

# Preface

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## **The Next Frontier**

Space is a limitless void. The stars and their planets occupy only a minute fraction of this endless expanse and, as of 2019, humanity knows of only one planet with the rare collection of elements needed to support life as we know it. Since before recorded history, humans have dreamed of exploring the cosmos, perhaps finding extraterrestrial life or establishing human colonies in the distant reaches of the galaxy. Presently, such aspirations are still strictly within the realm of science fiction and yet, the innate desire to explore the unknown continues to drive the question of whether humanity will ever venture beyond the confines of Earth.

The journey into space began after World War II, when the propulsion systems used to create the world's first ballistic missiles for warfare were repurposed for the scientific effort to explore the universe beyond Earth's atmosphere. Initially, this effort was fueled by nationalistic interests. The former Soviet Union and the United States competed to develop space travel technology in the Space Race of the 1960s, with both nations hoping for a military advantage. Due to fluctuations in political climate and priorities, interest in space science waxed and waned, and the United States has advanced little since the early 1970s. In the 2010s, however, public outlook on space has begun to change again, and an increasing number of scientists and politicians are urging for a new surge in space exploration. This new era of space science is heavily driven by private companies, the commercialization of space, military development. Together, these factors are contributing to the perception that America might be entering a new Space Age.

## **Military Might and Corporate Profit**

Two significant forces in the recent push for space exploration have aligned in the 2010s. In 2018, President Trump called for the formation of a sixth branch of the U.S. armed forces focused on defending U.S. assets in space. Trump is not the first president to urge for the militarization of space, and recent developments in technology has meant that the potential for hostile encounters in space—such as attacks on commercial or governmental satellites—has become a reality. Trump's plan called for the "Space Force," a multi-billion-dollar program that would have created the first new branch of the military since the establishment of the Air Force in 1947. However, Trump was forced to settle for the establishment of a new and largely symbolic branch within the Air Force which is currently in charge of managing American military defense of space.<sup>1</sup>

Trump's push for space militarization led to a number of other nations questioning their own military presence in space. France and China both announced plans to engage in space defense development.<sup>2</sup> As of 2019, military space technology is still in its infancy. The United States and many other nations operate a number of satellites performing both military and commercial functions. The most immediate goal of military space development would be to protect these assets, though most of the nations involved are also seeking to revive an idea first developed in the 1970s and 80s, that space-based technology could be used to prevent or deter nuclear attacks from terrestrial sources.

The second major development sparking renewed interest in space is space tourism, an emerging field in which a number of private companies are developing new technology—including craft capable of leaving and reentering Earth's atmosphere—or are partnering with other organizations to utilize existing technology. The ultimate goal is enabling private individuals to travel to space. As of 2019, there are few vehicles, anywhere in the world, that have been tested and proven to travel back and forth into space. A small number of companies, including Space X and Virgin Galactic, are in the final phases of testing technology that will be used to create a space tourism industry but nothing is ready for general consumption. The most basic space tourism packages cost about \$50 million, restricting the market to the extremely wealthy. Even within that market, additional challenges limit the appeal of space travel. Those interested in becoming one of the first to tour space recreationally must not only pay millions, also endure more than six months of difficult training to make a journey that is extremely physically demanding and dangerous.

Once in space, the only viable location to visit is the International Space Station (ISS), a facility constructed between 1998 and 2011 through a cooperative effort between five different space agencies. The National Aeronautics and Space Administration (NASA) estimated that the ISS would be viable only through 2015, but the facility has remained in working order, surpassing the expectations of experts. NASA recently expanded the life expectancy of the station through 2024, in part because of space tourism. Beginning in the early 2000s, a company called Space Adventures began taking the first civilian tourists to space, where they were allowed to visit the ISS. Though the Trump administration has announced plans to divest American interest in the station, the potential for the ISS to host space tourists is helping to maintain interest in keeping the station functioning and active. Most recently, in June of 2019, NASA released a proposal to sell packages in which tourists will fly aboard a NASA vehicle and then stay aboard the ISS; the basic entry price is \$59 million, which includes approximately \$35,000 per night aboard the International Space Station.<sup>3</sup>

The militarization and commercialization of space occupy a unique position in human culture, as both fields have cross-ideological appeal. While conservatives are more likely to embrace the need for militarization due to a pro-military industrial worldview, moderates and some liberals might also see value in protecting the increasing number of valuable space resources used for science and commercial purposes. Likewise, the commercialization of space appeals primarily to those who

favor private market development and corporatization, but there are aspects of commercialization with more generalized appeal. For instance, researchers in China (and to a lesser degree in the United States) are interested in utilizing advanced satellite technology to gather energy from the sun in space. While practical development in this field is distant, research suggests that harvesting energy from space might be more efficient than any terrestrial method, therefore helping to solve the climate change challenge.<sup>4</sup>

