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IS SPACE EXPLORATION A NECESSITY OR AN INDULGENCE?

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Abstract

As humanity extends its reach beyond Earth, the growing cost of space exploration has prompted an important question: is space exploration a necessity or an indulgence? This paper defines a necessity as an investment whose long-term benefits justify its costs and opportunity costs, while an indulgence is an expenditure driven primarily by aspiration without sufficient societal returns. Through an analysis of technological advancement, human survival, geopolitical competition, and opportunity cost, this paper argues that the necessity of space exploration outweighs its indulgence. Space exploration has generated transformative technologies such as GPS, advanced imaging systems, and emerging space-based solar power; enabled more accurate climate monitoring and disaster prediction; and become increasingly important to national security and geopolitical competition. Although space programs involve substantial financial commitments and may divert resources from urgent social needs, these concerns largely reflect questions of resource allocation and governance rather than fundamental flaws in space exploration itself. Ultimately, space exploration represents not merely an aspiration to reach beyond Earth, but an increasingly essential investment in humanity's technological progress, security, and long-term survival.

Keywords: *Space exploration; technological advancement; human survival; geopolitical competition; opportunity cost; space technology; national security; economic impact*

1. Introduction

On NASA's recent Artemis II mission, four astronauts made history by traveling farther from Earth than any humans had before. Nevertheless, despite the celebration surrounding this achievement, such missions raise a fundamental question: is space exploration a necessity or an indulgence?

The answer depends partly on how these terms are defined. In this paper, a **necessity** refers to an investment whose long-term benefits – including economic, technological, strategic, or humanitarian returns – justify its expenditure and opportunity cost. By contrast, an **indulgence** refers to an aspiration pursued without sufficient consideration of cost, alternative uses of resources, or broader social benefits.

Space exploration is often criticized as an expensive pursuit when governments continue to face urgent challenges on Earth, including poverty, healthcare needs, education inequality, climate change, and natural disasters. However, judging space exploration solely by its immediate financial cost overlooks the broader benefits it generates. Technologies developed for space missions frequently become valuable civilian applications; satellites have become essential to monitoring and protecting Earth; and space capabilities increasingly influence national security and geopolitical power.

This paper therefore argues that **the necessity of space exploration outweighs its indulgence**, particularly because of its contributions to technological advancement, human survival, and geopolitical security. At the same time, the paper recognizes that space exploration can become indulgent when poorly designed programs consume excessive resources without sufficient public benefit.

2. Analytical Framework and Approach

To evaluate whether space exploration should be considered a necessity or an indulgence, this paper examines four interconnected dimensions: **technological advancement, human survival, geopolitical competition, and opportunity cost**.

First, technological advancement measures whether investment in space produces innovations and economic benefits beyond the space sector itself. Second, human survival considers the role of space-based technologies in climate monitoring, disaster warning, and planetary defense. Third, geopolitical competition examines the growing strategic importance of space capabilities to national security and international influence. Finally, opportunity cost addresses the strongest argument against space exploration: whether resources devoted to space would generate greater social benefits if invested elsewhere.

Rather than treating space exploration as inherently beneficial or harmful, this framework evaluates whether its long-term technological, humanitarian, economic, and strategic returns justify its costs.

3. Results and Discussion

3.1 Technological Advancement

Space exploration requires significant financial investment, but its technological and economic returns can extend far beyond the original missions. Compared with other areas of government spending, NASA's budget represents a relatively small proportion of total U.S. government expenditure. In FY2025, NASA requested approximately USD25.4 billion for space exploration, representing about 0.35% of U.S. government spending (NASA, 2024a; Office of Management and Budget, 2024). By comparison, U.S. military expenditure reached approximately USD919 billion (USAFacts, 2026). These figures suggest that space exploration, while expensive in absolute terms, does not necessarily constitute an unaffordable luxury.

More importantly, space exploration generates both direct technological achievements and **spin-off technologies** that benefit civilian society.

