Recommendations from

The Eleventh Community Workshop for Achievability and Sustainability of Human Exploration of Mars

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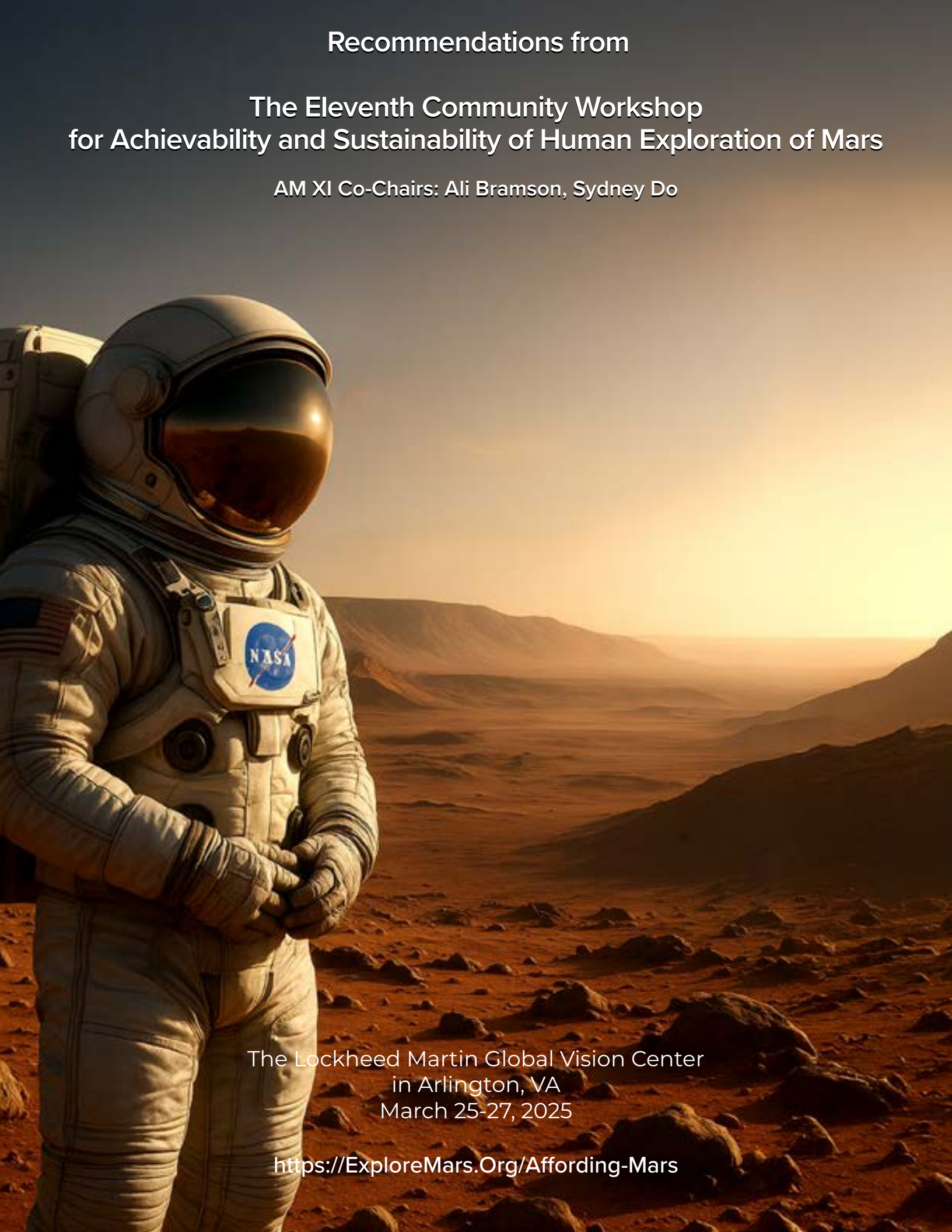

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https://ExploreMars.Org/Affording-Mars

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"Achieving Mars Workshop XI"

What is our future in space?

We are at a pivotal time in history.

To send humans to Mars in the next decade, we must start today.

NASA is the undisputed global leader in space exploration. Its successes across the Solar System have enabled the development of advanced technologies and the creation of entire industries that are now considered essential to our way of life. Today, NASA continues to lead humanity's return to the Moon, nurtures our growing space industry, and paves the way to Mars and beyond.

However, in the current space ecosystem, neither government nor private industry can go to Mars on their own. The notion of NASA vs. private industry is a false dichotomy. We must boldly go together.

Sending the first humans to Mars will be the riskiest mission ever attempted. We reduce that risk by continuing to build upon our impressive robotic exploration of the Solar System and our pioneering human exploration endeavors closer to home.

