Expert Insights

IBM Institute for Business Value

Exponential technologies at the edge of space

The future of industry and innovation in the space economy

IBM

Expert on this topic

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"What happens when space is no longer the domain of scientists, engineers, and pilots, but also of artists, athletes, and entrepreneurs?"

—**Dr. Shawna Pandya,** Vice President of Immersive Medicine, Luxsonic Technologies and Director, Space Medicine Group, International Institute for Astronautical Sciences

Key takeaways

Space-based data drives better decision-making.
Machine learning and AI can deliver real-time insights from the staggering amount of data satellites deliver each day, helping humanity respond faster to crisis and change.

Technology is enabling the democratization of space.
Affordable access to space-based technology is opening up the space economy—and democratization promises to launch a new wave of discovery.

The space race is a team sport.
Building an ecosystem of partners with different specialties is key to enabling exploration and long-term operations in the harshest environment humanity has ever known.

Space is the next frontier—and everyone is staking their claim. As Elon Musk, Jeff Bezos, and Richard Branson compete to become space travel tycoons, companies across sectors are jockeying for leadership in the nascent global space economy.

Nokia is working with NASA to build the first lunar cellular network.[1] Toyota is partnering with the Japan Aerospace Exploration Agency (JAXA) to develop a pressurized lunar rover.[2] And NASA recently awarded several lunar mining contracts in the interest of building industrial capabilities for the future.[3]

What's driving this flurry of commercial investment? The imminent exploration of the lunar surface.

NASA's Artemis mission, which plans to return humans to the moon in 2024, is advancing the agency's goal of launching sustainable, long-term missions by 2028.[4] In preparation for a more permanent human presence on the moon, 8 countries signed the Artemis Accords in October 2020, seeking to establish "safety zones" designed to prevent conflict while enabling research and commercial operation in space.[5]

"It's NASA's role to do the hard things, while bringing industry along with us as partners. Once industry has developed the capability to provide what only government could previously provide, then NASA should turn that capability over to industry and pivot to the next hard thing."

— **Robyn Gatens,** Director, International Space Station, NASA

> “The idea that we can eventually construct complex spacecraft in orbit rather than needing superheavy launchers to accomplish the task gives literally a whole new avenue for innovation.”

—Dr. Tanya Harrison, Director of Science Strategy, Planet Labs

Disruption and democratization

The space economy is expanding, and no one wants to be left behind. In Q2 2021, private investment in space companies hit a new high of $4.5 billion, which puts 2021 on track to surpass the record-breaking $9.1 billion raised in 2020.[6] And while the space industry is valued at roughly $350 billion today, Morgan Stanley estimates that it could surge to over $1 trillion by 2040.[7]

While the space race is on, no organization can win it alone. Public agencies, private companies, and scientific researchers must share knowledge and resources to enable long-term operations in the harshest environment humanity has ever known.

Innovations created by SpaceX, for instance, have revolutionized and energized the space tech industry. Its Falcon 9 rocket, the first orbital-class rocket capable of re-flight, has made space transport much more affordable.[8] Reusing the most expensive components of the rocket costs less than half of what it would take to build a new one from scratch.[9] And SpaceX has passed this cost efficiency on to NASA, which has used the Falcon 9 rocket to resupply[10] and even transport crew members to the International Space Station (ISS).[11]

Building an ecosystem of partners with different specialties is also key to solving the innumerable problems that come with living outside the Earth’s atmosphere. For instance, researchers are currently examining how long-term exposure to elevated levels of radiation impacts the genetic makeup of people and plants. They’re also identifying microbes they happen to find in flight.

But downlinking all that data takes a lot of time. On Earth, devices and systems in remote locations experience challenges related to network and data latency, maintenance, movement of large data, and delivering code. This gets amplified when dealing with systems in Earth’s orbit and beyond.

An edge solution designed by IBM has helped slash that lag time. Using a DNA sequencer the size of a candy bar, astronauts can now analyze samples on the International Space Station (ISS) rather than sending data to Earth for processing. This innovation, powered by Spaceborne Computer-2, cuts the time it takes to complete this task from 6 to 8 weeks to 6 to 8 *hours*.

This capability could allow future astronauts to analyze environmental samples in real time, helping them learn about new landscapes and identify potential sources of potable water. And this is just the beginning.

Imagine a world fully connected, from oceans to mountains, from deserts to glaciers, and from rural areas to the modern cities of the future. SpaceX Starlink, Amazon Kuiper, and others have launched mega constellations to provide broadband connectivity, potentially sparking a major disruption in communications across the globe.

