Preface

The Ultimate Frontier

In 1961, Soviet Cosmonaut Yuri Gagarin became the first human to leave the earth, and the first to see our planet, with his own eyes, from space. In this auspicious moment, the Soviet Union won the first leg of the "Space Race" with the United States, and also achieved something that, for the bulk of history, pretty much all humans had considered impossible. Over the next sixty years, many other firsts would be achieved. The United States would land the first humans on the Moon, the first people to walk on an extraterrestrial landscape, and the spacefaring nations of the world would eventually cooperate to build the first long-term laboratory in space, the International Space Station (ISS).[1]

This history, of real space science and space exploration, is but one part of what fuels attitudes and ideas about space in human culture. Humanity's ideas about space are also informed by centuries of space fantasy, and dreams about what might be out there. Might there be other species out there in space, or other planets on which humanity might find a home? This last question is especially important to some theorists and philosophers who, since the twentieth century, have theorized that humanity's ultimate survival, as a species, is dependent on leaving the Earth. The reasoning goes that Earth's resources are finite, and so that humanity's continued growth will eventually hit a limit with regard to resource availability. Beyond that, the sun will eventually burn out. If humanity is to exist forever, therefore, the only way for this to happen is for humanity to leave the earth, and to establish colonies among the stars. This concept, of humanity becoming a spacefaring and extraterrestrial culture, exists alongside and fuels more proximate efforts to learn from and study space and the universe beyond Earth.

Along with these dreams of humanity's space future, there are also opportunities in space. For decades, theorists have speculated that it might be possible to harvest minerals and materials from asteroids and other extraterrestrial bodies, while space also provides limitless access to solar energy. There are also threats from space, some natural, like the possibility of another asteroid or meteor crashing into Earth with potentially civilization-ending force, or human-made, like the threat of "space junk" orbiting the earth and threatening to potentially rain down in unexpected locations. Then there is the possibility of space weapons, whether on satellites on in piloted or unpiloted spacecraft. Attitudes about space exploration are generated from all of these many perspectives colliding, forcing citizens to weigh the cost and dangers of space exploration, against the potential gains and against the potential cost of ignoring the threats that space might possess.

Space as a Goal and a Product

As mentioned, American involvement in space exploration really began with the "Space Race," a competition between the United States and the Soviet Union to reach certain benchmarks. These goals included launching the first satellite into space, which was achieved first by the Soviet Union, launching humans into space, also achieved first by the Soviet Union, and ultimately landing on the Moon, which was achieved first by the United States. For both the Soviet Union and the United States, engaging in this contest was a major investment. The Apollo Program cost the United States nearly $26 billion between 1960 and 1973, which is approximately $257 billion in adjusted expenditures for the 2020s. If the subsequent Project Gemini and the robotic lunar program are added to the total, the National Aeronautics and Space Administration (NASA) would've spent around $49 billion, or $482 billion today.[2]

For some, these enormous expenditures have always seemed like a waste. Back in the 1960s, when the United States was in an arms and technology race with the Soviet Union, Americans backed the space program in part out of geopolitical fear, the fear that the Soviet Union would overtake the United States in science and technology, which would ultimately mean (at least symbolically) the decline of American culture as a global power. But, as the Soviet Union pulled back opinions on the space program began to change.

In 1979, polls indicated that 53 percent of Americans felt that the space program costs were not justifiable, while 41 percent felt that those costs had been justifiable.[3] This indicated that the public, at the dawn of the 1980s, has drifted away from space exploration as a relevant goal for humanity. A number of factors contributed to this low point in public opinion, including increased economic pressures in the United States, and the fact that NASA research and development had fallen into the background, after a peak of pop-cultural relevance in the 1960s.

