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The potential of microgravity: How companies across sectors can venture into space

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Should you move your R&D and manufacturing into the ether? A new McKinsey analysis explores the opportunities.

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When companies try to differentiate themselves from the pack, the same options emerge: developing innovative products, overhauling portfolios, capturing different customer segments, or opening new locations. Now, in a twist that may startle attendees at routine strategy meetings, they have another possibility: expanding their business into space.

It may seem far-fetched for any company outside the aerospace or defense sectors to pursue such opportunities, but a growing number of businesses are excited by the potential and are increasingly backing their plans with solid investments. Space offers a unique research and manufacturing environment to a broad range of sectors because of its near-vacuum state, microgravity (which confers weightlessness), and higher levels of radiation. These features may enable new processes or reveal new insights. (For more information, see sidebar "The unique properties of space.")

Many companies believe that the environment of space could help them discover new products, enhance their current offerings, or decrease development timelines. The number of patents with "microgravity" in the title or abstract soared from 21 in 2000 to 155 in 2020. To obtain greater clarity about the burgeoning opportunities in the space economy, we interviewed more than 20 industry experts and researched potential applications. We focused on four sectors: pharmaceuticals, beauty and personal care, food and nutrients, and semiconductors.

In addition to examining the impact and feasibility of different use cases for space, we also explored value pools and business models. The full impact of any commercial space opportunity is now difficult to estimate, but some exciting discoveries could benefit both businesses and society as a whole. If space-based R&D allows researchers to make breakthroughs in oncology compounds, for instance, the insights could save millions of lives.

A few caveats

In space, as in any nascent sector, the revenues from commercial growth opportunities are still uncertain. For this reason, a few caveats are necessary as companies contemplate next steps and potential partnerships with space companies.

First, cost is an issue. Before embarking on promising opportunities, researchers must determine if they could get the same insights in their terrestrial labs, which are less expensive to build and operate. It may be necessary to repeat these assessments periodically because scientific and technological advances may improve the accuracy and value of Earth-based experiments over time.

The next caveat relates to timelines. During our feasibility assessment, we did not estimate precisely when commercial opportunities might become possible, because so many constantly changing factors will influence the space economy. Launch costs are decreasing, for instance, but they must drop even further to allow most companies to take advantage of space-based R&D and manufacturing.

Finally, for any endeavor to succeed, traditional businesses and space companies must focus on forming close, mutually beneficial relationships. The space company must be fully integrated into the industry's ecosystem rather than a distant partner that provides occasional advice. If companies do not forge these strong ties, their space applications are likely to progress slowly.

Beyond the factors that could slow progress, it is important to note caveats related to the potential value of space use cases. We have analyzed current R&D spending and other factors to predict value, but the estimates are always subject to change.

The potential for real business impact, from faster drug evaluation to greater innovation with semiconductors

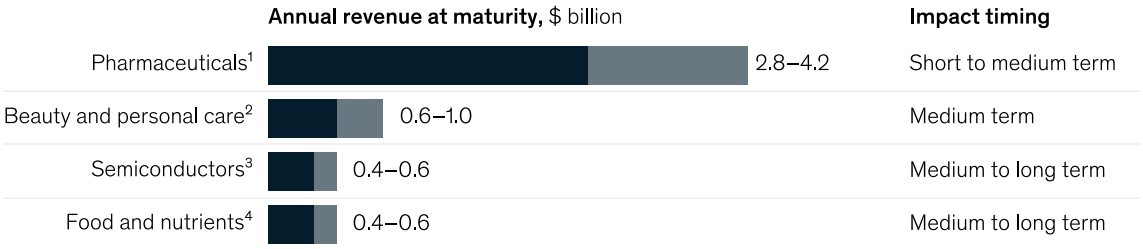
In our industries of focus, we pinpointed several promising opportunities after assessing three factors: the holistic impact, the feasibility, and the value creation possibilities and business models. (For more information, see sidebar “An assessment of commercial opportunities in space: Our methodology.”) If even one opportunity pans out, it could create a virtuous cycle in which more businesses begin exploring similar applications.