Plus, sending CubeSats and other nanosatellites into low-Earth orbit has become affordable, allowing researchers and educators from around the world to gather information and test systems at a whole new level. Global citizen science, combined with world-class research powered by the cloud, promises to launch a new wave of discovery.

All these technological advancements, paired with unparalleled growth in the global space industry and innovative public-private partnerships, are defining a new landscape for a new space age, leading the way toward the democratization of space.

And people around the world are excited for what this means for the future of humanity. In a recent IBV survey, 93% of global consumers said they were confident that advances in science and technology will help advance space exploration to improve life on Earth in the next five years.[12]

> "Space is a harsh and unforgiving environment for both biology and technology. It is a near-perfect vacuum, a high and potentially lethal radiation environment, a micro- or zero-gravity environment, and subject to extremes in temperature that are very challenging to accommodate."
>
> — **Bill Diamond,** President and CEO, SETI Institute

On the bleeding edge of space

IBM has partnered with NASA since the earliest days of the space program. Here's a brief history of how our computing power has helped humanity push the boundaries of the final frontier.

2021	Researchers at NASA and astronauts on the ISS sequence the genes of microbes found in space for the first time. An edge computing solution from IBM made the in-orbit analysis possible.
2014	The Orion spacecraft, designed to carry humans to Mars, completes its first test flight, powered by IBM processors.[13]
2001	The space shuttle Discovery conducts the first crew exchange on the new International Space Station (ISS).[14] NASA astronauts successfully store and bring back high-resolution digital images on IBM's one-gigabyte, one-inch IBM Microdrive.[15]
1997	The Pathfinder rover, equipped with an onboard flight computer powered by IBM technology, lands on Mars.[16]
1981	The space shuttle Columbia takes its first orbital flight.[17] The shuttle launch and launch preparation facilities in Florida were supported by a complex test data system designed by IBM.[18]
1969	Neil Armstrong and "Buzz" Aldrin became the first humans to walk on the moon as part of NASA's Apollo 11 mission.[19] IBM computers were central to the development of manned mission control and early spacecraft navigation.[20]
1958	Vanguard 1 becomes the first successful American satellite.[21] An IBM 704 computer conducted orbit calculations in real time so researchers could listen for signals as it approached their location.[22]

Leaping light years ahead

Here's a closer look at how exponential technologies are laying the groundwork for the next generation of space exploration—and what that could mean for life back on Earth.

Edge computing is a distributed computing model that allows local sensor data to be processed close to where it's collected, making it actionable almost instantly. This is especially advantageous when working in the vast expanses of space, where time and energy are at a premium. It also enables nearly real-time reactions, which is invaluable in an emergency.

For example, sensor-equipped swarms of nanosatellites can help make disaster responses faster and more accurate by offering near-immediate images of the areas affected. These satellite swarms, which fly about 250 to 370 miles above the Earth's surface, can also support the study of weather, and play a critical role in helping leaders better understand and create plans to manage climate change.

And pushing edge computing to the edge of space should accelerate the evolution of technology back home. Because such extreme use cases set a very high bar, these innovations and advancements can greatly benefit edge computing on Earth as we enter the era of 5G networks, Industry 4.0, and smarter homes.

Artificial intelligence (AI) and machine learning make sense of the information gleaned from low-orbit satellites much faster than a human ever could. Technologies such as Synthetic Aperture Radar (SAR), an all-weather imaging system, capture clear images in virtually all types of conditions and produce a staggering amount of data each day. The right insights can benefit precision agriculture and boost crop yield while helping to fight deforestation, wildfires, and climate change.

“Without sustainability, there will be no permanent human presence in space. Systems, programs, and human factors need to become far less dependent on frequent support from Earth.”

— Chris Carberry, CEO and Co-founder, Explore Mars

Using machine learning models, researchers can quickly clean the signal from the noise in their data downloads to tease out changes, trends, and anomalies that could be missed with standard analysis. During a natural disaster, for instance, these satellites can locate and assess the extent of the damage to a given building by automating the analysis of imagery, which helps government agencies expedite relief to affected areas.

The European Union (EU) is also creating an ambitious digital twin—a virtual representation of an object or system—of Earth to simulate changes in the atmosphere. The EU model is expected to use machine learning techniques to provide more accurate predictions of climate change. This model would leverage massive amounts of geospatial data gleaned from satellites.

“AI is critical in order to handle the sheer volume of Earth observation data that is coming down every day,” says Dr. Tanya Harrison, Director of Science Strategy, Planet Labs. “Machine learning and AI will be the only way to unlock the full potential of all of this data, for us to truly gain insights from it all.”

