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Why Moon and Mars? How NASA's Moon to Mars Architecture Paves the Way to Mars

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Abstract

The National Aeronautics and Space Administration (NASA) is establishing a long-term presence on the Moon to prepare humanity for the journey to Mars. Crewed lunar and Mars exploration are not two separate efforts; they are deeply entwined. NASA's Moon to Mars Architecture [1] — as described in the agency's Architecture Definition Document [2] — applies a systems engineering approach to achieve the nation's Moon to Mars Objectives [3], resulting in an evolutionary roadmap that proves capabilities needed for Mars at the Moon while developing requisite flight experience and industrial base.

NASA has over 60 years of experience in sending humans to — and operating in — low Earth orbit, including two decades of continuous human presence in space aboard the International Space Station. The agency has comparatively little experience with lunar exploration — nine Apollo missions on and around the Moon across five years. Thus far, humanity has only explored Mars with robots.

This paper highlights the major differences between these destinations, including the different gravitational environments, distances, communication delay times, human health and performance challenges, and flight dynamics parameters that a mission must account for. These challenges comprise four main facets of the Moon to Mars endeavour: national posture, engineering and design, operations, and the human system. This paper's analysis underscores that the first missions to Mars will be among the most arduous engineering challenges in history, far beyond anything yet attempted in spaceflight.

To ensure that the first human missions to Mars safely achieve their objectives, NASA will build experience in deep space operations by exploring the Moon. Proving Mars-forward technologies and capabilities during lunar exploration missions will reduce the risk of crewed Mars missions and help NASA develop concepts of operation for long-term, deep space exploration.

NASA is not waiting for its return to the Moon to begin planning for human Mars missions. Initial planning for Mars, including documenting key driving decisions, has already begun, enabling lunar and Martian exploration to inform one another. This parallel development approach ensures that the lessons NASA learns by returning to the Moon empowers the success of Mars missions, enabling the agency to achieve its exploration goals for the benefit of all humanity.

Keywords: Exploration, Architecture, Artemis, Moon, Mars, Crewed

Acronyms/Abbreviations

National Aeronautics and Space Administration (NASA)

United States (U.S.)

1. Introduction

Over 50 years ago, NASA landed astronauts on the surface of the Moon and returned them safely to Earth. The speed and success with which NASA executed the Apollo program have left many with the lasting impression that planetary exploration is relatively easy. However, this is not the case.



Fig. 1. The Crawl/Walk/Run Approach of Mercury, Gemini, and Apollo

The Apollo program's triumph [3] depended on political will, significant investments to the United States (U.S.) industrial base, and iterative development of exploration capabilities from Mercury [4] and Gemini [5] to Apollo [6]. This programmatic, crawl-walk-run approach built on increasingly ambitious architectures to develop the technologies and operational experience necessary to land on the Moon and safely return to Earth.

This development campaign led to the Moon landing: a historic event that assured the United States' leadership in human spaceflight for decades to come. Apollo program science and sample collection significantly advanced the discipline of planetary science. The missions continue to inspire global generations to dream of what lies beyond Earth. Only through this incremental, programmatic approach could NASA achieve this significant milestone in the history of humankind and reap its benefits.

Today, as the U.S. sets its sights on the first human missions to Mars, NASA's Artemis missions are returning crews to the Moon for the first time since Apollo. In doing so, NASA builds on lessons learned from Apollo's crawl-walk-run approach, building up to progressively more challenging missions and destinations through the evolutionary Moon to Mars Architecture.

This paper highlights the benefits of this evolutionary approach. It examines the relative challenges of human exploration in low Earth orbit, at the Moon, and for the Red Planet in terms of distance, gravity, and hazards. It presents four programmatic considerations empowering the success of NASA's human exploration architecture: national posture, engineering and design, operations, and the human system. Finally, it offers five principles for architecture implementation that will ensure the U.S. harnesses crewed exploration to its maximal benefit for its citizens and the global spaceflight community: fly often, build beautiful machines, revitalize domestic manufacturing, harness American innovation, and efficiently invest the people's treasure.