## The Past and Future

2019 marked the fiftieth anniversary of the first moon landing, and NASA and its partners, as well as many of the world's independent space agencies, hosted events and programs to commemorate this momentous achievement. New articles about the Apollo Program helped introduce a new generation to this tumultuous and innovative period and to the goals of the ongoing effort to study and explore space. With this flurry of coverage, readers worldwide were invited to consider how the interplay between economics, political campaigning, and military insecurity have played a role in the development of space science, and how much these elements should guide the development of space technology in the future.

NASA seized on public interest in the organization's past successes with the Apollo Program to discuss the organization's future plans. Among a wide variety of scientific projects, NASA is beginning operations for a series of new space vehicles, and has plans to again send astronauts to the moon as early as 2024. Even before the Apollo Program met its untimely end in 1972, the goal of exploring Mars was a leading priority for NASA. The idea that the Martian landscape may harbor life intrigued humans centuries before the first close-up images became available and before NASA succeeded into obtaining the first surface data from the planet via automated rovers. The planet has long occupied a central place in human mythology and remains a primary target for space science. NASA has plans to land another rover on Mars in 2021<sup>5</sup>, which will be equipped with new tools to search for evidence of microbial life. The search for extraterrestrial life remains a dominant strain of interest in space science, and NASA has plans to conduct detailed studies of Jupiter's moon Europa and Saturn's moon Enceladus, both of which contain ice and potentially liquid salt water, and may therefore harbor simple life beneath their frozen surfaces. The search for extraterrestrial life has drawn contributions from many spheres of science and remains among the most marketable to the public.<sup>6</sup>

While NASA and private organizations are concentrating on testing new passenger ships and automated tools for studying space, the renewed interest in space has reignited discussions of the enduring idea that humanity should visit and potentially colonize Mars. In the 1950s, as the seeds of NASA were first being sowed, researchers and engineers were influenced by science fiction. Experts in both the United States and the Soviet Union imagined that, possibly even within their lifetime, humans could be living in high-tech bases on the moon or on Mars. The effort to enable human astronauts to explore Mars is still a leading goal for NASA and many space scientists. However, with the vast expansion of reliable information on

Mars gathered since the 1950s, scientists now know just how difficult engaging in a manned mission to the planet would be, to say nothing of the possibility of settling there.

Writing in *Gizmodo*, George Dvorsky summarized the challenges of colonizing the “Red Planet,” noting that Mars is a cold, dead planet with a toxic atmosphere, deadly temperature swings, and insufficient gravity to support the internal workings of the human body. Many experts feel that, unless major changes occur in the development of space technology, a realistic human colony on Mars would be unlikely to occur within the next millennium. Dvorsky reasons that one of the reasons interest in colonizing Mars may be growing is that humanity worldwide is increasingly aware that the growing population is incompatible with Earth’s resources and are therefore drawn to models that might alleviate this situation.<sup>7</sup> Astrophysicist Martin Rees, in his book *On the Future: Prospects for Humanity*, dissuaded Americans from this way of thinking about humanity’s future, arguing:

“It’s a dangerous delusion to think that space offers an escape from Earth’s problems. We’ve got to solve these problems here. Coping with climate change may seem daunting, but it’s a doddle compared to terra-farming Mars. No place in our solar system offers an environment even as clement as the Antarctic or the top of Everest. There’s no ‘Planet B’ for ordinary risk-averse people.”

Space tourism might also contribute to climate change, as researchers have begun to note that a massive increase in space flight will likely provide a highly negative contribution to global warming, on a par with commercial air travel. As the new wave of space development is spearheaded by corporations, who have entered the market searching for profit, will these companies engage in responsible development and invest in technology to ensure that the commercialization of space doesn’t come at a further cost to Earth’s ecosystems? Before committing to the void of space, Americans must attempt to solve some of the world’s dire terrestrial problems, or there is a risk that the frontier of space becomes little more than another, less hospitable battleground.

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# 1

## Visions of Space



By Official SpaceX Photos, via Wikimedia.

Elon Musk's SpaceX, pictured above, is the first private company to send a spacecraft to the ISS, and one of many companies developing space technology for tourism and other commercial ventures. This photo was taken during Iridium-4 launch operations.

