The Center for Growth and Opportunity at Utah State University

Why go to space?

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Research in Focus

Space enthusiasm can be baffling to the uninitiated. Why are some nerds so enamored with space? Why should society spend any resources to go there? Why are billionaires jockeying to realize their visions for space development? Why do we give NASA over $20 billion per year, and the Space Force nearly as much? Why should we do any of this if we still have problems on Earth?

Imagine a switch that turned off American space capabilities.

If you flip it, there's no more NASA. Space Force and SpaceX disappear. All the weather and climate data that National Oceanic and Atmospheric Administration (NOAA) collects from space goes offline. The National Reconnaissance Office is suddenly blind.

What would happen? The quality of life on Earth would rapidly degrade. Democracies would find themselves increasingly threatened by authoritarian powers. We would lose vital scientific resources. Our institutions would experience a slow decline.

We must continue to invest in space if we want to flourish as a society and as a species.

Improving daily life on Earth

Space already has a surprising impact on modern life. This is particularly true for satellites. Global satellite communication systems are used by the broadcast industry, but also for critical safety-of-life functions aboard planes and ships, which sometimes travel out of range of other communication methods. Workers on board oil platforms use satellites to connect to civilization. As SpaceX's Starlink broadband satellite megaconstellation continues to grow, millions of rural households may soon get access to speedy Internet service for the first time.[1]

It's not just communication. Consider the value that satellite positioning adds. If you are on board a plane traveling through storm clouds or if you have cargo on a ship crossing the Pacific, the Global Positioning System (GPS) keeps you and your goods on track and safe. Without GPS, a lot of your smartphone's functions would go away. Forget about the entire business model of Uber and Lyft. Say goodbye to in-dash navigation.

An underrated way that satellites improve our lives is through accurate weather forecasting. As weatherman Al Roker notes in his book *The Storm of the Century*, the death toll was high during the 1900 Galveston hurricane in part because there was no official warning, a decision fueled by distrust of Cuban weather forecasts passed along via telegram, concern about falsely alarming the public, and the director of the US Weather Bureau's desire to closely control information.

With today's reliable weather forecasts, Galveston could have prepared for the storm and saved thousands of lives. Today's forecasts in the US are powered by NOAA's continually improving Geostationary Operational Environmental Satellite (GOES) system. Although some of the improvement in today's forecasts are attributable to gains in computing, NOAA officials say "no change has had as big of an impact on weather prediction as the invention and improvement of environmental satellites."[2]

Beyond satellites, space technology has contributed to our quality of life on Earth in countless ways. NASA's technology transfer program has generated thousands of spinoffs across dozens of areas.[3]

To highlight just one area where NASA research has generated new possibilities and commercial opportunities on Earth, consider vertical farms, which are now delivering fresh produce to grocery stores all over the country while economizing on soil, land, pesticides, and water. Being able to grow food in orbit is essential if we want to support large populations living there, but we will have to do it with limited space, water, and supporting mass.

To meet this challenge, NASA funded research to mature next-generation aeroponic growing techniques.[4] NASA also contributed to vertical farming by pioneering LED growing systems and the "light recipes" that enable them to produce edible plant mass as efficiently as possible.[5] Beginning in 2002, the agency even successfully tested these growing systems onboard the International Space Station.[6]

The commercial space industry is also on the cusp of providing new benefits to human beings on Earth. Gravity is one of the four known fundamental forces. The ability to operate in orbital microgravity is like having an off switch for one of the laws of physics. This capability is so fundamental that it would be shocking if it had no applications.

It turns out that some articles—certain pharmaceuticals, carbon nanotubes, and silicon wafers used in semiconductor manufacturing—can only be manufactured or can be manufactured with better tolerances in zero gravity.[7]

The low cost per kg of SpaceX's Starship rocket could make space manufacturing at scale viable for the first time. Varda is a startup that is offering zero-gravity manufacturing as a service.[8]

Perhaps the first commercial product that will be manufactured in space for use on Earth will be ZBLAN optical fiber. ZBLAN is a fancy fluoride glass with a theoretical attenuation 20 times lower than the silica fiber optic cables we use today. Today's undersea cables address the attenuation problem by placing a repeater every 100–150 km along the cable, at a cost of $1 million per repeater.[9]

ZBLAN fibers would require fewer repeaters, cutting the cost of undersea cables, which connect our portion of the Internet to Europe and Asia, by tens of millions of dollars. The catch is that manufacturing ZBLAN in gravity causes crystals to form in the glass.[10] Fibers manufactured in zero gravity feature much less crystallization and therefore less attenuation.[11] These better fiber optics will improve long-distance connectivity and lower the cost of our information infrastructure.

Protecting and preserving democracy

Space investments enable democratic countries to continue to defend themselves against space-capable authoritarian regimes like China and Russia. The military importance of occupying the high ground has been understood for millennia, and space is the ultimate high ground.