NASA's Moon to Mars Architecture is an evolutionary roadmap for human exploration that achieves progressively more complex exploration objectives. Just as Mercury and Gemini laid the foundation for Apollo, continued innovation in low Earth orbit and the Artemis lunar campaign will empower parallel development and execution of the first crewed missions to the Red Planet.

2. Building on experience: Exploration challenges by destination

Beginning with Project Mercury, the U.S. has over 60 years of crewed spaceflight experience in low Earth orbit. The Space Shuttle program [7] flew 135 flights, carrying a total of 355 people to space over more than 30 years. [8] NASA has also maintained a continuous presence on the International Space Station for over two decades. [9]

By comparison, human lunar exploration consists of just nine Apollo missions on and around the Moon over the course of five years (plus two missions in Earth orbit). Only 12 humans have ever walked on the

lunar surface. To date, only robotic missions have explored Mars.

Humanity's experiences at these three destinations inform one another, but there are also unique considerations that our experiences do not account for. This paper organizes them into three categories: distance, gravity, and hazards.

2.1 Distance

Exploring each destination presents unique challenges that NASA must address to ensure astronauts' safe return. Many of these challenges result from the destinations' sheer distance from Earth, which impacts travel time and communications delay.

The International Space Station orbits around 400 kilometres above Earth; [9] crews can reach or return from the station in as little as a few hours. [10] The light-time communications delay is essentially negligible — though there can be a few seconds of system latency. Station astronauts enjoy real-time conversations with flight controllers and loved ones on Earth and comforts like internet access through robust telecommunications infrastructure. [11]

At its farthest, the Moon is about 400,000 kilometres from Earth [12] — 1,000 times farther than the space station. It takes a crew about three days to reach the Moon from Earth. The light-time delay to the Moon and back is only a few seconds, but Artemis astronauts can expect total latencies of up to 14 seconds. [13]

The distance between Earth and Mars varies greatly depending on where the planets are in their orbits around the Sun. Their closest recorded encounter was in 2003, at about 56 million kilometres apart. [14] Unlike the Moon, the journey from Earth to Mars would be measured in months, not days. [15] Once at the Red Planet, astronauts would experience a one-way light-time communications delay between 4 and 24 minutes, making real-time conversation with Earth impractical. [16]

The relative distance of each destination from Earth changes the magnitude of the challenge. Travel times to low Earth orbit, to the Moon, and to Mars are measured in hours, days, and months, respectively. Autonomy and self-sufficiency become increasingly important as the light-time communications delay grows from negligible to a major operational consideration. Mission distance and duration can also have psychological effects that NASA must understand before sending crews into the unknown.

Comparing Low-Earth Orbit, Lunar, and Mars Missions

Distance from Earth



Fig. 2. Comparing Distances between Earth and Low-Earth Orbit, the Moon, and Mars

Comparing Low-Earth Orbit, Lunar, and Mars Missions

One-Way Journey Time



Fig. 3. Comparing One-Way Journey Times from Earth to Low-Earth Orbit, the Moon, and Mars

Comparing Low-Earth Orbit, Lunar, and Mars Missions

Light-Time Delay



Fig. 4. Comparing Light-Time Communications Delay from Earth to Low-Earth Orbit, the Moon, and Mars

2.2 Gravity

Overcoming gravity is one of the most fundamental challenges of spaceflight. Leaving a gravity well requires an incredible amount of energy, often described in terms of *delta-v*, the magnitude of change in velocity required to put a spacecraft on course to its destination. [17]

The *delta-v* to reach low Earth orbit can be considered a baseline, as a mission must first ascend out of Earth's gravity well before proceeding on to the Moon, Mars, or another destination. A mission requires additional *delta-v* to intersect a celestial body, descend into its gravity well, ascend back to orbit, and return to Earth, all of which vary based on the body's mass and distance from Earth.