# Space For Sale

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The exploration of space has resulted in a wealth of scientific data that has transformed many aspects of life. Developments in space technology have led to the invention of new consumer products and, as technology evolves, a number of entrepreneurs are looking at ways to increase the monetization of space. As of 2019, this includes “space tourism,” the now famous effort to open space travel to consumers. There are other opportunities for profit as well, including the possibility of harvesting natural resources from space to potentially alleviate resource shortages on Earth.

## Touring Space

The 1960s proved that human spaceflight was possible, raising the prospect of recreational space travel. In the early 1970s, Rockwell International, the company contracted by the U.S. government to work on the design for NASA’s space vehicles, began looking into the possibility of creating a passenger cabin for space flight. They imagined this housed in a shuttle’s cargo bay and holding 74 passengers for a 3-day journey orbiting the earth.

In the 1980s, NASA began experimenting with allowing non-governmental astronauts to accompany crews on Space Shuttle missions through its “Space Flight Participant” program, which was intended to gradually open up the experience of space to the civilian world. Charles Walker, an employee of aerospace manufacturing firm McDonnell Douglas, traveled aboard a space shuttle flight in 1984 as the first non-governmental astronaut to fly on an American spaceflight. The program hit a major setback in 1985, when teacher Christa McAuliffe was killed along with the crew when the space shuttle *Challenger* tragically exploded on take-off. The *Challenger* disaster was a setback not only for the idea of civilian space flight, but for the U.S. Space Program as a whole. Space shuttle missions were put on hold for two full years and the Space Flight Participant program was completely abandoned.

The 1990s saw the beginning of development in space tourism in earnest. The first company to enter the market was SpaceDev, which was founded in California in 1997 and later purchased by the Sierra Nevada Corporation. The first company to successfully offer civilian space tourism was Space Adventures, which was founded in 1998 in Virginia. Space Adventures utilizes Russian space technology and has secured permission to send individuals to the International Space Station (ISS) aboard Russian *Soyuz* spacecraft. The company sent their first client—U.S. entrepreneur Dennis Tito—into space aboard a *Soyuz* craft in 2001, making Tito the world’s first space tourist. Tito reportedly paid \$20 million for the opportunity and underwent more than six months of training at the Yuri Gagarin Cosmonaut Training Center at Russia’s Star City. Following Tito’s successful trip, Space Adventures

sent a small number of other clients into space, including Tito for a second trip, making him the first two-time space tourist.

The most recent client scheduled for a flight with Space Adventures was wealthy English singer Sarah Brightman, who began training for her flight (which carried a reported price of \$52 million) in 2015. However, it was soon announced that Brightman had either postponed or cancelled her trip. Writing in *Time Magazine* in May 2015, Jeffrey Kluger speculated that though space tourism had become a reality, the process—both for preparation and during an actual voyage into space—was so difficult that participants, even barring the extreme cost, were likely to remain limited. As Kluger explained:

On both the way up and the way down, the crew can pull more than 4 g's (4x the gravity of earth), and that's only if everything goes well. In 2008, cosmonaut Yuri Malenchenko and astronaut Peggy Whitson were coming home aboard a Soyuz when the rear part of the spacecraft—the service module—failed to separate as it was supposed to. That sent them on what's called a ballistic reentry of 30 degrees, causing them to pull a torturous 8 g's. The near-fatal plunge took 23 minutes to unfold. Even the best Soyuz reentry has been described by astronaut Scott Kelly, who is aboard the ISS for a marathon one-year stay and had been looking forward to Brightman's visit, 'like going over Niagara Falls in a barrel—that's on fire'.<sup>1</sup>

As Kluger notes, the space flight technology available in the 2010s ensures that space tourism remains both difficult and dangerous. To participate in Space Adventures programs, clients are required to participate in a minimum of six months of difficult training and additional training (at an additional cost) for optional activities. Despite these difficulties, the success of Space Adventures paved the way for a host of other companies. In the late 1990s, XCOR Aerospace and Bigelow Aerospace both entered the market. In 2002, controversial billionaire Elon Musk ventured into the field with the foundation of his SpaceX company, which planned to focus on innovative new space vehicles in addition to space tourism. This was followed by the entry of billionaire Amazon founder Jeff Bezos' Blue Origin company in 2004, and then billionaire Richard Branson's Virgin Galactic Rocket Laboratory in 2006.