One of the most consequential examples is the **Global Positioning System (GPS)**. Beginning in 1978, the United States launched the first NAVSTAR satellite, eventually developing a fully operational satellite navigation system (NASA, 2023). GPS has since become essential to transportation, communication, agriculture, finance, emergency services, and countless consumer technologies. By 2017, GPS had generated an estimated USD1.4 trillion in economic value, while a global navigation-system outage could result in approximately USD1 billion in economic losses per day (O'Connor et al., 2019).

Space exploration has also stimulated the development of new energy technologies. One emerging example is **space-based solar power (SBSP)**. As global electricity demand is projected to increase substantially by 2050, researchers have explored whether solar energy collected in space could supplement terrestrial energy production (Space Solar, 2026). Solar panels operating in space can potentially achieve higher efficiency than conventional ground-based systems because they receive more consistent sunlight. SBSP could therefore become a long-term source of clean energy if technological and economic barriers are overcome.

The influence of space research is also visible in everyday consumer and medical technologies. Among more than 1,300 documented space-related spin-off technologies is the digital imaging technology used in smartphone cameras (Launius, 2011). Researchers at NASA's Jet Propulsion Laboratory developed complementary metal-oxide semiconductor (CMOS) image sensors while investigating improved spacecraft cameras. The technology was later commercialized and became widely used in consumer electronics, automobiles, and medical devices. The global CMOS image sensor market is projected to reach USD49.12 billion by 2030 (Grand View Research, 2024).

Similarly, digital image-processing techniques developed during the Apollo program helped researchers produce enhanced images of the Moon. These advances contributed to the development of modern medical imaging technologies, including CT and MRI systems.

Thus, the value of space exploration cannot be measured solely by the number of successful missions or discoveries made beyond Earth. Its broader value lies in its ability to stimulate technological innovation that eventually improves economic productivity and quality of life on Earth.

3.2 Human Survival and Planetary Protection

Beyond technological advancement, space exploration has become increasingly important to humanity's ability to understand and protect its own planet.

Satellites provide critical data on climate change, atmospheric conditions, ice loss, deforestation, greenhouse-gas concentrations, and other environmental indicators. Weather satellites use sensors to detect electromagnetic radiation emitted or reflected by Earth, allowing scientists and meteorologists to monitor environmental changes at a scale that would otherwise be impossible (Mukhitdinova, 2023).

Space-based observation is equally important for disaster prediction and emergency response. Before modern weather satellites existed, populations had significantly less warning of approaching storms. During the 1900 Galveston Hurricane, for example, an estimated 6,000–12,000 people died and financial losses reached approximately USD30 million (Galveston Historical Foundation, 2023). Today, satellite systems such as the Geostationary Operational Environmental Satellites (GOES) provide continuous monitoring across the Americas. During Hurricane Helene, satellite observations contributed to early identification and warnings that gave communities valuable time to prepare or evacuate (Doelling, 2024).

Space exploration also provides humanity with the ability to identify potential threats beyond Earth. Near-Earth asteroid detection programs continuously track objects whose trajectories could potentially intersect with Earth. For example, in May 2026, observations of asteroid 2026 JH2 enabled astronomers to calculate its trajectory and determine that it would pass Earth at a safe distance (Mandrovsky, 2026).

The importance of such monitoring becomes clearer when compared with the 2013 Chelyabinsk meteor event. Because the object was not detected in advance, there was little opportunity for warning. The resulting explosion damaged approximately 7,200 buildings and injured around 1,500 people (Howells, 2023).

Therefore, space exploration is not simply about discovering distant planets. It provides humanity with information and technologies that help monitor Earth, predict natural disasters, and potentially defend civilization against future planetary threats.

3.3 Geopolitical Competition and National Security

The necessity of space exploration is also shaped by international politics. In an international system without a sovereign authority above states, countries must continually consider their own security and strategic interests. This condition contributes to what political scientists describe as the **security dilemma**, in which states increase their capabilities because they fear dependence on or vulnerability to other states (Jervis, 1978; Herz, 1950).

