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How will the space economy change the world?

Space is no longer the sole domain of governments and aerospace and defense companies. Businesses that pursue emerging opportunities now may gain a first-mover advantage.

by Ryan Brukardt

The passengers who boarded commercial flights just after World War II didn't know that air travel would begin to soar over the next decade, nor did the masses who first logged onto the internet in the 1990s realize that computers would one day provide much of their news, entertainment, and social life. And today, few people understand that the space economy—broadly defined as activities in orbit or on other planets that benefit human beings—could soon transform how they live and work.

Some hints of the coming changes are apparent, including the frequent headlines about SpaceX, Blue Origin, and other private companies launching their own rockets and deploying satellite constellations. These activities, once primarily the domain of government agencies, are now possible in the private sector because recent technological advances in manufacturing, propulsion, and launch have made it much easier and less expensive to venture into space and conduct missions. Lower costs have opened the door to new start-ups and encouraged established aerospace companies to explore novel opportunities that once seemed too expensive or difficult. The technological improvements have also intrigued investors, resulting in a surge of space funding over the past five years.

The potential for innovative space applications is immense, especially if established aerospace companies form partnerships with businesses that traditionally haven't ventured into orbit. Pharmaceutical companies might establish a lab on a space station to study cell growth, for instance, or semiconductor companies might manufacture chips in extraterrestrial factories to determine whether any aspects of the space environment, such as the lack of gravity, improve the process. Such possibilities, which might have seemed like the stuff of science fiction a few years ago, could become an essential part of a business across multiple industries in the near future.

But how and when should companies take advantage of their greater access to space and pursue emerging use cases? And how can they decide what opportunities are most promising when the technology is so nascent? Although much remains uncertain, companies that begin exploring these questions now could gain a long-term advantage.

The benefits of the space economy—with more to come

Space has long been a potent incubator for innovation—first from governments and large telcos and now from multiple private companies as well. From the launch of Sputnik 1 in 1957 through today, the space economy has delivered most of its value through satellite services, including communications and data and image collection and analysis. Satellites help large companies with multiple tasks, including inventory monitoring at distant locations, instant authorization of credit-card transactions, and international videoconferencing. Consumers use satellite technology whenever an online navigation system pinpoints their location, or when they make calls during plane flights or from rural locations that lack cell phone towers. And television viewers can thank satellites for beaming the signals that allow them to watch their favorite programs. The role of satellites in these activities is often overlooked—many people may think terrestrial computer networks provide the necessary connectivity—unless a glitch occurs and draws attention to the unobtrusive technology operating in the background.

In addition, satellites help world leaders address intractable social, environmental, and economic challenges. Consider a few ways that satellite data can provide insights—often more effectively and comprehensively than other sources:

- *Climate change.* More than 160 satellites monitor Earth to assess the effects of global warming and detect activities, such as illegal logging, that might contribute to the problem.[1] NASA has used an instrument mounted on its Aqua satellite to monitor environmental changes, including those related to ocean water, water vapor, clouds, sea and land ice, and precipitation, for more than 20 years. Other satellites provide information that can help government agencies take urgent action on wildfires, coastal erosion, and other climate-related natural disasters.

- *Food security.* Satellite data is increasingly used to monitor crop development and potential threats to harvests, such as drought or insect invasions. The SERVIR project, a partnership between NASA and the US Agency for International Development, uses data from Earth-imaging satellites and geospatial technologies to help governments address multiple issues, including food shortages.

- *National security.* Governments, often working with companies in the private sector, can use satellite images and data to gain valuable intelligence, such as information on the movement of troops or the installation of weapons systems.

[1] *Six ways space technologies benefit life on Earth*, World Economic Forum, Global Future Council on Space Technologies, October 16, 2020.

According to the not-for-profit Space Foundation, the space economy was valued at $469 billion in 2021, up 9 percent from 2020, the highest recorded growth since 2014.[2] Although the space economy now generates most value by enabling or enhancing activities on Earth, significant future value could arise from functions that occur entirely in orbit, such as in-orbit servicing, research and development, and manufacturing. That said, the satellite services available today will remain important and could be critical to some emerging use cases.

Finally, a tipping point

Researchers and other space enthusiasts have long discussed the potential for business activity in orbit, or even the development of space cities. But now, with lower costs and greater technological capabilities, the space economy may finally be at a tipping point, where businesses can conduct large-scale activities in space. As costs continue to drop, even more companies may contemplate space ventures; and for the first time, they might even be able to profit from forays into space.