Achieving Mars is an investment in today and the future. Continuing to explore our universe is how we inspire new generations, create greater prosperity, advance the human condition, and maintain our legacy.

To accomplish the goal of stepping foot on Mars, we recommend that the United States and its partners:

1. Dedicate activities and operations on the International Space Station ("ISS"), at future commercial low Earth orbit ("LEO") destinations, and in the Artemis missions to the Moon to prepare humans and hardware for the perilous journey to Mars.
2. Invest immediately in the development and in-space demonstration of the following key Mars-enabling capabilities:
   - Deep Space Transit Habitat
   - "Earth-Independent" human spaceflight operations
   - Integrated countermeasures to the harmful effects of long-duration deep space travel on human health and performance
   - Human-Class Entry, Descent, and Landing (EDL)
   - Nuclear Fission Surface Power
3. Update our aging Mars orbital communications, imaging, weather monitoring, and reconnaissance infrastructure.
4. Immediately initiate the human landing site selection process, by regularly convening experts from across the scientific, engineering, human health and performance, and policy-making communities to iteratively identify, analyze, and down-select candidate sites using the latest findings.

BUILDING UPON OUR SPACE EXPLORATION LEGACY

Over the past three decades, we have built an impressive legacy of sustained human exploration in low Earth orbit and robotic exploration across the surface of Mars. Extending this legacy to human Mars exploration will require capabilities many times beyond what we have accomplished so far. Human Mars missions will:

- Take humans over 500,000 times farther out from Earth than any previous human spaceflight, necessitating habitation systems and crew operations that are reliable, self-sustaining, and independent from real-time mission control support and regular logistics resupply from Earth.
- Last 3 to 6 times longer in duration than current International Space Station crew stays, increasing stress and risk to human health far beyond what is understood today.
- Require landing vehicles on Mars that are over 20 times heavier than that of any robotic mission attempted to date, necessitating new landing technologies previously untested.
- Require launching a rocket from the surface of another planet without dedicated launch facilities and real-time support staff — a feat that has never before been attempted.
- Require over 100 times the amount of electrical power used by existing robotic missions on Mars, necessitating new compact, transportable, nuclear power systems that can operate reliably in the Martian environment.

It is for these reasons that we prioritize the developments described in this document.

We mature critical technologies and capabilities by testing them in ways that increasingly replicate Mars mission conditions while minimizing unnecessary risk to our crew. This means leveraging robotics to learn as much as we can before sending humans on the perilous journey to Mars, while also testing systems with humans close to home, where help can be provided on short notice in the event that something goes wrong. In addition to prioritizing crew safety and well-being, we must also take steps to explore responsibly, such that we preserve the Mars environment and mitigate risks to stakeholders and society here on Earth. We accomplish the goals outlined above by:

Using the ISS as a Testbed for Safely and Progressively Increasing Earth-Independence of the Crew

The ISS has served as an incredible near-home testbed for developing methods to sustain human health and performance in microgravity. Gradually increasing ISS crew mission durations while incrementally reducing their reliance on mission control is a safe and measured approach that will increase the ability of future astronauts to operate independently of Earth. Similar strategies could also be deployed on future commercial LEO space stations, providing us with multiple avenues to mature methods for keeping astronauts safe and healthy on the long journey to Mars.

Using the Moon as a Proving Ground for Planetary Surface Hardware and Operations

Artemis missions will demonstrate hardware and operations in dusty, partial-gravity, planetary surface environments, outside of Earth's protective magnetic field — similar in many ways to what will be experienced on Mars. Humans have never before operated for extended durations in such environments, where the effect of increased exposure to space radiation on human health is unknown. With travel times of only 3–5 days, the Moon serves as a nearby testing ground where we can rapidly build experience, and mature technologies and strategies for Mars, while simultaneously fostering a new, cislunar economy.

Robotically Demonstrating Round-Trip Capabilities at Mars Before Sending Humans

No near-Earth environment exists for testing the end-to-end process of both landing on, and launching back off, the surface of Mars. These two operations require spacecraft to travel through the Martian atmosphere, which is known to be uniquely different from anything close to home. We have never before landed spacecraft on Mars of the size and scale needed for human missions. Therefore, before sending astronauts, it is imperative that we successfully demonstrate the uncrewed, robotic landing of a "human-class" lander on the Martian surface. Our experience is even more limited for launching crew from Mars for their journey home. Apollo launches from the Moon were supported by near real-time communications with ground controllers at Earth. The vastly greater distances out to Mars means there is always a telecommunications delay, up to 22 minutes each way, requiring astronauts to launch on their own, without the real-time support of a launch team of dozens of experts on Earth. No attempt has ever been made to launch from the surface of Mars. NASA's Mars Sample Return Mission serves as a unique opportunity to leverage an existing development to build this planetary launch experience.

