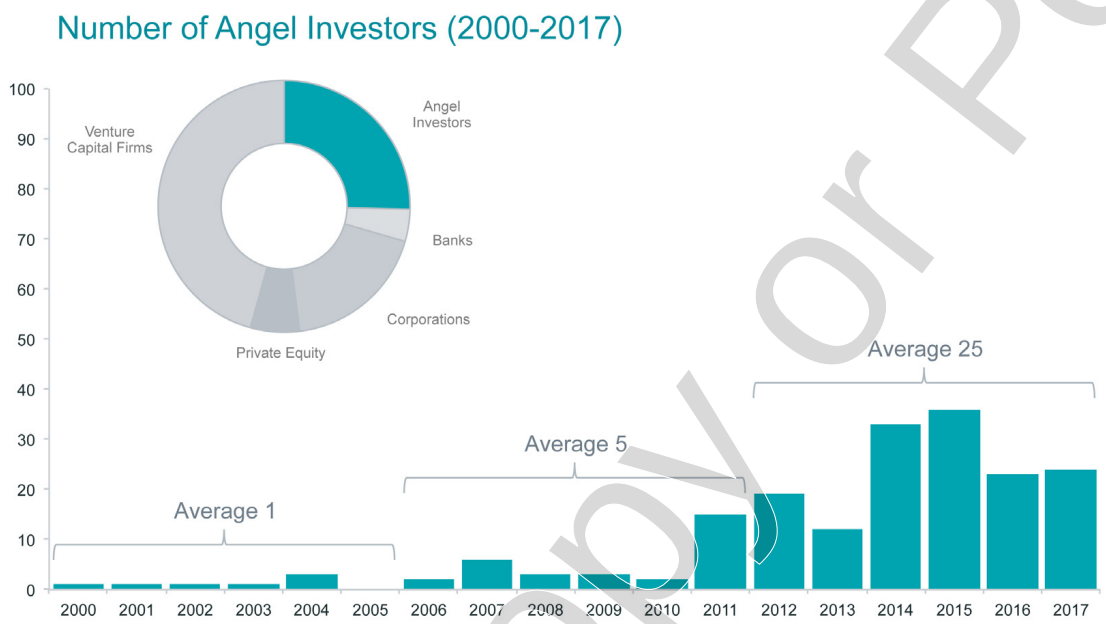
Though its last few years had seen many successes, Space Angels faced serious risks. It was still a small firm in an industry of behemoths. The more successful it was in making space a credible investment class, the more it risked attracting the attention of its competitors. And the possibility that the surge of interest in space would prove to be a fragile bubble loomed over the sector, especially as a substantial share of its funding was coming from a few wealthy individuals and many institutional investors were still hesitant to embrace space.

Space Angels had some big choices to make. Was its move toward conventional VC going to pay off by allowing for greater scale and thus leverage in deals? Or would the firm's ability to spot and nurture the truly game-changing space startups be weakened relative to when it operated under, and focused its efforts on, primarily an angel investing model? Would its mission to build the space financing sector be

better served by focusing on its own returns in the near term or by sacrificing those returns in the hopes of identifying a few exceptional, but riskier, longer-term investments? And how could it convince new classes of investors to pay attention to space, an asset class promising truly out-of-this-world returns?

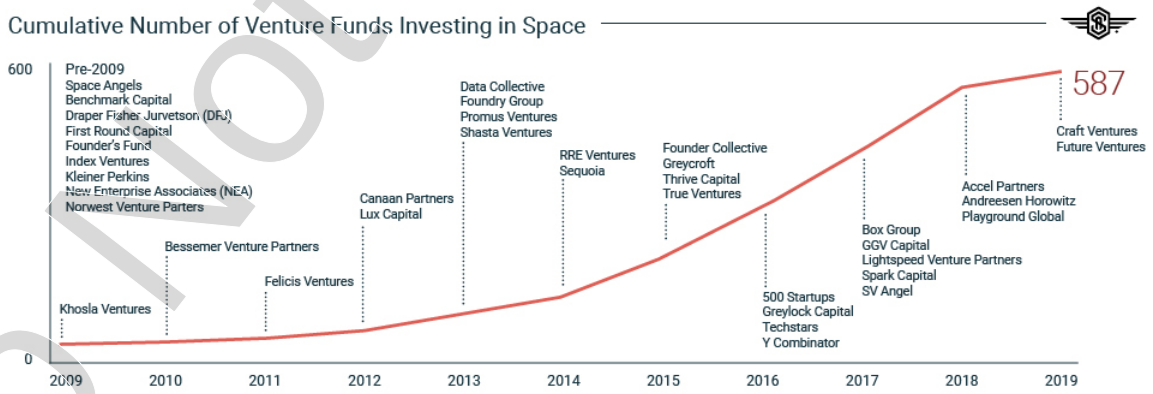
Exhibits

Exhibit 1a Number of space angel investors over time



Source: Bryce, "Start-up Space 2018". Accessed April 26, 2019. https://brycetech.com/downloads/Bryce_Start_Up_Space_2018.pdf.