Visiting Mars requires significantly more *delta-v* than visiting the Moon, given the immense difference in distances from Earth. The propellant required to achieve this *delta-v* for a given payload is a mass multiplier often called a "gear ratio." The gear ratio for a Mars mission is much greater than a Moon mission. In other words, it takes significantly more energy to deliver one kilogram of mass to Mars. [18]

Opportunities to launch Mars missions are also less frequent. Mission profiles that take advantage of the shortest distance between Earth and Mars must wait for planetary alignments that occur approximately every 26 months.

Additionally, microgravity and partial gravity are completely different operational environments. The Moon's mass is just 1% of Earth; Mars's mass is roughly 10% of Earth. [19] Surface systems on the Moon and Mars will operate under in one-sixth and one-third of Earth's gravitational force, respectively. While we have many years of experience operating in microgravity and low Earth orbit, systems and operational paradigms designed for microgravity will not inherently work in these partial-gravity environments.

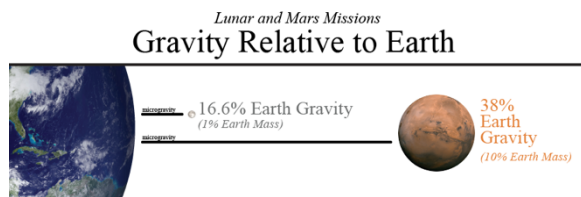


Fig. 5. Comparing the Gravity in Transit, on the Moon, and on Mars to Earth's Gravity

2.3 Hazards

While low Earth orbit missions have provided an excellent platform for developing exploration systems, missions to the Moon and Mars will subject explorers and exploration systems to challenges that cannot be tested on the microgravity platform. These challenges include dust, radiation, and transitions between gravity environments.

While astronauts on the International Space Station experience more radiation than they would on Earth's surface, Earth's magnetosphere still protects low Earth orbit. [20] Neither the Moon nor Mars has a similar protective feature. NASA must develop and test radiation mitigation technologies to keep explorers safe while in transit to and from and while at these destinations.

Dust contamination from lunar or Martian regolith can damage hatch seals or reduce solar array performance. [21] NASA will need to ruggedize space systems developed for relatively pristine orbital environments so that they can operate in dusty planetary environments.

Additionally, transitions between gravity environments will impact the human system in ways that NASA must understand to ensure safety and success. [22] Journeys to the Moon and Mars will place astronauts in microgravity and reduced gravity

environments that will impact their performance and health.

NASA can better understand these hazards by testing astronaut health and safety protocols and systems at the Moon, where mission support is readily available from Earth and, should issues arise, abort takes just a few days. This paradigm would better prepare the agency for Mars missions, where support is limited and mission aborts may not be feasible or could take months. [23]

3. Programmatic considerations: Four facets of the challenge

Just as the Apollo program required sustained, programmatic investments, a campaign of Moon to Mars exploration will be evolutionary. It will rely on thoughtful programmatic approaches that this paper organizes into four categories: national posture, engineering and design, operations, and human systems.

3.1 National posture

The Moon to Mars campaign will require and enable the United States' global leadership in space exploration. This includes developing the nation's industrial base, advancing technologies associated with space exploration, and expanding economic utilization at the Moon and Mars.

3.1.1 Space leadership

Leading exploration missions encourages a safe, peaceful, and prosperous future in space. NASA-led collaborations with international space agencies will provide a common set of principles for civil exploration. Implementing missions and partnerships through policies such as the Artemis Accords [24] reinforces the commitments by signatory nations to 1967's Outer Space Treaty, [25] the United Nation's Convention on Registration of Objects Launched into Outer Space, [26] the United Nation's Agreement on the Rescue of Astronauts, [27] as well as best practices and responsible behaviour for civil space exploration.

