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Perspectives on the future of space exploration

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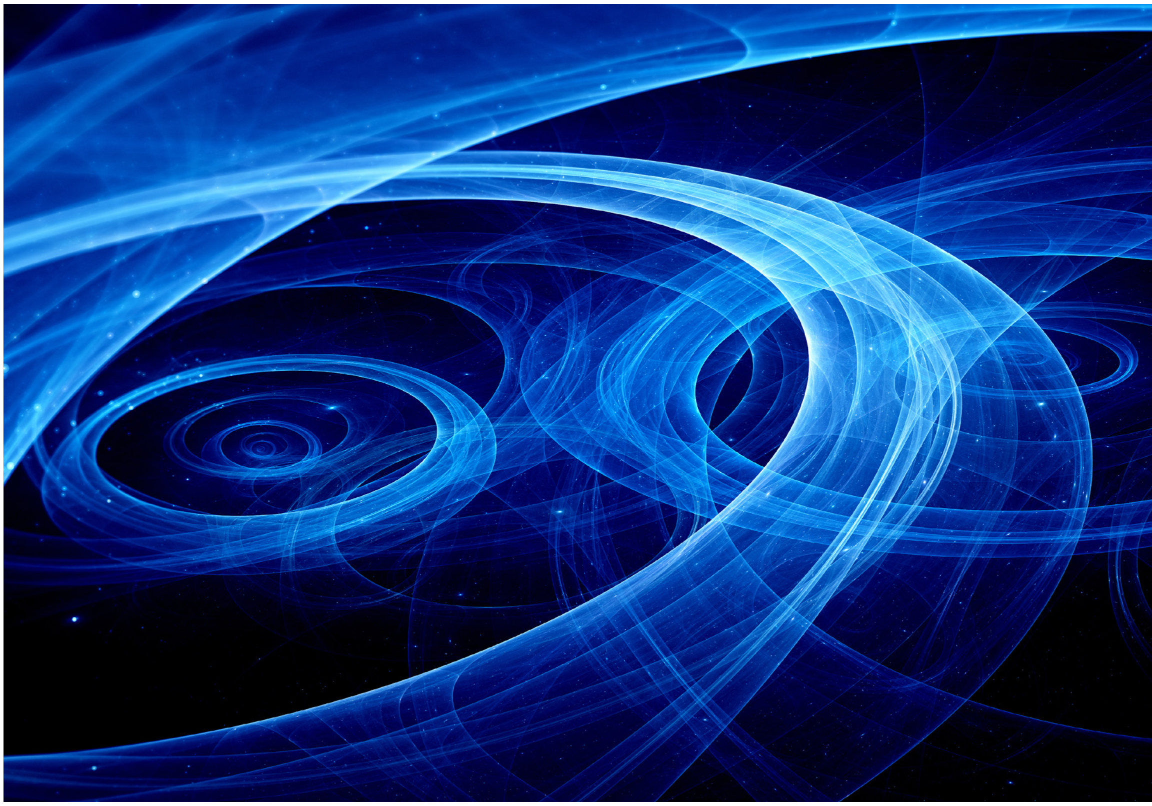

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Perspectives on the future of space exploration

Five leaders from industry, academia, and business outline the realities of sending new technologies, research methodologies, and business models into orbit.

Disruptive forces are changing the nature of space exploration. Because of advances in science and technology, researchers are designing experiments differently and tackling ever-more complex questions relating to data, discovery, and colonization. Due to changes in the economy and in industry funding models, private commercial enterprises are initiating projects that the government once led. Billionaire businesspeople are betting on a future in which public trips to Mars and back are reality, not a sci-fi fan's fever dream.

How can government and private organizations adapt to this changing reality? Last fall, five experts in space science and technology shared their perspectives on the future of space exploration as part of McKinsey's Imagine Get-Together event—a recurring salon led by McKinsey's Navjot Singh. The speakers opined on where space science—and the business of space exploration—was heading. They discussed how disruptive technologies are enabling new forms of space research, how funding mechanisms are shifting from the public to the private sector, as well as the challenges scientists face in addressing various unknowns relating to the exploration of Mars.

Jeffrey Hoffman, *a former astronaut and a professor in the department of aeronautics and astronautics at MIT:* New research technologies and approaches are dramatically changing space missions, as is the desire for manned missions to Mars. I'm the deputy principal investigator on a Mars oxygen experiment, or MOXIE, that is going to Mars on the 2020 Rover, which will launch in July 2020 and get to Mars in February 2021. This is one of the first big experiments involving in situ resource utilization—or living off the land. There are many ways to make oxygen on Mars. You could prospect for water there and extract oxygen from it, or you could dig up soil and pull oxygen from that. But that all requires mining, and you'd have to be where the resources are.