Over the next decade, public awareness about the benefits of the space program increased, predominantly because of the large number of consumer products that were linked to research conducted for the space program. Things like memory foam cushions, scratch-resistant lenses for glasses and cameras, and cordless power tools, were slow to enter mainstream uses, but with more than 2,000 products spun off from NASA research, the practical benefits of space research gradually became more and more familiar and apparent. NASA's own magazine, *Spinoff*, created to document and present technologies developed by NASA began publication in 1976, and continues in digital format in the 2020s. Among recent profiles, NASA's *Spinoff* featured a 2025 article about "dust-powered 3D printing," presenting two new 3D printers created through a program designed to test the feasibility of printing 3D housing and materials created from Moon dust.[4]

It wasn't just the release of more and more technology fueled by space science, but also the modernization of American culture, represented through the popularity of science fiction and fantasy. Increasingly, our shared myths took

The Value of Space

Humans have been fascinated by outer space since long before recorded history, but it wasn't until the latter part of the twentieth century that humanity, led by Soviet scientists, was able to launch objects into space, beginning a process of exploring space from *within* outer space, rather than from within Earth's atmosphere. This remarkable achievement was the beginning of a new stage in the scientific exploration of the universe, but was also the dawn of a new stage of human industry. Nearly three-quarters of a century later, space is viewed not only as a domain of exploration, but also as a source of revenue and economic innovation.

Why Explore Space?

In the fraught political climate of the 2020s, it is not unusual to ask why humanity would want to explore space? Building rockets and spacecraft is enormously expensive, and, for many Americans and people around the world struggling with much more proximate problems, the advantages to this exploration might not seem immediately apparent, but there are demonstrable advantages, the value of which might be subjective and appear differently to different people. There are, for instance, many economic advantages to space exploration, and this has been demonstrated by the ways in which innovations created for space have filtered back into public life, fueling consumer innovations and advantages. Likewise, space exploration provides scientists with a new and unique laboratory, and this has not only meant a new understanding of the universe, but also of earth, through our ability to observe and monitor Earth from space. Further, this laboratories in space have had unexpected advantages for the study of disease and human health. Finally, there are cultural and social advantages to the study of space. These range from creating shared goals, expanding the frontiers of discovery and inspiring imaginations and interest, and ultimately in determining the future of the human species and whether that future will remain tied to the earth, or will extend into the stars.

From War Games to International Communities

In the 1950s and 1960s, during the era of the now famous "Space Race," US interest in outer space was deeply tied to national and military insecurity and fear. The Soviet Union was in direct competition with the United States, with the goal of becoming the world's leading technological, economic, and military power. It was the Soviets who announced their intention to launch a satellite, in 1955, who ignited the space race and the fear of "falling behind" the Soviet Union in some new frontier of human knowledge and potentially strategic position, was enough

to drive American interest, to convince those with little to no interest in knowledge or science, to support a national push to explore space.[1] As these anxieties faded, many Americans lost interest in space exploration, while research continued.