3.1.2 Partnerships

To realize Moon to Mars exploration missions, NASA will need to leverage the expertise of its commercial and international partners. These partnerships enable NASA to engage a wider industrial and supply base, expand the range of ideas and systems that the agency can leverage, and increase the speed of innovation. [28] Partnerships can offer parallel

development opportunities, improve robustness through redundancy, and contribute to economic development.

3.1.3 Technology Readiness

Advances in deep space exploration and the capabilities to safely deliver, sustain, and return humans to Mars necessitate improvements across many technologies. Technology innovation and iteration at the Moon will help NASA develop the high-reliability capabilities needed for Mars missions, where repair and replacement may be infeasible. For example, in 2024, NASA selected nuclear fission power as the primary surface power technology for initial Mars missions. [29] Using this same technology for NASA's lunar surface infrastructure accelerates technology development into a flight project and reduces risk for subsequent Mars applications.

Partnerships also help keep NASA on the cutting edge of technology. Industry and international partners can invest in technology development efforts to fill architecture-driven technology gaps and enable exploration.

3.1.4 Economic development

The magnitude of Moon to Mars exploration requires the activation of the American industrial base. Robust, domestic engineering, manufacturing capabilities, and expertise form the backbone of the Artemis program and the journey to Mars. It also means fostering new companies and industries that will compete to offer cost-effective services to the U.S. government and economic benefit to the American people.

3.2 Engineering and design

Designing and developing hardware necessary to reach a destination becomes increasingly challenging as the distance from Earth grows. The performance needed for a Mars mission is far greater than for a Moon mission, which in turn is far greater than for a low Earth orbit mission.

3.2.1 Vehicle design

Currently, many providers can support human or robotic launches to low Earth orbit; fewer can support uncrewed missions to deep space destinations. Only one launch vehicle — the Space Launch System [30] — can support human launches beyond Earth orbit today. Similarly, while the U.S. makes use of several human-rated spacecraft to visit the International Space Station, it currently has only one vehicle rated for lunar

exploration — the Orion spacecraft. [31] Mars transportation vehicles exist only as early concepts.

Realizing a robust campaign of Moon to Mars exploration will require development of new vehicles to ensure a robust architecture with appropriate redundancy. Developing new commercial capabilities as lunar exploration expands can provide NASA more robust, flexible, and efficient transportation capabilities that can also enable Mars transportation.

3.2.2 Supplies and logistics

Lunar and Mars missions present a significant higher logistics and resupply challenge, given the sheer distances involved. NASA projects annual logistics needs of 5,000 to 6,000 kgs for four crew members operating on the lunar surface for approximately 30 days. [32] Mars missions, which could last two to three years, would require significantly more logistics and would likely need them positioned on Mars prior to launching human explorers. Depending on the trajectories NASA chooses for Mars missions, resupply opportunities could be as infrequent as approximately once every two years, meaning that the agency would need to send large amounts of logistics at once. Leveraging the lunar missions to plan for longer-duration deep space resupply will help NASA to optimize for efficiency, ensure appropriate shelf life of commodities, and develop techniques to minimize overhead.

3.2.3 Maintainability and reusability

The International Space Station's longevity has depended upon the availability of spare or replacement parts and crew time to repair, maintain, or upgrade systems. NASA estimates that similar maintenance tasks could take up over 24 hours of crew time over the course of a 28-day lunar surface mission [33] and a similarly large percentage of crew time for Mars missions. [34] These missions would not benefit from the frequent resupply opportunities in low Earth orbit and would require systems that are capable of operating uncrewed for long periods of time (e.g., while awaiting the arrival of crew after being pre-deployed at the Moon or Mars). NASA will need to demonstrate this advanced system reliability, which far exceeds the International Space Station's capabilities, to prepare for Mars missions.

