PARASTRONAUT FEASIBILITY FOUNDATIONAL RESEARCH STUDY

ABBREVIATED REPORT

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PARASTRONAUT FEASIBILITY FOUNDATIONAL RESEARCH STUDY ABBREVIATED REPORT

Since its establishment in 1958, the National Aeronautics and Space Administration (NASA) has been the international leader in human space exploration. A key part of maintaining this leadership and continuing to meet its mission is a healthy environment that fosters creative and innovative solutions.[1] The Agency has recognized that this environment must include its core values: Safety, Integrity, Excellence, Teamwork, and Inclusion.[2,3]

NASA's preeminent position in human space exploration gives it immense power and influence with the international space community. NASA's overarching vision to "reach for new heights and reveal the unknown for the benefit of humankind"[4] makes their official stance on diversity and inclusion extremely influential on increasing access to space for previously excluded individuals.

As of 2021, the Astronaut Selection Process outlines criteria to include education, work experience, and medical qualifications necessary to apply to the Astronaut Candidate Program. Due to inherent risks (i.e., radiation, isolation and confinement, distance from Earth, reduced gravity, and a hostile/closed environment),[5] astronaut selection includes incredibly stringent physical, psychological, cognitive, and technical requirements and requires the astronaut to meet current anthropometric requirements of both the spacecraft and the spacesuit.[6] Among these current requirements is the ability to pass the NASA long-duration space flight astronaut physical.[7] This physical includes specific medical, physical, and mental requirements designed within space hardware parameters and current operational procedures of human spaceflight to ensure the health and safety of the crew and the success of the mission. As such, individuals with known physical disabilities are currently disqualified from astronaut selection.

The Potomac Institute brought together military representatives, industry leaders, non-government organizations, and other relevant stakeholders to explore the feasibility of flying "parastronauts" in space. In order to explore this challenge, the Institute leveraged robust internal and external research, interviews with key subject matter experts (SMEs), and discussions with Institute Board of Regents members, including Major General Charles Bolden and Dr. Kathy Sullivan, to identify policy, technical, operational, and medical considerations to ensure the safety and productivity of potential parastronauts aboard human space missions. Herein is a summary of the findings and recommendations detailed in the report, including related policies across the US government and globally, as well as relevant considerations and hurdles to parastronaut inclusion.

From Potomac Institute research, informational interviews with key subject matter experts and stakeholders, literature review, the following two overarching findings were identified regarding parastronaut feasibility:

1. **NASA's current medical standards disqualify parastronauts.**
    a. **The US DoD currently has more inclusive policies regarding amputees than NASA's Astronaut Corp that vary across the branches of services.**
    b. **Increasing human access to space is being pursued in private industry and non-profit organizations. Commercial space flight policies currently envision greater inclusivity using baseline standards for crew members to meet (rather than more rigorous medical disqualification criteria) and leveraging technological advances.**
2. **Inclusion of parastronauts, while considered technologically feasible, will require additional research and development (R&D) and alignment of human systems and engineering risk assessment.**
    a. **Successful inclusion warrants a comprehensive understanding of overall mission risk comprised of both engineering and human systems risks, particularly in the areas of emergency procedures and spacesuit and spacecraft design.**
    b. **Some of the proposed solutions will require explicit experiments in space to validate safety and performance.**
    c. **Shifting societal views and policies have led to an emergence in research, and development of technological and medical advances, related to individuals with disabilities.**

From these findings, the Potomac Institute study team identified two corresponding recommendations regarding the inclusion of parastronauts into the Astronaut Corps:

1. **Revise medical standards and baseline fitness qualifications to reflect recent advances in science.**
    a. Evaluate current medical standards and astronaut selection criteria at the Agency level to ensure they are appropriate and modernized.
    b. Consider disabilities beyond the three physical disabilities (i.e., lower leg deficiency, short stature, and/or leg length difference) explored in this study.
2. **Employ experimental design utilizing technological and medical advances and relevant partnerships to inform overall parastronaut risk assessment and develop risk reduction pathways.**
    a. Determine the true costs (i.e., time, funding, resources) associated with parastronaut inclusion.
    b. Utilize parabolic flights to demonstrate parastronaut proof-of-principle.
    c. Leverage partnerships with industry to connect government with commercial and non-government organizations already pursuing research, development, technology, and engineering advances related to flying individuals with disabilities.