From space, we can survey every battlefield and peer behind enemy lines. Satellite imagery from both commercial and government programs is being used extensively in Ukraine to track Russian movements. To penetrate the clouds, some of these satellites use synthetic aperture radar, an imaging technique that uses microwaves instead of visible light. Unlike normal photographs, it works at night and in overcast skies.[12]

Surveillance satellites are far from a static endeavor. Recent spy satellites operated by the US National Reconnaissance Office operate in eccentric orbits that enable them to briefly get close to their targets—for example, the satellite known as USA-245 orbits with an apogee of 1,010 km and a perigee of 276 km.[13] In other words, it swoops in close to the Earth to get a high-resolution photo. Meanwhile, *MIT Technology Review* reported in 2020 that this satellite is being stalked by a Russian satellite.[14] By spying on our satellites, the Russians can get a good sense of what we are looking at.

America's ballistic missile early warning system is also largely based in space. The main layer of satellites that performs this function is called the Space-Based Infrared System (SBIRS).[15] Satellites that are part of SBIRS operate in both geosynchronous and highly-elliptical orbits, while other satellites in complementary systems operate in low-Earth orbit. These latter satellites are important for tracking the flight of any launched missiles, including the decoys released by modern Chinese and Russian missiles that make shooting them down harder.

SBIRS is getting close to the end of its intended service period, and may soon be replaced by what's known as the Next Generation Overhead Persistent Infrared System.

America's missile defense capabilities are for now focused on short- and intermediate-range missiles. We are still far from being able to protect the country from advanced intercontinental ballistic missiles, and maneuverable hypersonic weapons could make this challenge even more severe. Yet any level of missile defense is predicated on space-based missile tracking, so if we want to increase our capabilities, we need to continue to invest in space technology.

So far, no country has declared any space-based weapons, but they may yet be coming. One concept studied by the US Air Force is "rods from God."[16] The idea is to deorbit a large tungsten rod from space and steer it into a target, which it would strike with a speed of Mach 8–10. Since kinetic energy is a function of mass and velocity squared, these heavy and fast rods would pack quite a punch for a purely kinetic weapon, being able to penetrate today's nuclear bunkers.

Unlike conventional weapons, these hypervelocity rods would be almost impossible to intercept, could be launched with minimal risk of detection, and would take only a few minutes to hit their target, assuming a sufficient number of rod-launching satellites in orbit.

Since it is clear that warfare of the future will be ever more reliant on space, the major powers have all invested in anti-satellite weapons. The US, China, Russia, and India have all demonstrated the ability to shoot down their own satellites.

If a serious war broke out between space-faring nations, a lot of satellites would quickly get disabled. This could lead to reduced reconnaissance capabilities, loss of positioning services, and shorter missile warning times. Because attacks on satellites generate debris, there could be a chain reaction where one satellite's debris takes out other satellites. Access to low Earth orbit could be temporarily disabled.

To protect against anti-satellite weapons, we must invest in new, "proliferated" architectures. Today's satellites are juicy military targets. But if we used large constellations instead of single spacecraft to provide critical services, our capabilities would be more likely to survive first contact with the enemy.

In addition, we must invest in more maneuverable, evasive satellites as well as satellites that are capable of operating in ultra-low Earth orbit (between 200 to 300 km of altitude), where debris is swept away by drag in a matter of days and images have the sharpest resolution.

Enriching science

Space investment is worthwhile for pure scientific knowledge, even in the absence of any immediate practical benefit. If you love science, if you believe in science, if you think science is in any way beneficial, you should embrace space investments. We would not be as scientifically advanced as we are today if not for space.

If you care about Earth's climate, I have news for you: Our best data on how the climate is changing comes from space.

"We have this GOES [Geostationary Operational Environmental Satellite] series of satellites [that] dates back to the 1970s," says NOAA scientist Jordan Gerth. "And so, by continuing to watch geostationary satellites, we're now getting to the point where we can have a very robust, nearly 50-year look at how the atmosphere is changing."[17]

Newer, high-resolution imaging and Earth sensing satellites help us understand and control for effects like urban heat islands and land-use changes.

It's not just today's Earth that space can help us to understand. By modeling the Solar System with empirical data collected from both astronomical observatories and space probes, we can help understand Earth's deep past. For example, we know that when Earth first formed, it was too hot to sustain oceans. Scientists don't know for certain where the oceans came from.

Isaac Newton speculated that they were made from the tails of comets. For a while, the leading theory has been that the oceans formed from hydrated minerals deep in the Earth's mantle. But recent evidence suggests that some or all of the water that forms the ocean was brought via collisions with asteroids or planetesimals, perhaps even in the collision that may have resulted in the ejection of the moon from Earth's mass.[18]

Measurements from the NASA *Dawn* spacecraft tell us that as much as 30 percent of the mass of Ceres, the largest known asteroid, is water. As astrophysicist Martin Elvis notes in his book *Asteroids*, it would take only five Ceres-like asteroids to bring all of the ocean's water to Earth.[19] The next time you are standing on a seashore gazing out over the water, consider that all you see may have originated in space.