3.3 Operations

While NASA and partner space agencies have decades of flight experience, that experience has mostly been near the Earth. Humanity must develop experience and competency to operate in increasingly

remote environments. Closing this gap is a key facet of Moon to Mars activities.

3.3.1 Autonomy and Earth-independence

Low Earth orbit operations benefit from real-time connectivity. Ground teams can manage, control, and monitor vehicles, minimizing in-space work for astronauts. This connectivity also provides robust support for troubleshooting, medical care, and other contingency situations. Increasing distance and communication delays at the Moon and Mars will greatly reduce Earth-based flight control operations support, necessitating development of Earth-independent and autonomous capabilities.

3.3.2 Coordination and aggregation

As NASA's human spaceflight ambitions grow, so do the size and number of vehicles necessary to accomplish them. The Apollo program used a relatively simple single launch architecture; one Saturn V rocket launched everything needed for surface operations at the lunar equator. In contrast, the Artemis program's objectives for the lunar South Pole region [35] demand a multi-launch architecture that considers interoperability and aggregation of systems at exploration sites. International and commercial partnerships can help NASA achieve that aggregation.

Mars architectures will be even more complex, requiring perhaps dozens of launches and landings to aggregate required systems. Developing operational experience and standards for coordination during lunar missions will help ensure success of Mars missions. As a comparison, the assembly of the International Space Station required more than 40 missions and over 260 spacewalks in the relatively simple low Earth orbit environment. [10] Mars missions will require similar coordination and aggregation operations in far more complex orbital mechanics environments.

The chemical propellant mass required for even a minimal Mars human-class mission could be in the hundreds of thousands of kilograms. Even the most mass-efficient Mars architectures could exceed the mass of the space station. Aggregating this mass could require many launches of super-heavy lift vehicles. For comparison, the largest robotic payloads delivered to Mars so far have been roughly the same mass as a small car. As both architectural mass and mission time increase, so do the relative scope and scale of vehicle complexity.

3.3.3 Risk and contingency planning

Human spaceflight is inherently dangerous, but NASA must balance risks through effective mission

planning and systems engineering. Distance from Earth magnifies mission risk because abort opportunities become longer and fewer. Aborts from low Earth orbit are possible in a matter of hours, while aborts from cislunar space and the lunar surface would take days. During Mars missions, however, aborts would take much longer, on the order of months, or, depending on orbital dynamics and the phase of the mission, might not be possible at all. [23]

Reliable, redundant, and mission-tested hardware helps to reduce mission risks. Additionally, all planetary exploration experiences will help NASA to prepare appropriate procedures for emergency and contingency operations when abort isn't feasible.

3.4 The human system

The survival of the human system is the most important aspect of any crewed exploration mission. For NASA, safety is paramount to mission success.

3.4.1 Health hazards

The five main hazards of human spaceflight are space radiation, isolation and confinement, distance from Earth, altered gravity fields, and hostile/closed environments. [22] These hazards are especially heightened by the distance, duration, and complexity of Mars missions. Crew members will need to survive the trip to Mars, which will likely exceed current spaceflight duration records, adjust after landing on the Red Planet, and then complete the return journey to Earth, all while mitigating the physiological and psychological challenges of spaceflight.

Understanding the effects of spaceflight on human physiology, psychology, and individual and team performance will keep astronauts safe and healthy as they explore the Moon, Mars, and beyond. Many techniques developed in low Earth orbit, such as exercise protocols, will be extensible to lunar and Mars missions, but these missions will also require new design solutions, health countermeasures, operational paradigms.

3.4.2 Operational experience

Experience, medical data, and lessons learned from lunar operations will buy down risk for future Mars missions (i.e., the risks of a Mars mission attempted today). For example, lunar surface missions will require astronauts to transition from microgravity to partial gravity and back again.