Our early analysis suggests that the opportunities in our chosen industries could potentially capture billions of dollars in value (exhibit). Here are a few possible applications in pharmaceuticals, beauty and personal care, food and nutrients, and semiconductors.

Exhibit

Businesses that collaborate with space companies may capture value in multiple industries.

Revenue growth forecasts of selected industries if they collaborate with space companies



[1]Extrapolation based on capturable contract research organization (CRO) market and oncology therapeutic area portion of the pharma market.
[2]Extrapolation based on capturable CMO market for production and skin care portion of the beauty and personal care market, excluding fragrances.
[3]Extrapolation based on R&D spend along value chain in semiconductors by player archetype and portion of semiconductors in computer and electronic products.
[4]Extrapolation based on capturable CMO market and nutraceuticals portion of food functional ingredients market.
Source: BCC Research; company reports; Euromonitor International; Evaluate Pharma; expert interviews; Food and Agriculture Organization; IC Insights, *The McClean Report*; IHS Markit; IQVIA Pharmadeals; Kentley Insights; MarketsandMarkets Research; National Science Foundation; *Nutrition Business Journal*; PitchBook; S&P Global; Technavio; Transparency Market Research; web searches; McKinsey analysis

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Pharmaceuticals

The pharmaceutical industry spends about $280 billion annually on R&D and $80 billion on work with contract research organizations (CROs)—businesses that specialize in conducting clinical trials. Space companies may eventually capture some of this funding if they can increase the returns from innovation, improve the success rates for compounds in development, or cut product development timelines. Consider a few potential use cases:

- *Cell cultures for predicting disease models.* These cultures develop in well-known patterns on Earth, but the novel environment in space would shift growth patterns and reveal new insights. Such variations, which scientists are still attempting to identify and understand, might depend on the cell involved. Similarly, space radiation might change gene expression and growth patterns, which could yield new insights.

- *Organoids.* These miniaturized and simplified versions of organs resemble living human tissues and can be used as 3-D models to evaluate disease. Scientists now create organoids in labs through a lengthy, resource-intensive process that requires complex scaffolds to promote 3-D growth. But in a few recent collaborations between academic institutions and space organizations, scientists grew organoids from embryoid bodies to greater maturity levels, without scaffolds, during unattended missions in orbit. Other potential benefits of space-based R&D in organoid production are still largely theoretical, but exciting. For instance, scientists have hypothesized that the environment of space might enable the production of organoids from specific adult stem cells—something not possible today.

- *Direct drug research.* To understand the benefits of this use case, consider oncology drugs, now the industry's largest product group. Many of these compounds fail in development, so the risk–return ratio is very poor. If companies explore new R&D methods for developing oncology drugs in space, they might achieve breakthroughs that would increase their success rates, accelerate product development cycles, identify new targets for potential drugs, or differentiate their candidates from existing products. Our early analysis suggests that companies that develop one novel oncology drug through space-based R&D could obtain an average net present value of $1.2 billion.

Many other use cases, including the manufacture of retinas in space, are under investigation. Overall, our research on hypothetical use cases suggests that companies could potentially obtain $2.8 billion to $4.2 billion in revenues from pharmaceuticals in space.

Beauty and personal care

In the beauty and personal-care segment, skin care has emerged as one of the most promising segments for space opportunities: it is expected to account for more than 34 percent ($208 billion) of industry revenues by 2025. To date, R&D spending has been relatively low in this area, but trends suggest that it may soon rise, especially since many consumers are increasingly interested in products that have scientific data supporting their efficacy.

Overall, two areas stand out. The first, premium skin care, has an estimated compound annual growth rate (CAGR) of 13 percent through 2024 (compared with 3 percent for mass-market products). It is expected to reach $93 billion in value by 2025. Space-based R&D may unlock new insights about skin care because the harsh space environment, including high radiation levels, accelerates aging. Any new findings from space may carry a lot of weight with consumers who want scientific evidence of efficacy. These findings could also help differentiate and market products.

