From the intersection of computational science and technological speculation, with boundaries limited only by our ability to imagine what could be.

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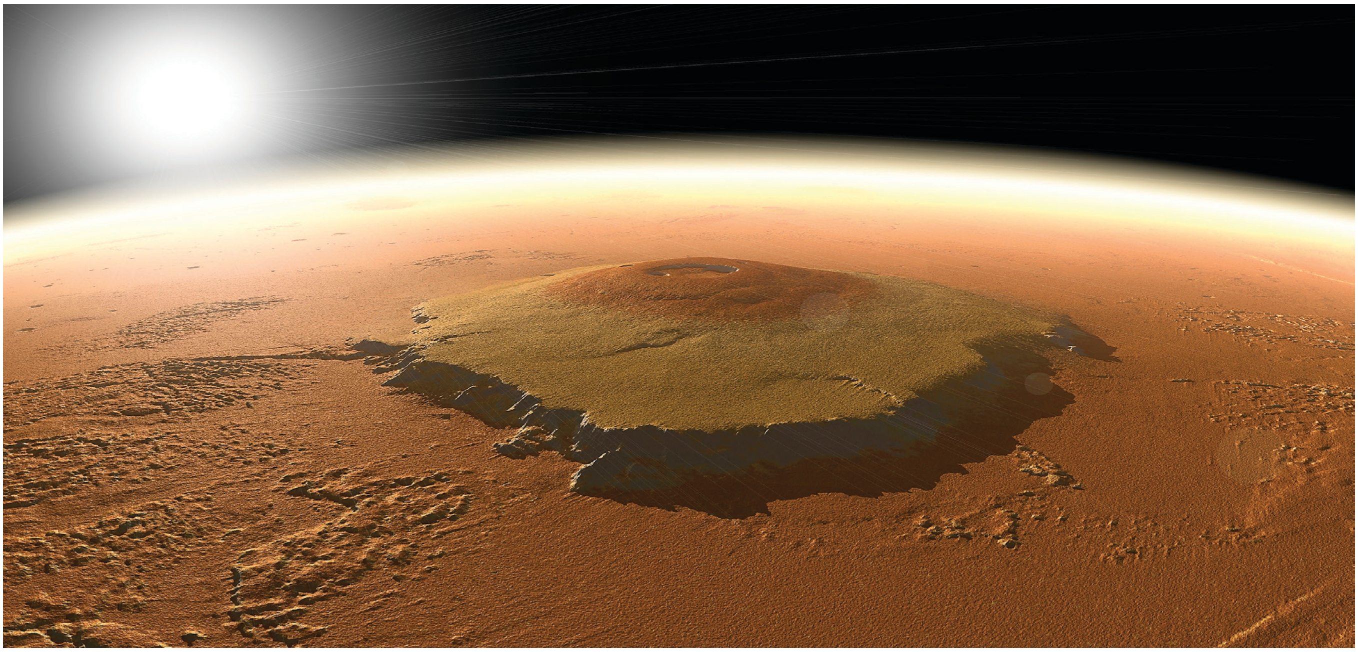
Future Tense
Becoming a Multi-Planet Species

Imagine hyper-realistic virtual space exploration limited only by the data we are able to collect.

HUMANS AND ROBOTS together are symbiotically creating a new age of exploration, extending human presence and evolution to transform us into a multi-planet species. Not as humans vs. robots or as robots vs. humans. Such characterizations are archaic. Our multi-planet evolution will be a continuum of human and robot, with us physically present on Earth and Mars and virtually present beyond. Humankind must make it to Mars to overcome the physical and psychological limit of being confined to our fragile singular planet. But technologies for exploration beyond Mars are evolving so quickly that by the time we settle on the Red Planet our species will be completely immersed in and interacting with worlds throughout the solar system and even beyond. Let us imagine how that might be, looking into our future.

It is July 20, 2069, the 100th anniversary of humanity's first landing on another world. Dr. Angela Okonjo is reviewing, one last time, her prepared speech for the Anniversary Program. She is director of Mars Base 1, the highest-ranking human resident on Mars, whose population is now several hundred people distributed on three bases around the planet. "How strange it is," she thought, "that I, an information sciences major at MIT, immersed deeply in the world of robotics engineering and artificial intelligence, should be the representative of human exploration on another world." But she realized it was not strange at all; all exploration involves humans and robots, humans deeply involved in so-called robotic missions, and robotics hard at work on so-called human missions.