Astronauts returning to gravity after long duration in microgravity undergo a range of physiological adjustments that require time for readaptation. Astronauts on Earth enjoy extensive assistance during

these adjustments; astronauts on Mars will not have this luxury. NASA's longest human spaceflight record, 371 days, is significantly shorter than reference Mars mission. [36] Time spent in microgravity just in transit to Mars would be longer than the typical stay on the International Space Station.

It could take astronauts days to readapt to Martian gravity and perform an EVA. Residual effects of the sustained period in microgravity during the journey to Mars could persist for longer. [37]

NASA does not yet have a complete picture of how a journey to Mars would affect astronauts' health and performance. Increasing the duration of lunar surface missions, with the Moon serving as an analogue for Mars, will give NASA the opportunity to study how the human body reacts to those transitions and perfect its operational approach and medical countermeasures for the first human Mars missions.

The challenge of adapting to gravitational transitions is just one example. NASA will need to develop new operational competencies to address the many challenges outlined in this paper. In many cases, the capability gaps that NASA must address are not limited to technology. They also include experience and operational know-how. Just as early spaceflight missions paved the way for Apollo and decades of experience in low Earth orbit contributed to the Artemis program, lunar exploration will teach NASA to operate at Mars.

4. Implementing architecture:

Five principles to meet the challenge

NASA's Artemis program is a monumental, multi-decadal effort reshaping NASA and the U.S. industrial base. Simultaneously, it is strengthening U.S. national posture, ensuing continued leadership in space while fostering new and existing relationships with international partners.

The principles below — developed by NASA leaders in human exploration — outline how architecture implementation can ensure NASA harnesses crewed exploration to its maximal benefit.

4.1 Fly often

Thousands of individuals across NASA, the domestic and international aerospace industry, partner agencies, and the science community are working together to realize Moon to Mars exploration. They work with a singular focus: to return humans to the lunar surface and use the lessons learned there to send the first humans to Mars.

This campaign of sustained science and exploration will require an unprecedented cadence of deep space missions on a complex and dynamic schedule. Under

Artemis, launches of the world's most powerful rockets will become commonplace, but that does not mean they will be simple. Flying often will make NASA and its partners more capable than they've ever been.

Everyone in the Moon to Mars enterprise shares responsibility and accountability for each mission. They must solve problems with urgency and maximize safety at every turn. Engineers, scientists, and support personnel all enable exploration.

Theory only goes so far; sometimes flying is the best way to discover the unknown unknowns. Lessons learned from flying often will help the agency to find efficiencies and process improvements that make human spaceflight safer and less costly.

4.2 Build beautiful machines

The new generation of rockets, spacecraft, and support equipment returning humans to the Moon have required — and will continue to require — huge advances in engineering. Artemis missions will launch aboard the largest rockets ever built, utilize reusable spacecraft, and integrate contributions from around the world.

These are elegant machines that draw on virtues from the earliest days of human spaceflight: simplicity and redundancy. The Apollo program found success in redundancy — ensuring that missions can minimize failures (be they mechanical, software, or human) and, when failures do arise, adapt to them in stride. [3] The Artemis campaign is building upon this key lesson with dissimilar redundancy, in which different, independent systems provide the same functions, ensuring that no single failure holds the mission back.

Human spaceflight requires excellence across disciplines. Physics has the final say in any design; unimpeachable, inspiring engineering will ensure we achieve our goals, flying safely and successfully every time.

4.3 Revitalize domestic manufacturing

While the Apollo program benefited from an existing domestic industrial base, it required NASA and the aerospace industry to build new spacecraft, rockets, ground facilities, equipment, and factories. The years since Apollo have seen a reduction in this industrial capacity; NASA's Moon to Mars exploration represents an opportunity to rebuild not just to the level of the Apollo era, but beyond.

Our factories and their workers are returning us to the Moon. Artemis already leverages suppliers in all 50 states and from partners around the world. It creates high-quality jobs across a wide variety of industries. Tradespeople and technicians of all disciplines —

manufacturing, metallurgy, welding, sewing, and many, many more — support the mission every day.