NASA's mission is to

"drive advances in science, technology, aeronautics, and space exploration to enhance knowledge, education, innovation, economic vitality, and stewardship of Earth."

As technology continues to advance, NASA should continue its forward-thinking mentality regarding astronaut medical standards and criteria to ensure it has access to the best set of expertise and talent available to support successful missions. It should be comfortable with growing technological capabilities and medical advances and make changes when viable. Expanding astronaut selection to include parastronauts could lead to new innovations and benefits to the safety and performance of future crews. These advancements provide potential translation to improvements for terrestrial health and medical care. For example, advances in understanding spaceflight associated neuro-ocular syndrome (SANS) have enhanced our capacity to evaluate eye health and function. As well, studies on reduced gravity-associated bone loss have implications for the treatment of osteoporosis. To maintain their cutting-edge technological status, NASA and international space agencies must investigate the feasibility of parastronaut inclusion and relevant policy implications, including the comprehensive understanding of the overall mission risk, which is comprised of both human systems and engineering risks.

Integrating parastronauts into NASA's Astronaut Corps requires a thorough understanding of the technical, operational, medical hurdles, relevant policy implications, and effective alignment between the human systems needs and engineering systems requirements. New technologies and medical capabilities will enable improved performance of crew members – with or without disabilities. We must reasses current astronaut requirements to ensure continued safety and performance of a more inclusive human spaceflight program.

For the context of this study, "**parastronaut**" is defined as an individual with a certain physical disability, i.e., lower leg deficiency, leg length difference, and short stature.[7]

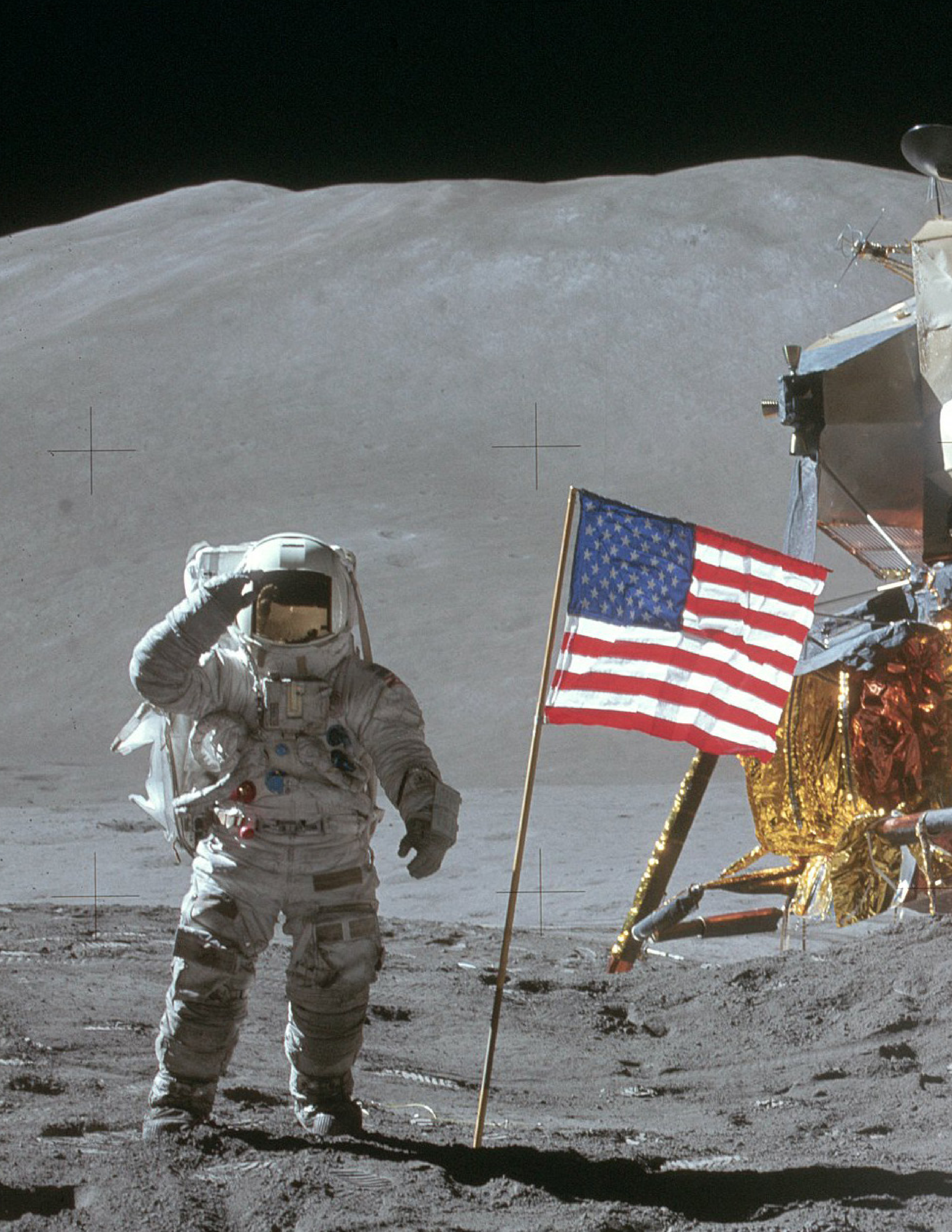
Lower Leg Deficiency:	unilateral or bilateral foot (below ankle) or leg (below knee) loss
Leg Length Difference:	described as an individual's lower limbs being unequal in length
Short Stature:	defined as height that is two standard deviations below the corresponding mean height of a given age, sex, and population group