She would commemorate not just the Apollo human Moon landing but a century of extraterrestrial robotic exploration, extending human presence throughout (but not yet beyond) the solar system. Remarkably, the "flexible path" for humans to Mars laid out 60 years ago had been followed—the first human venture beyond (albeit barely) the Moon in 2025; the first human interplanetary flight three years later; the first [CONTINUED ON P. 135]



DATA NASA/JPL/GSFC, IMAGE OLIVIER DE GOURSAC

[CONTINUED FROM P. 136] round-trip flight around Mars five years after that (2033), followed by the initiation of a Mars orbit outpost in 2038; and a landing on the surface six years later in 2044. The Mars goal laid out by President Barack Obama in 2010 following the report of his Review of U.S. Human Spaceflight Plans Committee in 2009[a] had proved sustainable, as well as internationally appealing, with nearly 20 nations represented on the three bases now on the Red Planet. The bases were still outposts, dependent on Earth supplies, but in the 25 years since the first landing on Mars their use of indigenous Martian resources had increased to the point that power, propulsion, and water were completely Martian-supplied and 25% of the food was locally grown. Oxygen, along with manufactured supplies, was imported from Earth, though less and less so.

Dr. Okonjo would give her speech from inside a domed amphitheater at the Tharsis Bulge near Mars's equatorial region. Behind her was Olympus Mons, the tallest mountain in the solar system, the backdrop chosen for the amphitheater locale. Most human activity was conducted underground or in protective shelters, but having Martian vistas was important to the explorers whose goal was planetary settlement. She reflected, "In a time period shorter than between Columbus's first landing on a small Western Hemisphere island to the beginning of the first European settlement in North America 111 years later, we had moved from the first human landing on another world to the beginning of a new-world settlement. May our vision for Mars be even more bright and far-reaching than for America four centuries ago."

At the same time, 2069, back on Earth, another explorer, Carlos Gupta, is stepping through a portal in his home office directly into his AI display. There, information is processed from data streaming back from robotic Europan submarines. It will be organized into holographic virtual-world displays for human observation, experience, and interaction, convincingly real. The data comes from the six submarines now roaming the Europan ocean, plus three more on Europa's icy surface, serving as both backup vehicles to the explorers below and as surface observation and communication outposts. Included are optical images, visible, infrared, and ultraviolet; sound at a range of frequencies spanning several times the human range; mass spectrometer and chemical data providing the equivalent of olfactory and taste data; and even tactile data from the many appendages and external sensors on the submersibles.

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The data processed into the classical five senses of information by the AI programs in Gupta's computers provides the five classical human senses of sight, hearing, smell, taste, and touch to the explorers in the virtual world created through the display. The AI also provides the arguably not-so-classical sixth sense of intuition to help humans in the virtual world infer an equivalent real-world experience, including observation, inference, hypothesis, conclusions, and predictions.

Gupta can reflect, with an irony opposite of Okonjo's on Mars, on being a stay-at-home explorer of other worlds. With his training as an experimental and field astrobiologist working in extreme environments, Gupta would have expected to have the experience of being physically off-Earth in a new world, not exploring virtually in his own home. But in less than a century after a large subsurface Europan water ocean was first detected, he was able to immerse himself in that ocean to search for, maybe even interact with, putative extraterrestrial life there.

The virtual world Gupta explores is also available to millions more on Earth, creating a sense of being there that enables human presence far beyond the limits of physical human travel. Rather than wish for non-invented technologies or devices that break the laws of physics for human space travel to a theoretically habitable world around another star, say, 100 trillion kilometers from Earth, we get there much sooner in virtual worlds created through real data and real human interaction. A nano-spacecraft loaded with nano- or even pico-technology sensors flying at enormously high velocity propelled by lightsails pushed by large laser arrays in our solar system can stream data from an exoplanet to earthbound supercomputers, or AI machines. We will create a virtual world in which we extend our human presence. Even in this century we can do this at the outer planets of the solar system, without the kind of laser arrays needed for interstellar flight. Perhaps we can conduct missions in this century out to 1,000 astronomical units where we might image a habitable exoplanet using a solar gravity lens as our telescope. If there is life out there we might actually see and touch it.

With such exploration there will be no need or motivation—cultural, scientific, or psychological—to have humans physically go beyond Mars. But humans will not be limited. At the same time we reach to the stars we will be settling on Mars, providing an infinite vista for growth and development. Occupying another world also addresses real or imagined existential threats to our home planet. Our species could thus survive even an asteroid impact, pandemic, climate catastrophe, or nuclear war. We will be settlers on Mars and explorers of worlds beyond, feeling our human presence throughout and beyond our solar system.

Back now to 2016 ... I see no contradiction or conflict in these two paths for human-robotic evolution—on Mars physically, in the Universe virtually. We are actually on these paths already, making me optimistic about our future as the most cosmic of explorers. ■

a See the Committee's 2009 report at https://www.nasa.gov/pdf/396093main_HSF_Cmte_FinalReport.pdf and President Obama's announced goal in 2010 incorporating much of its recommendations at http://www.nasa.gov/news/media/trans/obama_ksc_trans.html.

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