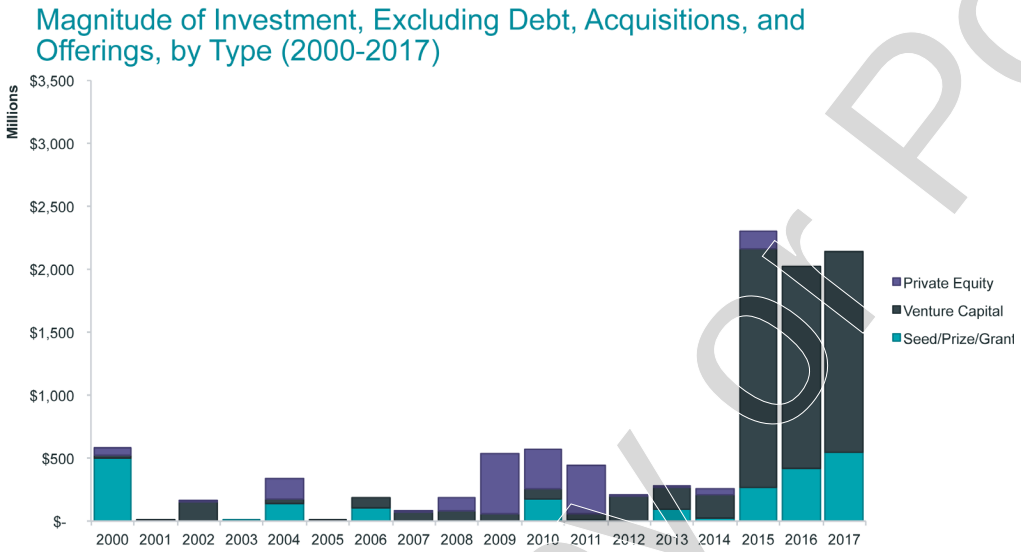
Exhibit 1b Number of funds investing in space over time



Venture Capital interest in Space continues to grow. In Q1, 32 new firms made their first investments in the Space economy, bringing the total to 587. Craft Ventures and Future Ventures are two notable first-time Space investors this year. Craft Ventures led the Series A for Swarm Technologies, a company launching an IoT constellation designed to connect smart devices on a global scale. Steve Jurvetson, a veteran space investor (SpaceX, Planet), made his first space investment out of his new fund, Future Ventures, in an undisclosed company.

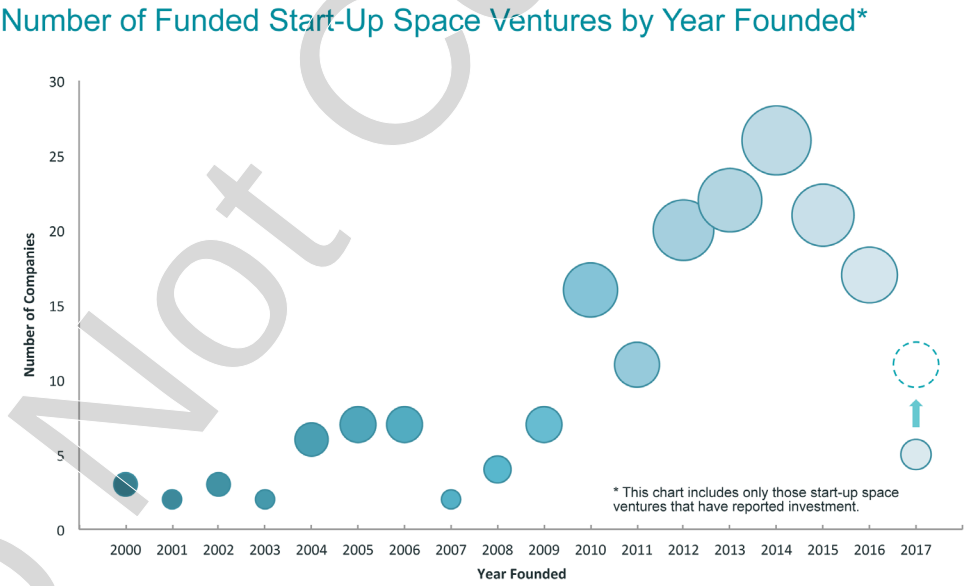
Source: Space Angels Q1 2019 Space Investment Quarterly. Accessed April 26, 2019. https://www.spaceangels.com/post/space-investment-quarterly-q1-2019.