While astronomy can be carried out on Earth, we can get a better picture of the universe using space telescopes. The Hubble Space Telescope, for example, has not only captured stunning images of other galaxies, it has provided our most accurate estimate of the age of the universe so far.[20]

The James Webb Space Telescope, which is on the cusp of beginning operations, will capture photons traveling from the first stars and undoubtedly make many new discoveries. As I argued in *Works in Progress*, the holy grail of astronomy is a lunar telescope array, one that benefits from being located outside of our atmosphere while also being able to combine signals from multiple instruments like the arrays on Earth do.[21]

Such an array could prove or disprove theories of dark matter while also searching exoplanets for signs of life.

Speaking of life, it is possible that life on Earth originated out there. We know that microbial life appeared on Earth almost immediately after the end of what's known as the Late Heavy Bombardment, a period when a disproportionally large number of asteroids collided with the Solar System's inner planets. One of these asteroids may have brought with it the ingredients for life or even live single-celled organisms.

Additional evidence for this, aside from the suspicious timing, comes from the fact that interstellar space is littered with a wide variety of organic molecules.[22] In 2003, glycine, *an amino acid*, was found in interstellar space.[23] On June 6, 2022, Japan announced that it had detected more than 20 amino acids in an asteroid sample.[24] This was the first asteroid sample larger than a few micrograms of dust, so it means the first time we really looked, amino acids were there.

The biggest molecules we have found in the interstellar medium are buckminsterfullerene, C_{60} and its relative C_{70} fullerene. These soccer and rugby ball-shaped molecules are rare on Earth.

Buckminsterfullerene was first theorized in the late 1960s and first generated in 1984. They have been detected in both neutral and ionized forms by the Spitzer and Hubble space telescopes, respectively. Their signatures are not detectable from Earth-bound observatories because they are blocked by moisture in the atmosphere.

"Our confirmation of C_{60}^{+} shows just how complex astrochemistry can get, even in the lowest density, most strongly ultraviolet-irradiated environments in the Galaxy," said astrochemist Martin Cordiner, part of the team that used Hubble to detect ionized buckminsterfullerene.[25]

And finally, space is the only place you can do physics with really high energies. The universe is home to unbelievably extreme conditions—in black holes, neutron stars, exploding supernovae, and the relativistically moving jets that occur when matter near the edge of a supermassive black hole is flung out into the cosmos at high fractions of the speed of light.[26] High-energy astrophysics is thriving due to improvements in ground- and space-based instruments that let us observe matter at the extreme densities and other conditions that only occur in space. If we ever "solve" physics, it will be in large part because of continued investment in advanced space observatories.

From fundamental laws of physics to the origin of the universe to the origin of life to the near-inevitability of non-terrestrial life—there is plenty of science left to be done in space.

Satisfying humanity's need for a frontier

The final reason for continued investment in space—and for me, the clincher—is the need for a frontier. Human institutions develop rigidity and rot over time, and they must be renewed by striking out into new terrain and rebuilding. It's even better if the new outpost of civilization is fraught with peril.

Our greatest advancements have come when the stakes are high and lives are on the line. There is a clarity of purpose when settlers face a life-or-death struggle. While I am grateful that modern life is safe and cushy, our society has lost the urgency that comes from a challenge to survive.

Some have suggested that there is no need to colonize Mars when Earth's oceans, Antarctica, or even the Utah desert are unexplored and desolate. They are much closer. Yet even if these underexploited terrestrial resources are far cheaper to get to, that is part of the problem. We are not going to send scientists to Antarctica and withhold life-saving interventions from them if they become necessary, and consequently such a mission would not really embody any hope of providing institutional renewal.

On Mars, help might be two years away. The first Martian settlers will likely rely on resupply missions from Earth every two years, but if something goes wrong in between shipments, there's no way to get emergency parts or medical supplies. The Martians will have email contact with Earth, but for the most part, they will be on their own. They will need a survival paranoia—an overriding attention to the problems that could snuff out the life of their fragile colony. In many cases, it will be innovate or die.

The ability to commit at will to an innovate-or-die outcome is something we have lost in Earthly life. We still face crises that test our mettle from time to time. We innovated our way through World War II and, to a lesser degree, the COVID crisis forced the commercialization of mRNA technology.[27] But these crises come stochastically, and not because we choose them—nor would we ever choose them. Only in human space exploration can we credibly (given the high value we place on human life) put people in such precarious vulnerability for years on end.

The frontier of space is different from any Earthly endeavor also in its physical extent. Once we conquer Mars, there is the asteroid belt. The moons of Jupiter and Saturn. Maybe we can terraform Venus. If someday we have mastered the resources of the Solar System, we may have the technology to go beyond it.

In contrast, the pseudo-frontiers of Earth, such as the ocean, are one-and-done. Once we master the ocean (which we should do in any case), there's no obvious next step.

If a genuine frontier is indispensable for the health of human institutions, then there is no choice but to expand outwards. Perhaps we could delay our expansion into space for a short time while we build new cities in the Utah desert, but at some point, very soon, we would run out of expansionary challenges on Earth. Then our only option would be to take a leap into space.

It's very unlikely that our species, on a civilizational timescale, will regret going into space. The resources of the Milky Way are unbelievably vast. It's extreme parochialism to think Earth is all that matters. But even in the shorter run, the frontier of space will have salutary effects on our culture and rate of innovation.

It's time to take our place in the cosmos.

Let's go.

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Endnotes

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