Our experiment addresses this limitation. Mars has an atmosphere that is about 95 percent carbon dioxide. Using an instrument about the size of a large shoe box, we're going to pump and compress the Mars atmosphere up to about the atmosphere pressure of one Earth and feed it into an electrolysis unit to make almost 100 percent pure oxygen. It's a small experiment—it will only produce about ten grams per hour (half as much as a person would need). But it's a start—a joint experiment between MIT and [NASA's] Jet Propulsion Lab that's pretty complex. When you first split carbon dioxide, you get carbon monoxide and oxygen. But if you let the process go too far, the carbon monoxide gets split into carbon and oxygen, and the carbon chokes up your whole apparatus, and it comes to a screeching halt. The ultimate idea would be to send a rover or spacecraft to Mars, one Mars cycle (about 26 months) early. That asset would be equipped with an oxygen-producing unit to fuel a return vehicle. After a year and a half, once we can verify that we can accomplish a return trip, we can commit to sending a crew to Mars.

Advances in materials science are enabling these kinds of ventures. We're developing nanomaterials, biomaterials—stronger, lighter substances that can go further in space but use fewer resources. They're prompting space scientists to consider applications that previously might have seemed unrealistic.

Jon Morse, *cofounder, chairman, and CEO of BoldlyGo, a nonprofit research organization:* There have been significant technological advancements in satellite remote sensing, and the cost of access to space is coming down dramatically. These are both areas that space science can leverage. But there needs to be an awakening on the part of major research foundations and high-net-worth individuals and families to the opportunity for frontier space-science missions that would have global visibility and leave a strong legacy.

Philanthropic giving and commercial interests could contribute to a new wave of space-science missions—and not just CubeSats, the miniature satellites that are relatively inexpensive to develop. The model of private funding for ground-based telescopes—like the 200-inch Hale telescope on Mt. Palomar or the twin ten-meter Keck Telescopes in Hawaii—has been around for 200 years, and it's time to adapt it to space science and exploration. In fact, some large, modern ground-based telescope projects are in the billion-dollar class—enough to build two Kepler missions. It would be helpful for NASA to actively promote private investment and public–private partnerships for scientific missions. Offering prizes for scientific outcomes could attract venture capital in addition to philanthropy.

John Serafini, *senior vice president of Allied Minds, a venture-capital fund focused on space-science start-ups:* Traditionally, the typical Space 2.0 start-up is not marketing itself based on revenue achievement and scalable growth. Rather it is marketing its value based on its vision and a projection of revenue that is often multiple years in the future. Our opinion has been that there needs to be more discipline in the funding process for these companies—what we would refer to as more of a revenue-based approach. What we do is develop an investment hypothesis, identify and license technologies that fit that hypothesis, and then we build start-up companies. One of our companies, for instance, is focused on solving a practical problem—data transmission. It uses optical technology to transmit information to a ground station. This technology is faster than more commonly used radio-frequency capabilities. The parties that use the optical transmitter can move terabytes of data with less difficulty, at less cost. It is small but it pushes data quickly across even limited bandwidth. Eventually, the start-up wants to establish a relay-node network to offload data from satellites and move them to the ground—from origination in space to receipt from terrestrial servers within seconds. Building commercial space enterprises like this one is not without its challenges—chief among them are privacy and regulatory issues. But we work with our customers and with regulatory agencies to help build awareness of and support for what we're doing.

Mitchell Burnside Clapp, *formerly of DARPA, president and founder of Embassy Aerospace:* There are many skills that we haven't mastered that are absolutely essential to colonization and the extension of the human endeavor into space. We know what humans can do. We know what robots can do. But the things that robots and humans together can do, working as a team, is a relatively unexplored area. Say I use a robot that vacuums the floor for me—all I've done is set a task for the robot. If I were cleaning the house and the robot were holding items for me as I dusted the shelves and then helped me put them back, or if the robot had figured out when I was running low on cleaning supplies and brought me more, that would be true human–robot cooperation. You can imagine a world in which we cooperate and enable capabilities that neither of us can have alone. These are the kinds of investments we should be making in space. If we organize our activity around creating a cis-lunar economy and go from there, we will, in fact, do a wonderful thing for expanding human civilization.

Priyamvada Natarajan, *professor of astronomy and physics at Yale University:* The future of space is not just an engineering problem but a much more challenging biological problem. We can solve the engineering problem; there is a lot of effort and innovation going on in that sector. But we are lacking innovation, ideas, and funding in understanding exactly how organic molecules in our bodies and in plants will react to radiation on Mars—the kinds of radiation levels we have never been exposed to before.

We need further study on radiation-shielding technologies, for example, perhaps even deploying other life forms like cyanobacteria to develop radiation-resistant coatings. We are likely to see a lot of cancer popping up, much more than what we're used to on Earth. If the goal is to create a colony on Mars, we have to build resources and protocols for dealing with the physiological and cognitive changes that radiation and other environmental impacts will create. It might be prudent to first consider setting up a moon base to prepare for Martian life. Even if we could build underground colonies, as some investors hope, oxygen will still be an issue—unless we could clone a set of species that would not require oxygen at all, or at the very least require less of it. Colonizing Mars might well require major biological leaps in terms of transforming humans to be more adaptable.

What's clear is that we cannot use space exploration as an escape hatch so we don't have to confront what we've done on our own planet. We should pay just as much attention to retaining life here and not repeating our mistakes in the next frontier. We're already seeing signs of our Earthly habits in space. There is a growing amount of space debris, the result of decades of experiments, government testing, and collisions. Many technical solutions have been proposed to clean things up, but who takes the lead?

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