Exhibit 2a Investment in space startups over time (source and total amounts)



Source: Bryce, "Start-up Space 2018". Accessed April 26th, 2019. https://brycetech.com/downloads/Bryce_Start_Up_Space_2018.pdf.

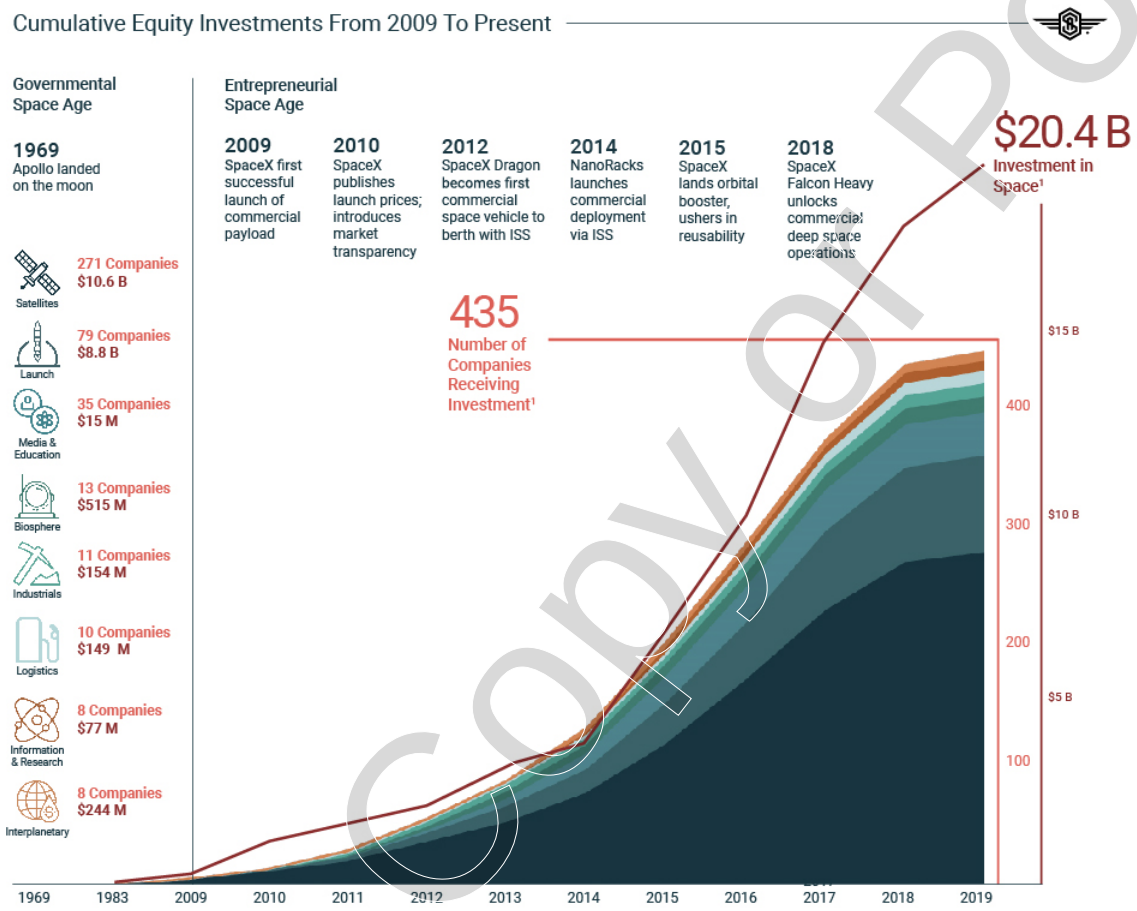
Exhibit 2b Investment in space startups over time (number of receiving firms)



Source: Bryce, "Start-up Space 2018". Accessed April 26th, 2019. https://brycetech.com/downloads/Bryce_Start_Up_Space_2018.pdf..