Upgrading Our Aging Mars Orbital Infrastructure to Enable Mission Planning and Execution

Our existing fleet of Martian orbiters is aging, with many already operating over a decade past their expected lifetimes. Moreover, the interplanetary telecommunications service they provide does not have the capability to send back the sheer volume of data needed to plan and ultimately execute human-class Mars missions. Identifying and characterizing the right landing site, and ultimately accomplishing the goal of sending humans to Mars will require upgrades to our existing orbital infrastructure, including: (1) high-resolution cameras to identify hazards that impact landing safety and surface activities; (2) specifically tuned radar instruments to identify science and resource targets, like buried ice; (3) atmospheric monitoring instruments to enable dust storm and wind predictions vital for safe Mars landings and surface operations; and (4) high-capacity telecommunication satellites for increased data relay. It is vital that we update our infrastructure to support the data acquisition and communication needs of future human Mars missions. Without these, risks to crew safety and mission success will exceed any level previously accepted.

Using the Landing Site Selection Process to Facilitate Cross-Disciplinary Development of Site- and Science-Specific Mission Architectures to Inform High-Level Decision Making

Just as one would pack differently for a trip to the beach versus the mountains, where we choose to land humans on Mars affects what equipment to take and the science to be accomplished, as well as the type of systems we build to get us there. This becomes increasingly important for the selection of the first human Mars landing site, not only because it affects crew safety, but also because it serves as our first foothold on the red planet. Our experience from exploring Mars with robots has taught us that regular, community-wide landing site workshops help to focus and accelerate work towards identifying and resolving specific mission, science, and technology needs. Such workshops enable: (1) cross-disciplinary discussion between typically disparate communities, including those from science, engineering, human health and performance, policy, and commercial industry; (2) dissemination of the latest data and new findings across disciplines; (3) full end-to-end mission scenarios to be "gamed" out, to identify needs and gaps to be addressed as the Mars architecture develops and evolves; and (4) the collection of community-consensus input into landing site selection and architecture decisions.

The first and only Mars Human Landing Site workshop was held 10 years ago. We have learned much since then, and much work and coordination remains. It is now time to re-engage the community of space exploration experts towards identifying specific landing sites on Mars, and architecting missions and science campaigns around them.

OUR NEXT BOLD STEPS

We have been developing concepts to send humans to Mars for over half a century... the time has now come for us to commit to going — to provide the impetus to make the necessary decisions, build the necessary equipment, and support the iterative process of testing and learning that leads to successful missions. Putting humans on Mars will require bold advancements. By pooling the strengths and expertise of NASA, private industry, and strategically built partnerships, we can push our current capabilities to what is needed to achieve Mars.

What is our future in space? The answer to that question is in our hands.

Exploring space allows us to understand and set humanity's place in the universe. In doing so, we answer the most fundamental science questions, such as: "Are we alone?". We also inspire current and future generations, and we innovate new technologies and solutions for a better life here at home. A sustained program of exploration consists of a continuous series of increasingly ambitious endeavors that continue to push the boundaries of human knowledge. A responsible program of exploration prioritizes crew and public safety, builds upon lessons learned from our deep history of robotic and human exploration, and allocates adequate resources to identify and mitigate risks as they are uncovered. It is only through a sustained, responsible program that we will accomplish the historic achievement of sending explorers to Mars. In pursuit of this goal, we make the recommendations described in this report.

Where did these findings come from?

These are the results from the Eleventh Community Workshop for Achievability and Sustainability of Human Exploration of Mars ("AM XI"), which was held March 25–27, 2025 at the Lockheed Martin Global Vision Center in Arlington, VA and hosted by Explore Mars, Inc. a 501(c)(3) non-profit. The Achieving Mars Workshop series, now in its 11th year, brings together experts from across the space community to build consensus on key issues related to the human exploration of Mars. Participants include individuals from across NASA and government, industry and commercial partners, and academia. The annual AM workshops have been an essential opportunity for a broad community to contribute to the development and justification of the human space flight program.

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About Explore Mars, Inc.:
Our Vision: Advancing human exploration of Mars and beyond no later than the 2030s, for a sustainable and inclusive future for us all.

Our Mission: Explore Mars is a global community where innovators, pathfinders, and policymakers of all ages collaborate to establish a human presence on Mars no later than the 2030s. We envision a world where the human drive to explore and discover propels us into a thriving, inclusive, and environmentally responsible existence on Earth and beyond. We connect people and organizations, pushing the boundaries of the space ecosystem to welcome stakeholders who are passionate about building a peaceful and prosperous multiplanetary future for decades to come.