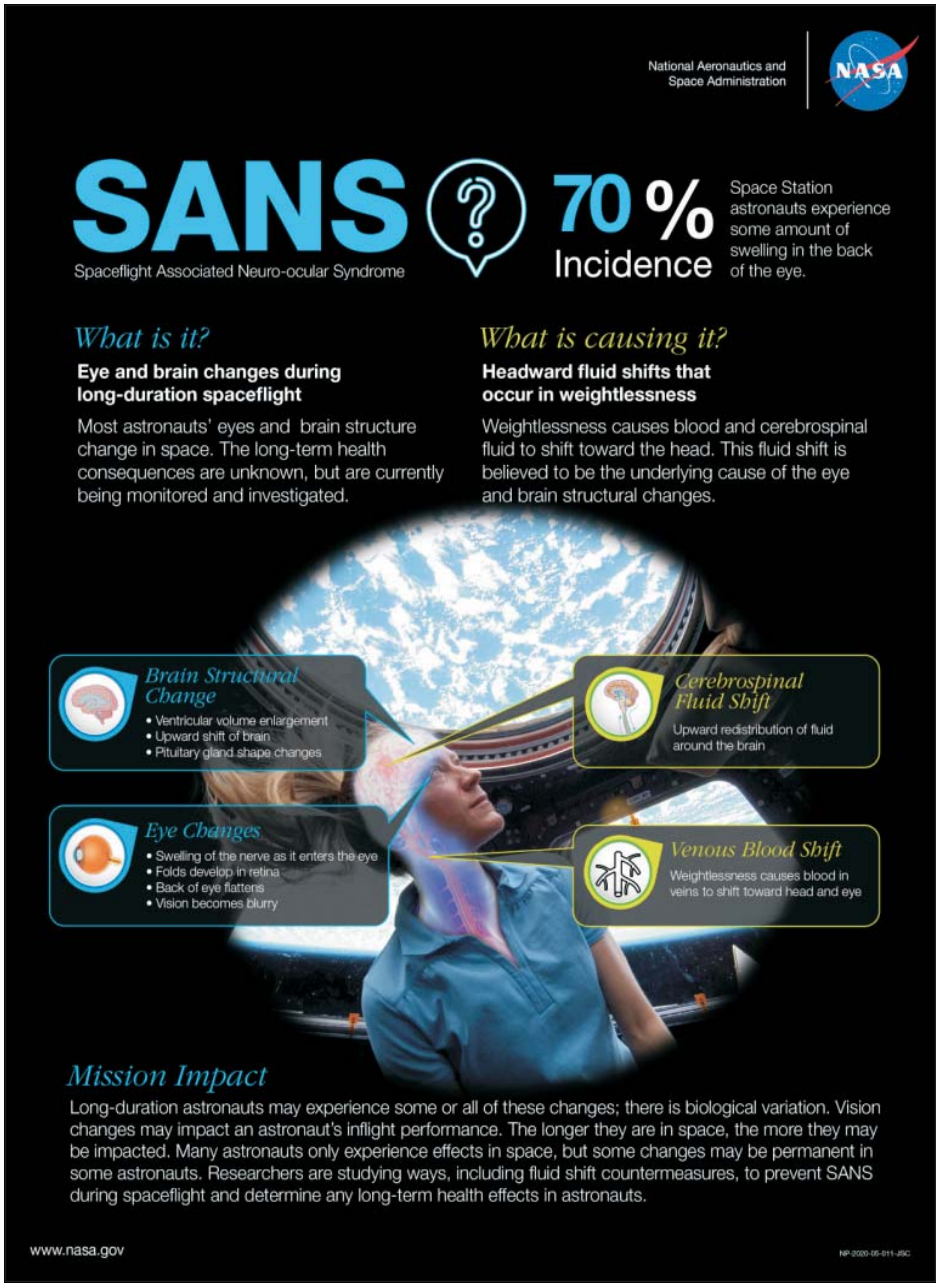
Though public interest was born out of fear, anxiety, and competitiveness, scientists don't tend to be as hawkish as military strategists. Those who train in the sciences quickly learn that science is, and has always been, international, that the best solutions are found by inviting innovation from other cultures and from working together. The rockets that allowed US scientists to beat their Soviet rivals in the space race, for instance, were taken from the designs of German scientists (which is a whole other complicated story given that some of those scientists were also Nazis).

Led by scientists more than the military minded, space exploration became more and more cooperative, even as military posturing and planning continued to operate in the background. The "Star Wars" missile defense system of the 1980s, for instance, is an example of how the military-minded continued to try and find better strategic military advantages from space, even as scientifically minded organizations were increasingly working together. This increasing cooperation was practical, because it allowed nations and space science agencies to, essentially, share their budgets by sharing the results of their budgetary spending. The 1998 launch of the International Space Station (ISS), with the involvement of fifteen countries and five international space agencies, was a major achievement in international diplomacy and connectivity, as well as providing a platform for scientific endeavor.

The election of Donald Trump (twice) brought back militant rhetoric surrounding America's future in space. Trump famously created the "Space Force," a new branch of the military to replace the Air Force's existing space divisions. While not ultimately all that significant, the creation of the Space Force invited Trump commentary on space, and it was largely filled with the rhetoric of dominance and defense. In 2025, Trump suggested supporting a program to create a "Golden Dome" missile defense system, as one focus for American space technology, and projected that the project could be completed in around three years, for a cost of around $175 billion. Experts agreed, to a large degree, that the project, cost, and completion time were unrealistic, but others worried that this kind of thinking about space risked setting off another arms race, one that could be dangerous for humanity in the long run, and could escalate tensions and raise the risk of nuclear holocaust.[2]

Technology and Industry

Military posturing aside, the benefits of space technology research, in the United States, have been considerable over a long period. In 1989, the National Aeronautics and Space Administration (NASA) conducted a study to look at the economic cost-vs.-benefit of space science over the years from 1976 to 1986, finding that there had been $21.6 billion in sales of products connected to technology



Results from another CSA study, MARROW, indicate that microgravity is a primary contributor to reduced red blood cell (RBC) count in astronauts, known as space anemia. The researchers found higher numbers of RBCs were eliminated in space than on Earth, and this change persisted throughout the duration of the space mission. Longer exposure to spaceflight appeared to worsen the condition. Elimination of RBCs sharply decreased upon astronauts' return to Earth.