More launches, lower costs

The costs for heavy launches in low-Earth orbit (LEO) have fallen from $65,000 per kilogram to $1,500 per kilogram (in 2021 dollars)—a greater than 95 percent decrease.[3] Computer-aided design, 3-D printing, and other innovations have contributed to the cost reductions by streamlining the manufacturing process and improving supply chains. The emergence of new commercial launch providers that prioritize efficiency is also helping. For instance, engineers at these companies have developed reusable components for launch vehicles, which lowers costs while promoting sustainability. The recent increase in launch frequency, particularly at SpaceX, is accelerating the drop in costs.

Current R&D efforts could reduce launch costs even further. Relativity Space, for instance, plans to use 3-D printing, artificial intelligence, and autonomous robotics to build a fleet of fully reusable, low-cost rockets. The first launch for these vehicles is planned for 2024 at Cape Canaveral, Florida. Similarly, SpaceX plans to conduct a full-scale, orbital test flight for its reusable Starship launch vehicle—the tallest and most powerful ever built—in late 2022.

Smaller satellites, bigger gains

The size and weight of satellites have fallen significantly in recent years because of various advances, primarily driven by private companies, such as the use of lighter solar panels and more efficient batteries. These changes, combined with greater use of commercial, off-the-shelf components, have decreased satellite costs and made their launch and operation feasible for many more organizations. Greater satellite demand is also improving costs because manufacturers obtain economies of scale by increasing production volume. These lower costs have helped alter the space landscape. Large

[2] See "Space Foundation releases The Space Report 2022 Q2 showing growth of global space economy," Space Foundation, July 27, 2022; and Michael Sheetz, "The space economy grew at fastest rate in years to $469 billion in 2021, report says," CNBC, July 27, 2022.

[3] Thomas G. Roberts, "Space launch to low Earth orbit: How much does it cost?," Aerospace Security, September 1, 2022.

government satellites, some of which cost upward of $1 billion and tend to be deployed in orbits far from Earth, are now outnumbered by smaller commercial satellites in LEO, often deployed in constellations, that can cost $100,000 or less.

In tandem with the cost decrease for satellites, researchers have created new technologies, such as higher-resolution sensors, that are boosting image capture, data processing, and other functions. Satellites can now collect, analyze, and transfer much larger stores of data than they could just five years ago.

Greater investment, more innovation

Public agencies, especially NASA and the US Department of Defense and Intelligence Community, have traditionally provided most space investment. While these agencies will continue to be a major source of funding, the combination of lower costs and more sophisticated technology is attracting more investment from both special-purpose acquisition companies (SPACs) and private investors—a trend that is driving innovation.

In 2021, private-sector funding in space-related companies topped $10 billion—an all-time high and about a tenfold increase over the past decade. The percentage of global space R&D funding coming from the US government decreased from about 70 percent to around 50 percent over the same period.[4] Meanwhile, the number of space-related start-ups funded annually increased more than twofold from 2010 to 2018.[5] Commercial funding could surpass government funding within 20 years, a trend that government is largely embracing and that could lead to mutually beneficial public–private partnerships.

New use cases and more momentum

Although much uncertainty persists, analysts are so optimistic about space that some believe it will become a $1 trillion industry, thanks to enhancements to existing use cases and the development of entirely new applications. Much progress, including further reductions in launch and operational costs, must be made before many ambitious space projects can become a reality, but continued technology improvements are encouraging companies to increase their investments in the space economy now. The new use cases can be divided into two broad categories: space-for-Earth applications, which facilitate terrestrial activities, and space-for-space applications, which only involve activities that occur in orbit.

Space-for-Earth applications

Satellites are becoming more sophisticated each year, allowing researchers to enhance existing use cases and develop new offerings. Many companies have recently deployed smaller, less expensive satellites in LEO—an orbit that is ideal for high-bandwidth, low-latency communications—to provide better satellite connectivity. While most past efforts to launch LEO constellations failed because of high costs, limited demand, and inadequate funding, the situation is much different today. SpaceX's Starlink has already

[4] "The space report online," Space Foundation, 2021; *The space economy at a glance*, OECD, July 22, 2011.

[5] *Start-up space: Update on investment in commercial space ventures*, Bryce Tech, 2021.

launched an LEO constellation and has paying customers for its satellite broadband network. OneWeb and Amazon's Project Kuiper, among others, also plan to deploy LEO constellations soon. Satellite imaging, another technology frequently used in current applications, has also improved and could enable multiple new use cases by providing more detailed and accurate information.