As of 2019, most of the initial companies that entered the space tourism industry have failed to achieve any measurable success. In 2006, industry pioneer Space Adventures announced that the company would begin offering "space walks" for visitors to the ISS at an additional cost of \$15 million; as of yet no tourist space walks have been conducted. Progress in space tourism stalled considerably in October 2014 when Branson's Virgin Galactic suffered the crash of its *VSS Enterprise* test vehicle, resulting in the death of one pilot and severe injuries to another. Despite this tragedy, Virgin Galactic emerged as one of the most viable space tourism companies of the 2010s. The company finally reached space in 2018 with a crew of two trained astronauts, becoming the first company to successfully launch a privately developed manned space vehicle. Though the flight only lasted 16 minutes, and the crew consisted of veteran test pilots C.J. Sturckow and Mark Stucky, the victory was a major step forward in terms of proving the viability of the company's



plans.<sup>2</sup> In 2019, Virgin Galactic became the first space tourism company to go public, drawing \$800 million in investment from Branson through his Social Capital Hedosophia Holdings Corp, which the company announced would provide funding until it could begin turning a profit.<sup>3</sup>

Criticisms of space tourism programs are centered primarily on the prohibitively high cost, which thus far means that even the most basic space tourism options are available only to the extremely wealthy. Further, current technology poses limitations and makes civilian space flight difficult and dangerous, thus further limiting the recreational value and broader public interest in the industry. These concerns may be overshadowed by an emerging scientific concern: that space tourism and the repeated use of rockets to break Earth's atmosphere might contribute markedly to climate change. A 2010 study published in *Geophysical Research Letters* raised this concern after data suggested that the atmospheric impact of commercial space flight would be comparable to commercial air travel, which is one of the most significant contributors to global warming overall. Particles emitted by rockets used in space flight might remain in the stratosphere of the Earth for as long as a decade, eventually raining down and contributing to pollution. Space tourism companies have yet to create plans to address the potential environmental impact of their activities, but this is a major concern that must be addressed as the industry moves forward or space tourism companies might find themselves at odds with the scientific community.<sup>4</sup>

### **Other Commercial Opportunities**

Space tourism is the most popular topic in the field of space commercialization, but there are other ways to take advantage of extraterrestrial resources. One of the most promising is the potential to harvest solar energy directly from space, thereby removing the atmospheric obstacles that complicate the collection of solar energy from the Earth's surface. This emerging field, known as Space-Based Solar Power (SBSP), is not currently a reality, but a significant number of scientists have suggested that such a method might prove a viable way to eliminate reliance on fossil fuels.<sup>5</sup>

The idea of collecting solar energy from space is older than many might realize. Visionary science fiction author Isaac Asimov is often credited with inspiring interest in this process with his 1941 short story "Reason," which featured a space station designed to harvest energy from the sun and transmit it to planets using microwaves. Solar powered satellites became a reality in the 1970s thanks to improvements in systems for collecting and storing solar energy. Between 1976 and 1980, NASA spent \$50 million on a study of SBSP and another major feasibility study was done in the 1990s, which concluded in 2000. At that time, the scientists involved in the program concluded that achieving SBSP using a large solar power satellite (SPS) would require significant advancements in current technology. However, the team laid out a potential road map for how this might be achieved over a period of decades.<sup>6</sup>

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# Super Fast Travel Using Outer Space Could Be \$20 Billion Market, Disrupting Airlines, UBS Predicts

By Michael Sheetz  
CNBC, March 18, 2019

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UBS believes there will be very lucrative ramifications from the space flight efforts currently led by Virgin Galactic, SpaceX and Blue Origin.

A lengthy UBS report published on Sunday found that, in a decade, high speed travel via outer space will represent an annual market of at least \$20 billion and compete with long-distance airline flights. Space tourism will be a \$3 billion market by 2030, UBS estimates.

“While space tourism is still at a nascent phase, we think that as technology becomes proven, and the cost falls due to technology and competition, space tourism will become more mainstream,” UBS analysts Jarrod Castle and Myles Walton wrote in the note. “Space tourism could be the stepping stone for the development of long-haul travel on earth serviced by space.”

UBS expects the broader space industry, which is worth about \$400 billion today, will double to \$805 billion by 2030 when accounting for these innovations. While these sub-sectors would be a small part of that, Castle and Walton said “the outlook for the space economy, space tourism and long-haul travel using space has become much more bullish.”

Private space companies “are investing aggressively across the space opportunity,” UBS said, and the firm believes access to space “is the enabler to broader opportunities for investment.”