Space Exploration Is Not a Luxury, It's a Necessity

By Daniel Fillion
The Conversation, April 15, 2024

Oh, come on Daniel, space travel is so expensive, and pointless!

These were the words of my friend Max, during a Christmas party where I was discussing my thesis project: studying places on Earth where the living conditions are so extreme, they could hold lessons for future space missions.

This disdainful attitude toward space research is actually quite common.

Space exploration is currently booming. Just think of the Artemis missions, SpaceX's ambitious plans for Mars, the deployment of the James Webb telescope or the recent "race to the moon."

A number of large-scale projects are getting the green light now, mainly from NASA, including the Artemis II mission that will carry four astronauts to the moon, which will have Canadian astronaut Jeremy Hansen aboard. This will be a first since 1972. Incredibly, it's been 50 years since the last human mission to Earth's natural satellite.

Although many people find space exploration inspiring, others are skeptical and even angered by what they see as an unjustifiable waste of resources and money on an activity that only spreads pollution to another place. This sums up the feelings of my friend Max.

In this article, I will try to prove him wrong.

Humans Are Explorers First

My great curiosity has led me to travel to extreme places so I can study them. But I am not the only one with this desire to explore.

In my Grade 9 history class, my teacher stood on top of her desk and, with a grave and serious tone, went on to act out Jacques Cartier's arrival in North America in her own, colourful style. A few years earlier, I had learned about how the first humans left their caves to climb mountains. One hundred and thirty years ago, humans sailed further and further south until they saw the glacial landscapes of Antarctica for the first time. At the same time, humans were attempting to dominate the skies and aiming for the beyond with planes and rockets—which is how we got to the moon.

What is the common denominator in our history? Exploration, of course.

Human nature is characterized by a propensity to travel, to look further and to discover. We are all curious by nature. If we stop wanting to explore, we stop being human.

The Earth Has Rings

So, my friend Max, let me invite you outside. It's a beautiful, starry night with no moon. It's a bit cold, but at least the atmosphere isn't too humid, which makes the sky more transparent. We can see stars flickering. Some are blue, others are red. And the more our eyes adapt, the more the sky reveals its secrets.

Suddenly, something else stands out. It's another light, but it's not flashing, and it's moving quite quickly. A shooting star? No, the atmosphere would have burned it up in a few seconds.

It's a satellite, one of thousands that orbit the Earth like rings. These satellites are a direct consequence of space exploration. We would be living in a completely different world without them.

Indeed, not an hour goes by in our lives when we don't use a satellite.

Satellites are a direct consequence of space exploration. We would be living in a completely different world without them.

On the one hand, you would likely have gotten lost on your way here, Max, because there would have been no GPS to show you which exit to take. And secondly, I wouldn't have been able to help you find your way because there would be no Wi-Fi. We can push our thinking even further; agriculture, environmental monitoring, communications, the weather, even banks, all of these depend on satellites.

But how does this work? You have to understand that these satellites move so quickly they actually circle the Earth several times a day. Combined with a very large workforce, they provide a complete view of the globe. From the middle of the oceans to the highest mountains and the almost inaccessible poles, we have eyes everywhere. By drawing on this vast quantity of observations, we obtain data on changes to the earth's surface, the spread of forest fires, the movement of winds, the melting of ice and many other things, while enabling global communication and credit card transactions.

Space exploration was the trigger that enabled us to develop and operate these technologies. And it doesn't stop there.

Two Birds, One Stone

The practice of medicine in remote areas also benefits from space exploration. It's not easy for communities in remote areas to access health care, especially since hospitals don't always have the sophisticated equipment they need.