5G networks and the Internet of Things (IoT) work together to move data long distances as quickly as possible. As more infrastructure is built, users on Earth and in space can speed up transmissions by opting for the most cost-effective and reliable path available—and this demand just keeps growing.

“What we have seen in the terrestrial realm is that more connectivity drives a higher expectation and demand for data usage, and we will likely see that in the space domain as well,” says Katherine Monson, Chief Commercial Officer, Analytical Space.

Creating an interwoven fabric of both terrestrial and space-based connectivity will also increase the resilience of communication networks overall. “Imagine how powerful it would be to have a unified network that performs as well the day before, the day of, and the day after a hurricane, tsunami, earthquake, or any other earthly catastrophe,” says Cole Crawford, CEO and founder, Vapor.io. “Think about how quickly zip codes end up with connection parity.”

Blockchain is a shared, replicated, and decentralized system that stores transactions in an immutable data ledger. The trust, traceability, and transparency blockchain provides is particularly valuable when it comes to optimizing cargo on resupply journeys to the ISS.

In addition to safety, a primary concern of ISS resupply missions is ensuring that every single payload component is compliant with regulatory requirements—and that the payload arrives on time. Blockchain provides near real-time information that can improve the scheduling and auditing process behind each payload, which is critical when dealing with the costs and constraints of sending cargo to space.

Blockchain can also play a key role in the manufacturing of assets for the space industry, such as satellites, gateways, and rockets. It helps provide transparent end-to-end tracking in the supply chain for trust and visibility between suppliers, contractors, transportation, regulatory authorities, and customers. This is essential for aerospace projects, where there is often no room for error—but this level of visibility and control can improve results for businesses across sectors.

“The *‘we’re in this together’* ethos of COVID-19 will hopefully last, and our industry can translate that into an understanding of how space can be used to protect life on Earth.”

— Clifford W. Beek, CEO, Cloud Constellation Corp.

Energizing space-based research

Next-gen tech powers revolutionary discoveries on the International Space Station (ISS).[23]

One acre of solar panels power the ISS.

350,000: The number of sensors on the ISS.

50+ computers control the systems on the ISS.

More than **3 million lines** of software code on the ground support more than **1.5 million lines** of flight software code.

4 hours: The flight time to reach the ISS.

Shockwaves to the system

The first wave of space exploration transformed life on Earth within a single generation. It gave us personal computers, mobile phones, and global positioning systems (GPS). It enabled medical advancements ranging from CAT scans and MRIs to lifelike artificial limbs. It laid the groundwork for the smart cities and renewable energy infrastructure that promise to power a more sustainable future.[24]

And the ripple effect is ongoing. In September 2020, NASA released the results of its first-ever agencywide economic impact report. It showed the agency generated more than $64.3 billion in total economic output during fiscal year 2019, supported more than 312,000 jobs, and generated an estimated $7 billion in federal, state, and local taxes across the US.[25]

Looking forward, consumers around the world see the exciting potential of the sector's hard work. When asked which industries are the most innovative in the way they leverage advances in science and technology today, 42% said aerospace, followed by electronics (38%) and information technology (34%).[26]

"Developing space-capable technologies is impacting everything from materials science to system, subsystem, and component design and fabrication, thereby offering the potential to improve system performance, reliability, and cost across multiple technologies and applications," says Bill Diamond, President and CEO, SETI Institute.

The next wave of space innovation will give humanity new tools to tackle some of its biggest problems, from education inequality to climate change. And it will make it easier for more people to get involved, driving faster innovation and more equal opportunities for business development. It will democratize access to space.

"Access to the right information at the right time can have transformative outcomes, creating economic opportunity and bringing communities closer together," says Aude Vignelles, the Australian Space Agency's Chief Technology Officer.

> "Today, we rely on countless high-tech devices that are vulnerable to solar storms. We need to enhance US resilience to space weather in all its forms by identifying current and future vulnerabilities and mapping the technologies and policies needed to address the gaps."
>
> — **Dr. Madhulika Guhathakurta**, Senior Advisor for New Initiatives, NASA/Goddard Space Flight Center, Heliophysics Division

Notes and sources

1 Goldman, David. “NASA and Nokia are putting a 4G network on the moon.” CNN Business. October 19, 2020. https://www.cnn.com/2020/10/18/tech/4g-network-moon-trnd/index.html

2 Wall, Mike. “Toyota, Japan to Launch Huge Moon Rover for Astronauts in 2029.” Space.com. July 23, 2019. https://www.space.com/toyota-japan-moon-rover-2029-timeline.html