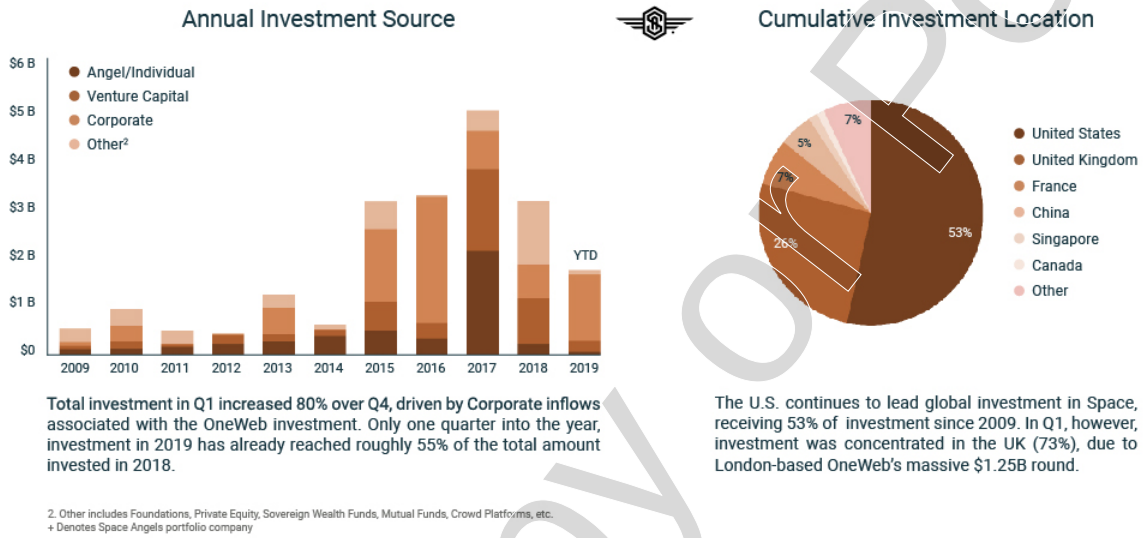
Note: Excludes companies that have not announced investment, including many founded in the last few years. In the 2017 Start-Up Space report, only eight angel- or venture-backed start-up space companies were reported as having been founded in 2016. In the 2018 Start-Up Space report, the 2016 number increased to 17 companies. This suggests that the number of reported start-up space companies founded in 2017 may increase in the future.

Exhibit 3a Equity investments in space over time (total amounts and number of companies)



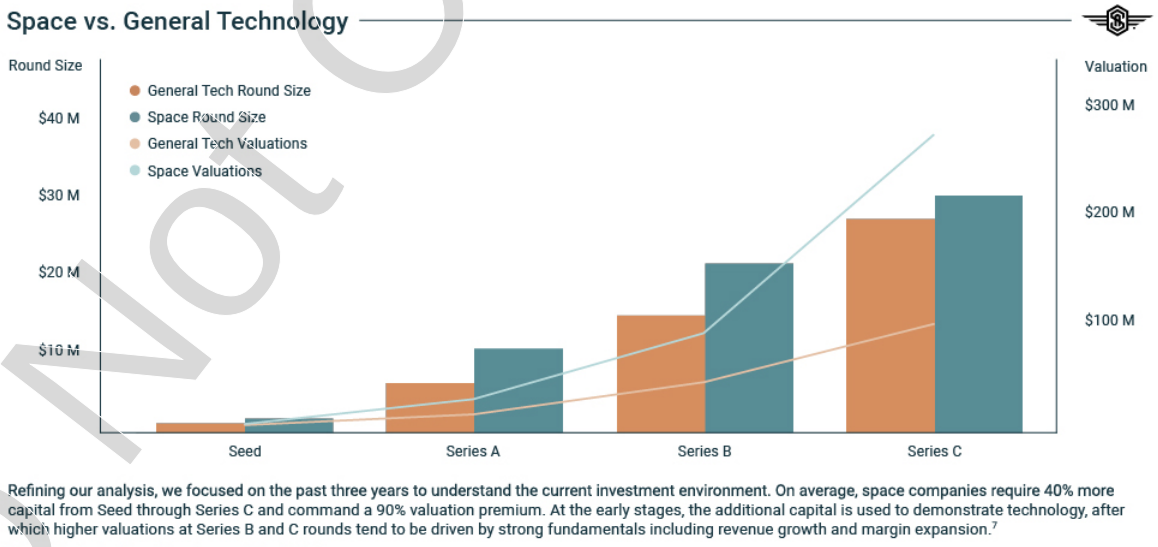
Source: Space Angels Q1 2019 Space Investment Quarterly. Accessed April 26, 2019. https://www.spaceangels.com/post/space-investment-quarterly-q1-2019.