If you think about it, when astronauts explore space, they become a small population in a very, very remote region. It's true. What happens if someone has a really bad stomach ache? Or breaks an arm? They don't have time to come back home for treatment, so we have to react, and quickly.

Is It Worth It? The Costs and Benefits of Space Exploration

By Matthew S. Williams
Interesting Engineering, May 29, 2025

Ever since the Sunset of the Apollo era and the Soviet Union collapsed (thus ending the Cold War), there has been an unavoidable question regarding space exploration.

It has become even more relevant in recent years in response to new proposals to send astronauts to the Moon and Mars.

"Given the sheer cost, is space exploration really worth it?"

Let's face it; space exploration isn't exactly cheap! It takes millions of dollars to send even a single robotic mission to space and billions of dollars to send astronauts to orbit.

If you're looking to send explorers to even the nearest celestial bodies, chances are the costs will run into the hundreds of billions.

To be fair, exploring space, the other celestial bodies of the Solar System, and the Universe at large also comes with innumerable benefits. The problem is the most obvious benefits are largely intangible. How do you put a dollar value on scientific knowledge, inspiration, or expanding our frontiers?

What About Earth?

For those debating the worth of space exploration, things often turn toward the issue of how many problems we have here on Earth. As the argument goes, we've got enough challenges here at home—climate change, hunger, overpopulation, and underdevelopment. These should take priority over exploring and/or establishing a human presence in other worlds.

For example, in a recent op-ed piece, Amitai Etzioni—an adviser to the Carter administration—countered some of the arguments for colonizing Mars and other planets in the Solar System (as put forth by luminaries such as Stephen Hawking and Elon Musk). Addressing the argument that humanity needed to do so to survive long-term, Etzioni wrote:

> [W]hat the droughts, the fires, the hot summers, and the melting glaciers call for is not an escape from Earth, but a redoubling of the efforts to save it... What is needed are major technological

> breakthroughs that will allow for protecting earth while sustaining a healthy level of economic activity... To make such breakthroughs we need major concentrations of research and development resources, talent, and leadership, all of which are in short supply. Hence, any serious Mars endeavor will inevitably cut into the drive to save Mother Earth.

While these arguments have a certain logic, they are subject to three major assumptions/fallacies. First, they seem to be built around the idea that space exploration and addressing our many problems here on Earth are mutually exclusive rather than complementary.

One of the greatest benefits of human spaceflight and space exploration has been the ability to study Earth from orbit. This has allowed us to learn an unprecedented amount about our planet's climate and weather systems, not to mention giving us the ability to measure these systems and the impact that human agency continues to have on them.

It also gave rise to the understanding that our planet is a single, synergistic, and self-regulating complex system—the Gaia Hypothesis. Originally proposed by famed scientists James Lovelock and Lynn Margulis in the 1970s, this scientific theory is one of the cornerstones of the modern environmentalist movement.

Second, there is the assumption that directing funds into space exploration and space-related ventures will deprive other efforts (such as addressing climate change, alleviating poverty, feeding the hungry, etc.) of vital resources.

Once again, the same type of "either/or" reasoning is at play, with no apparent room for "and." When you get right down to it, there is no basis (other than facile logic) for thinking that money spent on scientific endeavors in space means there will be less money from addressing problems at home.

What's more, there is no guarantee that money not spent on space exploration would be automatically diverted to dealing with social, economic, and environmental issues. While the argument appeals to a certain concern for humanity and social justice, it is not born out by reason.

Third, if the argument comes down to the question of resources being better spent elsewhere, why single out space exploration? Why not something that's even more expensive and has less demonstrable benefits? Why not something like military spending?