3 Davenport, Christian. “A dollar can’t buy you a cup of coffee but that’s what NASA intends to pay for some moon rocks.” *The Washington Post*. December 3, 2020. https://www.washingtonpost.com/technology/2020/12/03/moon-mining-contracts-named

4 “What is Artemis?” NASA. July 25, 2019. https://www.nasa.gov/what-is-artemis

5 “Moon rising: 8 nations sign lunar settlements, exploration pact.” Al Jazeera. October 13, 2020. https://www.aljazeera.com/economy/2020/10/13/moon-rising-8-nations-sign-lunar-settlements-exploration-pact

6 Sheetz, Michael. “Investments in space companies hit record $4.5 billion in the second quarter, report says.” CNBC. July 14, 2021. https://www.cnbc.com/2021/07/14/space-capital-q2-report-shows-record-4point5-billion-invested.html

7 “A New Space Economy on the Edge of Liftoff.” Morgan Stanley. February 17, 2021. https://www.morganstanley.com/Themes/global-space-economy

8 “Falcon 9.” SpaceX. Accessed July 30, 2021. https://www.spacex.com/vehicles/falcon-9/

9 Fearon, Robin. “Expanding Space Exploration Possibilities with Retrievable Spacecraft.” Discovery. Accessed July 30, 2021. https://www.discovery.com/technology/Reusable-Rockets

10 Sempsrott, Danielle. “SpaceX’s 22nd Cargo Resupply Mission Underway as Dragon Journeys to Station.” NASA. June 3, 2021. https://blogs.nasa.gov/spacex/2021/06/03/spacexs-22nd-cargo-resupply-mission-underway-as-dragon-journeys-to-station/

11 “NASA’s SpaceX Crew-2 Astronauts Headed to International Space Station.” NASA. April 23, 2021. https://www.nasa.gov/press-release/nasa-s-spacex-crew-2-astronauts-headed-to-international-space-station

12 IBM Institute for Business Value Human Insights Global Survey of 14,526 adults, July 2021

13 Gaudin, Sharon. “The Orion spacecraft is no smarter than your phone.” *Computerworld*. December 4, 2014. https://www.computerworld.com/article/2855604/the-orion-spacecraft-is-no-smarter-than-your-phone.html

14 Leary, Warren E. “Shuttle Primed for Crew-Exchange Mission to Station.” *The New York Times*. March 7, 2001. https://www.nytimes.com/2001/03/07/us/shuttle-primed-for-crew-exchange-mission-to-station.html

15 “21st century storage chronology.” IBM. Accessed August 3, 2021. https://www.ibm.com/ibm/history/exhibits/storage/storage_chrono21.html

16 “IBM Highlights, 1996-1999.” IBM. Accessed August 3, 2021. https://www.ibm.com/ibm/history/documents/pdf/1996-1999.pdf

17 Taylor, Alan. “The History of the Space Shuttle.” *The Atlantic*. July 1, 2011. https://www.theatlantic.com/photo/2011/07/the-history-of-the-space-shuttle/100097

18 “IBM and the Space Shuttle.” IBM. Accessed August 3, 2021. https://www.ibm.com/ibm/history/exhibits/space/space_shuttle.html

19 “July 20, 1969: One Giant Leap For Mankind.” NASA. July 20, 2019. https://www.nasa.gov/mission_pages/apollo/apollo11.html

20 “IBM and NASA: Working Side-by-Side to Land on the Moon.” IBM. July 18, 2019. https://www.ibm.com/blogs/policy/apollo-moon-landing

21 “Vanguard 1.” NASA. Accessed August 3, 2021. https://nssdc.gsfc.nasa.gov/nmc/spacecraft/display.action?id=1958-002B

22 “Computers in Spaceflight: The NASA Experience.” Accessed August 3, 2021. https://history.nasa.gov/computers/Ch8-2.html

23 “International Space Station Facts and Figures.” NASA. May 13, 2021. https://www.nasa.gov/feature/facts-and-figures

24 “20 Breakthroughs from 20 Years of Science Aboard the International Space Station.” NASA. October 26, 2020. https://www.nasa.gov/mission_pages/station/research/news/iss-20-years-20-breakthroughs

25 “NASA Report Details How Agency Significantly Benefits US Economy.” NASA. September 25, 2020. https://www.nasa.gov/press-release/nasa-report-details-how-agency-significantly-benefits-us-economy

26 IBM Institute for Business Value Human Insights Global Survey of 14,526 adults, July 2021

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