Exhibit 3b Equity investments in space over time (source and location)



Source: Space Angels Q1 2019 Space Investment Quarterly. Accessed April 26, 2019. https://www.spaceangels.com/post/space-investment-quarterly-q1-2019.

Exhibit 4 Space investment vs. general technology investment, by round



Source: Space Angels Q3 2018 Space Investment Quarterly. Accessed April 26, 2019. https://www.spaceangels.com/post/space-investment-quarterly-q3-2018.

Appendix A: Space Angels Investment Criteria

Criteria for selection of portfolio companies:

- Is the team ready to work day and night?
- Do they have unwavering confidence?
- Does the team have entrepreneurial experience?
- Has the team worked in a start-up before? Was it successful, was it not?
- Do they have a technical expertise?
- Do they have a prototype ready?
- Do they have customers and does the prototype have some commercial traction?
- Does their product already generate revenue?
- Does their product serve as improvement over existing services?
- Have they done their due diligence/homework and know enough about the market they are entering?
- Have they researched their competition? What is stopping a big company from doing overnight what they are planning on developing?
- Have they already talked to public investors?
- Are there any legal risks, lawsuits against them?
- Have they raised enough money?
- Do they have scalability?
- Are they resourceful and capable of doing a lot with a minimum of money?
- Are they capable of changing direction when necessary?
- What will work on the market and be useful now? It should be a technology that will be needed in 14 to 18 months (rather than a technology that would start being needed in 10 years) and would make substantial money in 5 to 10 years.

Follow-up efforts with portfolio companies

- The Start-up's executive team is introduced to the Space Angels team and they define together how Space Angels can help.
- They offer their help through:
  a) Marketing development
  b) Connections to SA's network and other potential useful partners
  c) Assist the start-up with their hiring process
  d) Guide them through rounds of financing
  e) Teach them how to lead a board meeting
  f) Find a work space
- The company joins SA's community of partners. At these early stages, businesses face similar challenges. It is important to de-risk the companies and accelerate their pathway to growth, supply talents from their own networks and help them navigate through their new partners.
- SA shares a set of tools such as tips on how to manage their stakeholders, do cap table management, use CARTA (software to manage cap tables), share best practices, and help them nurture relationships with their other investors. SA also helps them map out what resources their investors can bring.

Source: Casewriter interviews with Space Angels.

Appendix B: Space Angels / Space Capital Portfolio Companies

ACCION SYSTEMS
Accion Systems is developing revolutionary ion beam propulsion technologies for satellites that are light, powerful, and affordable.

ANALYTICAL SPACE
Analytical Space is developing a cost-effective, high-throughput satellite data relay service using Cubesats with laser downlink capabilities.

ASTROBOTIC TECHNOLOGY
Astrobotic will be the first private company to regularly deliver customer payloads and communication services to the Moon's surface.

ATLAS SPACE OPERATIONS
ATLAS' network of RF satellite ground stations will offer reliable delivery of big data from LEO satellites at one-third of the cost of legacy providers.

BECAUSE LEARNING (F.K.A. ARDUSAT)
Because Learning is an interactive STEM platform that enables any school to run experiments from Earth to space, through the Spire satellite network.

BRIDGESAT
BridgeSat is developing an optical communications network that offers secure delivery of big data from LEO at low cost and high speeds.

GHGSAT
GHGSat monitors greenhouse gas emissions from individual sites anywhere in the world.

HAWKEYE 360
HawkEye 360 is uses radio frequency to help monitor transportation across air, land and sea

ICEYE
ICEYE's SAR remote sensing solution will allow real-time access to satellite imagery without the limits of traditional optical sensors.

ISOTROPIC SYSTEMS
Isotropic is developing phased array antenna terminals at 20% of the current costs and 9x the performance

KEPLER COMMUNICATIONS
Kepler Communications is a space-based telecommunications company that provides real-time access to assets in orbit.

LEOLABS
LeoLabs provides a practical, cost-effective solution to debris tracking, management, and mitigation.

MADE IN SPACE
Made in Space is bringing manufacturing to space through a suite of products that can be used on Earth, in low Earth orbit, and beyond.

NANORACKS (BOARD OBSERVER)
NanoRacks is the leading commercial provider of hardware and services in low-Earth orbit for microgravity research and space station utilization.

OXFORD SPACE SYSTEMS
Oxford Space Systems is designing and delivering innovative, scalable satellite structures that save on both build and launch costs.