Investments by NASA give the aerospace industry the opportunity to create incredible new machines. NASA missions have provided key investments in reusable rockets, cutting-edge communications technologies, and a new generation of commercial robotic lunar landers. NASA provides the spark for building a sustained, thriving aerospace industry.

Building on the lessons from NASA's Commercial Crew [38] and Commercial Lunar Payload Services [39] programs, the Artemis campaign gives commercial partners the opportunity to design, build, and operate spacecraft and own larger pieces of the mission. In returning humans to the Moon, NASA is building a robust space exploration economy, employing thousands of workers.

4.4 Harness American innovation

NASA is a symbol of the American entrepreneurial spirit. Its achievements in early human spaceflight, landing the first humans on the Moon, and leading international cooperation in space through the International Space Station illustrate what humans can accomplish when they work together toward lofty goals.

These experiences also provide essential lessons for exploration to come. Across its history, NASA has developed an unrivalled suite of tools, systems, and capabilities for solving big, ambitious problems, like landing humans to the Moon, studying the universe's deepest secrets, or maintaining a decades-long human presence in Earth orbit. The Artemis program is putting that toolbox to work to accomplish NASA's Moon to Mars Objectives [2] and propel humanity onward to Mars.

Innovation also means adapting and adjusting to achieve an end goal. NASA's Moon to Mars Objectives clearly establish what we want to accomplish in exploring the Moon and beyond. NASA and its partners must be flexible and adaptable as they work toward these goals. This requires making major decisions in a thoughtful way, executing with dedication, and, when something doesn't work, adjusting accordingly.

4.5 Efficiently invest the people's treasure

Artemis will return humans to the Moon for the benefit of all humanity. This is a massive undertaking requiring time, money, and personal effort. NASA strives to be a good steward of the resources with which it has been entrusted, continuously striving to make our solutions simpler and more cost-effective through elegance and efficiency in engineering.

Since its very beginning, spaceflight has represented an extraordinarily valuable investment, generating returns many times beyond the initial costs. Scientific discoveries in space and the engineering solutions that make those discoveries possible have generated new technologies, sustained countless businesses, and spawned entire industries. [40]

In 2023 alone, NASA's work generated more than \$75.6 billion in economic output [41] and hundreds of thousands of jobs from the agency's \$25.6 billion dollar budget [42]. That's less than one percent of the total U.S. federal budget and about three dollars of economic output for each dollar spent. That year, Moon to Mars activities alone generated more than \$23.8 billion in total economic output and supported over 96 thousand jobs nationwide. [41]

Additionally, spinoffs and technology transfers from NASA's work impact people's lives every day. [43] As the Artemis campaign and Moon to Mars effort continue to advance, those returns will only grow.

Efficiency is a virtuous cycle: as we find more efficient, right-sized solutions, we free up time, resources, and people to tackle new projects. Exploration is not a zero-sum game — as our ambitions grow, so too do the benefits.

5. Conclusion

NASA's Moon to Mars Architecture seeks to achieve a sustained, evolvable campaign of exploration that maximizes scientific return and technology development for the benefit of all. It aims to realize a lasting campaign of science and discovery that feeds forward to future exploration while returning value to everyone on Earth.

Exploration of the cosmos remains a great calling for humanity. Each step from our home planet offers increasing opportunity, challenge, and risk. To enable sustained exploration, NASA must take the next giant leap, leveraging lessons learned from Apollo and the Artemis program as a testbed to send the first humans to Mars.

NASA will develop essential technology, capabilities, and operational experience at the Moon to reduce risk for Mars missions. Returning to the Moon is not in opposition to humanity's journey to the Red Planet. Lunar exploration will put Mars within our reach.

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Moon to Mars Architecture. Together, we are laying a foundation for long-term, crewed exploration of the Moon, Mars, and beyond for the benefit of all humanity.

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