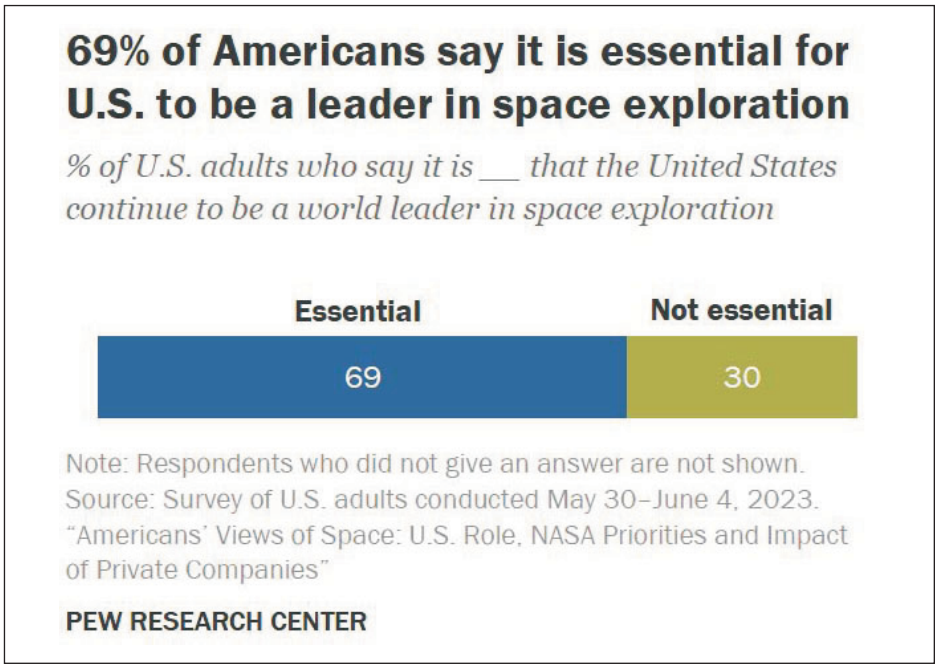
According to the Stockholm International Peace Research Institute, in 2014, roughly $1.8 trillion US was committed to military expenditures worldwide. Could this money not have been better spent on humanitarian aid, addressing extreme poverty, or assisting the transition to renewable energy worldwide?

To be more specific, let's look at the fifth-generation F-35 Lightning II combat aircraft, which began development in 1992. According to estimates compiled in 2016, it has cost over 1.5 trillion dollars to get this fighter from the drawing board to procurement by the US and other nations' armed forces.

Americans' Views of Space: U.S. Role, NASA Priorities, and Impact of Private Companies

By Brian Kennedy and Alec Tyson
Pew Research Center, July 20, 2023

In a changing world of space exploration defined by intensifying private efforts and competition between a growing number of nations, Americans continue to see an essential role for the United States as a leader in space exploration, according to a new Pew Research Center survey.



About seven-in-ten Americans say it is essential that the U.S. continue to be a world leader in space, while 30% say this is not an essential role for the country. Support for a U.S. leadership role in space is widely held across groups, including by majorities of Republicans and Democrats alike.

More than 50 years ago, space exploration was a race to the moon between the U.S. and the former Soviet Union. In 1998, the International Space Station

Websites

Blue Origin Enterprises, L.P.

www.blueorigin.com

Blue Origin Enterprises is a private space technology company headquartered in Washington state which participates in the launch of space vehicles and the development of technologies involved in space exploration. The organization has produced the New Shepard Rocked and is heavily involved in the emerging space tourism industry. In 2019, Blue Origin owner Jeff Bezos announced the development of a lunar lander in hopes, with a crewed Moon landing projected for around 2029. The organization has received funding from the federal government, including through the National Aeronautics and Space Administration (NASA), for assistance in developing technologies with potential NASA applications.

Committee on Space Research (COSPAR)

www.cosparh1.cnes.fr

The Committee on Space Research (COSPAR), established in 1958, is an international organization, headquartered in France, that promotes peaceful cooperative involvement in space research, and operates an open forum for scientists from any country involved in space exploration research. COSPAR supports original research and also provides information for students and researchers interested in the international developments in space science and therefore provides a glimpse of the kinds of research happening around the world.

National Aeronautics and Space Administration (NASA)

www.nasa.gov

The National Aeronautics and Space Administration is an independent federal agency, established in 1958, and in charge of coordinating research and space exploration programs funded by the federal government. NASA provides a wealth of information for members of the public and researchers interested in space science and exploration, including research reports and evaluations of the benefits of space science research in America and around the world. The organization also specifically provides resources for educators and classrooms, providing lessons on space technology, exoplanets, and other topics.

The Planetary Society

www.planetary.org

The Planetary Society is an American nonprofit nongovernmental organization (NGO) that promotes and supports space science research and exploration.