Some of the most important space-for-Earth applications include the following:

- *Internet services in remote locations*. Terrestrial networks are often difficult or uneconomical to install in underserved or rural areas. Beyond basic inconveniences, a lack of connectivity can interfere with vital services, including provision of remote learning or online medical consultations. By providing internet services to these areas, satellite connectivity could increase educational equity and social interactions and improve public health, especially in cases where the COVID-19 pandemic still limits some in-person interactions.

- *Agriculture*. Space-based remote sensors collect a multitude of data, including images, information on weather patterns, and measures for electromagnetic waves, all of which have applications for agriculture. McKinsey's annual digital farmer adoption survey shows that 29 percent of row-crop farmers and 45 percent of specialty-crop farmers already rely on such data or plan to do so. The greatest value from satellite sensors for agriculture relates to yield-improvement opportunities. For instance, farmers can use satellite images to identify areas that require replanting early in the season, rather than conducting a manual inspection that might be time consuming and miss some areas of the field.

- *Energy*. Utilities can use satellite data to monitor vegetation that might be interfering with critical infrastructure, including power lines. By addressing the problems before they escalate, companies might avoid power outages.

- *Mining*. Satellites can support some of the most important functions at mining companies. Better connectivity might improve productivity at remote sites by helping headquarters-based experts communicate with local staff to solve problems. Satellite data can also help mining companies map emissions, monitor shipments along the supply chain, and improve exploration efforts by identifying mineral-rich areas.

- *Insurance*. Better imaging might allow more insurers to cost-effectively assess risks and damages at remote locations, with improved resolution and greater image-sequencing frequency pinpointing problems more clearly and eliminating the need for in-person visits. Pilot tests of radio-frequency-based mapping, which can detect "hidden" shipping activity, could help maritime and commodities-based hedge fund customers track the movement of goods overseas.

Space-for-space applications

Many of the emerging "space for space" applications are now possible for the first time because lower costs make frequent launches and long-term missions more financially viable. Consider a few use cases that could gain traction:

- *Research and development*. Space R&D is not a new application, but businesses outside the aerospace sector have not traditionally undertaken large-scale projects in this area.

With lower costs and better technologies, however, this could change as companies build upon the research done to date on the *International Space Station*. Among other applications, pharmaceutical companies could develop cell cultures for predicting disease models. While these cultures develop in well-known patterns on Earth, the novel environment in space would shift growth patterns and reveal new insights. Similarly, consumer goods companies might want to develop products in space, where high levels of radiation, a near vacuum-like state, and zero gravity might improve design and manufacturing. For instance, a manufacturer of beauty products might discover new information about skin care in the harsh space environment, which accelerates aging.

- *Manufacturing, construction, and assembly.* Super-heavy launch vehicles, such as SpaceX's Starship, may make it easier for companies to create factories or manufacturing plants in orbit. Some semiconductor companies are already exploring the potential for creating chips at such facilities, since the natural vacuum in space could potentially facilitate innovative thin-layering techniques by reducing or eliminating gases during production.

- *Greater exploration and habitation in space.* Innovative forms of deep space exploration, including crewed missions to Mars, might become possible if technologies such as nuclear propulsion continue to advance. Some leaders, including Jeff Bezos of Blue Origin, are already speculating that large numbers of people may even be able to live and work in space. Recent headlines about space tourism may be the first sign that space is no longer the domain of a few carefully selected astronauts.

Activity in most of these space-for-space areas is now very limited, but further technological improvements, such as laser communication between satellites and better edge processing (making sense of data in space, rather than after downloading it) could accelerate progress. Although it's still difficult to determine which use cases, if any, will gain significant traction, industry stakeholders may promote progress by considering measures that will help space companies and others navigate the new landscape. For instance, guidelines about use of orbits might help reduce the chance of collisions in space that could result in debris.

Thanks to lower costs and greater access, space is no longer the sole domain of large aerospace companies or public agencies with vast budgets. It's a place that can deliver many benefits—both on Earth and in orbit—to almost any business sector. Across industries, from pharmaceuticals to semiconductors, some companies are already expanding their space capabilities, exploring new use cases, or piloting innovative applications. In a few years, industry leaders may compare these early movers to businesses that recognized the internet's potential in the early 1990s and moved quickly to establish an online presence. The challenges ahead—both technological and financial—can't be understated, but the potential of space is also immense. Companies that ignore it, either because they are bogged down in current challenges or underestimate the opportunities ahead, might eventually find themselves scrambling to catch up to the early leaders. Q

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