Space has increasingly become part of this competition. Modern military operations depend heavily on satellite communications, navigation, intelligence, and surveillance. The Russo-Ukrainian War demonstrated this dependence particularly clearly. Satellite infrastructure was targeted at the beginning of the conflict, while Starlink terminals later helped maintain communications for hospitals, schools, critical infrastructure, and military operations in Ukraine (Bingen, 2025).

This example illustrates an important transformation: space capabilities are no longer isolated from events on Earth. Communications, navigation, intelligence, and military coordination increasingly depend on space-based infrastructure.

Space exploration also functions as an instrument of national power. China, for example, has identified space capability as a major component of its long-term national strategy and has pursued the development of an independent space infrastructure (Xinhua News Agency, 2017). Its BeiDou Navigation Satellite System provides an alternative to the U.S.-operated GPS system, reducing dependence on foreign infrastructure while strengthening China's technological and geopolitical autonomy.

The economic dimension of this competition is also significant. NASA's FY2023 economic impact report estimated that NASA supported more than 304,000 jobs and generated over USD76 billion in economic output (NASA, 2024 b). Globally, the space economy expanded from approximately USD546 billion to USD570 billion between 2022 and 2023, accompanied by more than 26,000 additional jobs (Gorman, 2024).

Therefore, investment in space exploration is not simply an expenditure on scientific curiosity. For modern states, it increasingly represents an investment in technological independence, economic growth, national security, and geopolitical influence.

3.4 Opportunity Cost: When Does Space Exploration Become an Indulgence?

The strongest argument against space exploration concerns **opportunity cost**. Government resources are limited, and money spent on space programs could instead be used for healthcare, education, poverty reduction, or other immediate social needs.

Pakistan provides an illustrative example. During 2017–18, Pakistan had an average annual income of approximately USD1,641, with around one-third of its population living in extreme poverty. Nevertheless, its government allocated approximately USD43 million to its space program (Richter, 2020). Critics argue that such spending represents a poor allocation of scarce resources when basic human needs remain unmet.

Critics also raise concerns about the long timelines of space programs, which can make accountability difficult, and about government support for private space companies when the benefits may disproportionately accrue to corporations or wealthy individuals.

However, these concerns do not necessarily demonstrate that space exploration itself is an indulgence. Instead, they highlight the importance of **effective governance, prioritization, and resource allocation**.

A poorly designed or underfunded space program may indeed represent inefficient spending. Yet this does not mean that investment in space technology inherently produces low social returns. Even projects that fail to achieve their original objectives can generate scientific knowledge, engineering expertise, and technologies that contribute to future missions and civilian applications.

The key question, therefore, should not be whether governments should explore space at all, but **how much they should invest, which projects deserve funding, and whether the expected long-term benefits justify their opportunity costs**.

4. Conclusion

Space exploration occupies a complicated position between necessity and indulgence. It requires substantial resources, and governments must remain accountable for how those resources are allocated. When a mission consumes excessive public funding without meaningful scientific, economic, humanitarian, or strategic value, it can reasonably be considered an indulgence.

However, the broader evidence demonstrates that space exploration increasingly functions as a necessity. It has generated transformative technologies such as GPS and advanced imaging systems; strengthened climate monitoring and disaster prediction; created economic activity and employment; and become essential to national security and geopolitical competition. Most importantly, it provides humanity with technologies and knowledge that may prove critical to addressing long-term threats to civilization.

Ultimately, space exploration is not simply about humans looking beyond Earth out of curiosity. Humanity increasingly depends on space-based infrastructure for communication, navigation, environmental monitoring, security, and technological progress. The challenge is therefore not to choose between space exploration and human welfare, but to ensure that space exploration is conducted responsibly, strategically, and with the broader interests of humanity in mind.

Space exploration may have begun as an aspiration, but as civilization becomes increasingly dependent on space, it is becoming an essential component of humanity's progress, security, and long-term survival.

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