## Revolutionizing Long Distance Travel

Long haul airplane flights that are more than 10 hours in duration would “be cannibalized” by point-to-point flights on rockets, UBS said. The firm pointed to SpaceX’s plans to use the massive Starship rocket it is building to fly as many as 100 people around the world in minutes. SpaceX said that Starship would be able to fly from New York to Shanghai in 39 minutes, rather than the 15 hours it takes currently by airplane.

UBS estimates that there are more than 150 million passengers a year that fly routes longer than 10 hours. Last year, those routes saw 527,000 routes on airplane that had an average of 309 seats, UBS said.

“If we assume that 5 percent of these flights in the future are serviced by space at \$2,500 per trip, the revenue opportunity as of today would be more than \$20 billion per year as of today,” UBS said

“Although some might view the potential to use space to service the long-haul travel market as science fiction, we think ... there is a large market,” UBS said.

UBS noted that “it is unlikely that a rocket will carry over 300 people anytime soon,” so the Starship’s capacity of 100 will be the maximum for the foreseeable future. However, UBS believes there may be an “increased frequency of space travel during

the day to enable the same volume of passengers,” the firm said.

“Given the length of long-haul commercial travel, and the rules around crewing and take-off and landing time slot restrictions at airports, we think a re-usable rocket (especially if not land-based) would have materially better utilisation rates than a commercial plane,” UBS said.

As a result, UBS believes the \$20 billion estimate “could prove conservative,” the firm said. More than 10 percent of people in a recent UBS survey said they would choose a spacecraft over an aircraft for long distance travel.

“While the timing of such a long haul service is uncertain, we think our base-case assumptions are conservative,” UBS said.

### Space Tourism’s Market Potential

The billions of dollars pouring into private space companies represents “a high level” of capital formation, UBS said. Even though space tourism “is still nascent,” UBS said they believe the sub-sector “will become mainstream as the technology becomes proven and cost falls.”

To date, space tourism has largely been limited to the few flights organized by U.S.-based Space Adventures. Over the past two decades, the company has flown seven tourists using Russian Soyuz rockets. At a reported cost of more than \$20 million per person, the private clients typically spent over a week on board the International Space Station.

But now “there are a number of commercial space ventures to open up sub-orbital travel,” UBS noted. Virgin Galactic and Blue Origin are leading those efforts, both getting steadily closer to launching paying tourists.

“This area seems to be the market that has the greatest potential to gain traction quickly,” UBS said.

Virgin Galactic is deep into the development program of its spacecraft. Last month, the space venture owned by Sir Richard Branson sent test passenger Beth

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**More than 10 percent of people in a recent UBS survey said they would choose a spacecraft over an aircraft for long distance travel.**

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Moses on Virgin Galactic's spaceflight—a first for a private U.S. company. Virgin Galactic's spacecraft holds up to six passengers along with the two pilots. As the company has more than 600 would-be astronauts signed on to launch, Moses' work is key to preparing Virgin Galactic for commercial operations. Tickets for Virgin Galactic's flights are priced at \$250,000 each.

UBS believes Virgin Galactic's business model, as both a tourism company and manufacturer of spaceships, mimics the growth of businesses in the early days of aviation.

"In this way history could repeat itself as United Airlines today can trace back its roots to the Boeing Aircraft & Transport Company," UBS said.

Blue Origin, the company founded by Amazon CEO Jeff Bezos, is also nearing its first spaceflights with human passengers. Blue Origin is developing the New Shepard rocket system for the company's space tourism business.

As both Virgin Galactic and Blue Origin utilize reusable spacecraft systems, UBS believes the companies will be able to make space tourism "a more common occurrence" as reliability increases and prices decline.

"We estimate space tourism will be a \$3 [billion plus per year] opportunity growing at double digit-rates," UBS said. "This would be similar to what happened in commercial aviation, especially after the rise of low-cost airlines."

SpaceX could also see significant cash flow from space tourism, UBS believes, through two different ventures. Elon Musk's company just completed a historic test flight of its Crew Dragon capsule, which will be able to send as many as four astronauts to the space station. UBS estimates that NASA will pay SpaceX about \$58 million on average per astronaut, compared to the \$81 million per astronaut for flights on Russian Soyuz rockets.

The second SpaceX opportunity is for early flights of Starship to send tourists on missions beyond the Earth's immediate orbit. In September, Musk announced Japanese billionaire Yusaku Maezawa signed with SpaceX to fly around the moon on Starship. Maezawa expects to fly in 2023, with six to eight guests joining him for the flight.

### **Print Citations**

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