Another important use case involves the production of active ingredients—vitamins, retinol, and other substances directly responsible for a skin care product's effects. R&D spending in this area, now about $460 million annually, has an estimated CAGR of 19 percent. By 2025, such active ingredients are expected to generate $1.5 billion in value. Space-based R&D might help companies to develop or manufacture active ingredients in skin care products: microgravity reduces the sedimentation rate and the impact of buoyancy, making it easier to combine different substances, including those in yeast extracts. Preliminary scientific studies have also demonstrated that yeast cultivated in space have a higher growth rate and metabolic production, which could make products more effective.

Food and nutrients

The human-nutrition industry accounts for about $10 trillion in value. Within this segment, nutraceuticals—any food-derived product that has health benefits in addition to basic nutrition—are expected to represent $17 billion in value by 2025.

Probiotics—foods containing live bacteria and yeast with health benefits—are particularly popular within the nutraceuticals category and may be a good target for commercial activities in space. They are gaining popularity thanks to increased consumer interest in health and wellness issues, including those related to the immune system. The R&D intensity of probiotics is among the highest in the food ingredient industry. They represent about 30 percent of overall nutraceutical R&D spending.

Space-based R&D could help companies discover and develop new probiotics—routinely in demand from consumers—since the growth and metabolic expression of these products may differ in space. Space experiments might, for instance, help scientists better understand environmental influences on probiotics and increase the efficacy of probiotic products. Research suggests that consumers may be willing to pay a premium for innovative probiotics and that the discovery of a novel probiotic strain with health benefits could generate $100 million or more in commercial value.

Another potential use case involves the production of probiotics. As with beauty products, researchers may find that space provides a favorable environment for culturing and harvesting certain microbes, such as lactobacillus strains, found in probiotics. Microbes may, for example, grow more rapidly in suspension in space, given the lack of shearing effects in bioreactors.

Semiconductors

Semiconductors represent one of the largest global markets, with sales estimated to reach about $725 billion by 2025, when research spending will hit about $90 billion.

Fabrication in space could reduce the number of gravity-induced defects (from contaminants landing on chips) and increase output. The benefits would be relatively small, however, because semiconductor yields—the amount of usable chips—are already 97 to 99 percent, since many processes occur in highly sanitized clean rooms. A more important advantage might come from the natural vacuum in space, which could potentially facilitate innovative thin-layering techniques by reducing or eliminating gases during production. If space-based R&D could lead to the creation of smaller semiconductor structures, the benefits could be huge.

A few efforts to manufacture products in space are already under way. In 2020, for instance, a company received a NASA grant to investigate an autonomous and high-throughput process for creating, in orbit, high-quality chips at lower cost. But our analysis suggests that it may be ten years or more before large-scale, cost-efficient semiconductor manufacturing occurs in space. Among other obstacles, the heavy equipment now used in manufacturing would be difficult to transport there.

If space manufacturing does become possible, it might produce some environmental benefits, since the terrestrial manufacturing process requires high amounts of energy and other resources. If companies can use solar power in space or otherwise decrease resource requirements, that could both reduce costs and promote sustainability.

Some of the most visionary researchers and corporate leaders have been imagining space-based R&D, manufacturing, or other business activities since the early 1960s, when the first crewed flights took place. These ideas seemed implausible for many years, but recent technological advances—including those in robotics and AI, seamless space–earth communication, and unattended cell-feeding machines—have changed the game. Launch costs have also fallen, making space more accessible to businesses in traditional industries. Other technologies, including cubesats, a class of nanosatellites, are much less expensive.

After decades of research, artificial intelligence is finally enabling powerful new computing algorithms. Space-based R&D and manufacturing could also be nearing the point when they transform business and society. Much is still unknown, and many technological advances must still be made. But if large-scale space-based R&D and manufacturing do prove viable, companies that forge ahead now could become the pioneers directing the course for years to come.

1. According to NASA, people in space are exposed to 50 to 200,000 millisieverts (mSv) over six months, compared with 620 mSv on Earth.

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