PLANET (F.K.A. PLANET LABS)
Planet owns and operates the largest private satellite fleet in orbit, and provides the most consistently up-to-date images of our Earth's surface.

PLANETARY RESOURCES (ACQUIRED)
Planetary Resources was an asteroid resource prospecting and mining company. Acquired by Consensus in 2018.

RADIAN AEROSPACE
Radian is a single stage to orbit human spaceflight company.

SPEQTRAL (BOARD DIRECTOR)
Quantum Key Distribution (QKD) company based out of Singapore, leveraging small sats to deliver global service

SPACEX
SpaceX designs, manufactures, and launches advanced rockets and spacecraft.

SKYWATCH (BOARD OBSERVER)
SkyWatch is applying Big Data to Remote Sensing, making data accessible to everyone on Earth in minutes.

TOTUM LABS
IOT satellite constellation with ability to provide indoor coverage of assets.

URSA MAJOR TECHNOLOGIES
Ursa Major is developing high performing, 3D-printed rocket engines at a fraction of the cost of traditional engines.

VECTOR
Vector provides affordable and reliable access to space by combining dedicated microsatellite launch and software-defined satellites.

WORLD VIEW ENTERPRISES
World View is pioneering a new frontier at the edge of space and leading the way in the emerging stratospheric economy.

Source: Provided by Space Angels to casewriters

Appendix C: Competing Space Funds

Operational (Funded):

- Seraphim (UK Government and Corporate incumbent fund), 2016
- NewSpace Capital Fund (Luxembourg), 2018
- Luxembourg Government Fund (Luxembourg), 2019

Announced (Unfunded):

- CosmiCapital fund (France)19
- Global Space Ventures (US, Europe)
- Japanese Government Agency Fund (Unnamed) (Japan)20
- NewSpace Capital Fund (US)
- Starburst (France, US)
- Starbridge Venture Capital (US)
- Space Fund (f.k.a. Star Century Partners) (US)
- Space Ventures Investors (UK, Australia)
- Spacetec Partners (Germany)
- SpaceBit (UK)

Source: Casewriters and Space Angels.

Endnotes

[1] Phone interview with Dylan Taylor, November 28, 2018.

[2] Bryce Space and Technology, 2018 Start-Up Space Report.

[3] See Jeff Foust, "'Golden Period' for space startup investment continues", *Space News* September 12, 2018.

[4] BNN Bloomberg, The Case for Investing in Space, December 13, 2018 https://www.youtube.com/watch?v=0asjfR-_0Jw&t=236s.

[5] http://fortune.com/2019/01/10/space-startups-spacex-bezos-vc/.

[6] https://www.cnbc.com/2018/12/12/heres-what-happened-at-morgan-stanleys-inaugural-space-investing-summit.html.

[7] https://www.cnbc.com/2018/10/19/morgan-stanley-is-betting-vector-can-launch-a-lot-of-small-rockets.html.

[8] See Jeff Foust, "'Golden Period' for space startup investment continues", *Space News* September 12, 2018.

[9] Bryce Space and Technology, 2018 Start-Up Space Report.

[10] https://spacenews.com/luxembourg-establishes-space-agency-and-new-fund/ and Bryce Space and Technology, 2018 Start-Up Space Report.

[11] Phone interview with Dylan Taylor, November 28, 2018.

[12] Figure provided by Space Angels.

[13] http://www.switch.vc/big-ideas/follow-on-rates-matter-for-founders.

[14] https://www.spaceangels.com/expedition.

[15] Planetary Resources, Inc was acquired by ConsenSys for an undisclosed sum in late 2018. See https://spacenews.com/asteroid-mining-company-planetary-resources-acquired-by-blockchain-firm/ for more detail.

[16] Ramana Nanda and Matthew Rhodes-Kropf, "Investment Cycles and Startup Formation," *Journal of Financial Economics*, 2013. http://people.hbs.edu/rnanda/Nanda_RhodesKropf_JFE.pdf.

[17] This section draws heavily, including long verbatim quotations, from another work by the author (Matthew Weinzierl) published as part of a Harvard Business School Digital Initiative online feature on space.

[18] Technically, these are the two *Nash Equilibria* of the game, defined as those sets of strategies from which no player has an incentive to deviate, given the other player's strategy.

[19] https://business.esa.int/news/cosmicapital-venture-fund-to-boost-new-space-ecosystem-europe.

[20] https://www.cnbc.com/2018/03/20/japan-offers-940-million-to-boost-nations-space-startups.html.