RELEVANT POLICY AND CURRENT REQUIREMENTS

NASA seeks similar demographics as the US military for the Astronaut Corps, maintains similar medical and health standards, and is bound by similar US government policy. Further, most astronauts come from military backgrounds. As of 2016, roughly two thirds of current and former astronauts also served in the US Armed Forces (219 of 330 astronauts).[8] As such, the Potomac Institute focused on relevant US military policies that could help inform decision-making related to parastronaut polices and identified several case studies to highlight individuals with disabilities that have returned to combat service or spaceflight related activities.

Americans with Disabilities Act (ADA) is a foundational governing policy regarding discrimination in civilian positions. The US Armed Forces are exempt from the ADA, as is NASA, regarding astronaut selection, specifically. The DoD also considers diversity to be a leadership requirement and a strategic imperative – both critical to mission readiness and accomplishment.[9] DoD recognizes that as US demographics continue to evolve, the DoD must position itself to capitalize on the broad range of talent across the country by attracting, recruiting, developing, and retaining the best and brightest. For DoD, greater inclusivity of diverse backgrounds translates to greater connection to the citizens it serves.

The DoD currently disqualifies individuals for military service for a variety of health and medical reasons. For comparision to the three outlined parastronaut physical disabilities, the DoD disqualifies any individual from entering service if they have lower limb deficiencies, short stature (below approximately 4' 10"), and/or leg length differences significant enough to cause a limp, as outlined above. Each branch of the US military has specific standards for disqualification as detailed, but generally follows the aforementioned standards. While individuals with missing limbs may not enlist in active military roles, those who experience amputations while serving have the option to remain in a combat or non-combat role depending on their degree of injury and the imposed functional limitations. An individual that experiences a limb loss while serving on active military duty must demonstrate they can perform at the same physical level and meet the same physical standards as individuals with no limb loss in order to return to active duty. The DoD does not offer alternative accommodations or adaptations to the certification/recertification of its active-duty service members following a traumatic limb injury and/or loss; however, each service has revised its policies in recent decades to allow individuals the opportunity to re-qualify for active duty.



Case Study: Army Lieutenant Joshua Pitcher

1stLt. Pitcher lost his left leg below the knee in a combat explosion in 2012. Once he received his prosthetic, he learned to walk on it in one week and ran the Army 10-Miler on it three months later. He was recertified for active duty in January of 2013, passing the fitness test in the top 10% of all active-duty soldiers. 1stLt. Pitcher went on to also recertify as an airborne paratrooper and eventually lead a platoon of 21 other paratroopers in Northern Afghanistan. On active duty, he wears "a prosthetic that includes a curved blade at the bottom, which allows him to dig into the mud and snow for balance."[10]

Case Study: Marine Staff Sergeant Jason Pacheco

SSgt. Pacheco is the first amputee to return to a combat zone in an infantry military occupation specialty. He returned to combat in 2011, 15 months following his injury – a right leg amputation below the knee, soft tissue damage to his left leg, and amputation of his right pinky finger.[11] Part of his return to active duty required successful completion of the Combat Fitness Test, which requires Marines "in battle dress uniform to sprint a timed 880 yards, lift a 30-pound ammunition can overhead from shoulder height repeatedly for two minutes, and perform a maneuver-under-fire event, which is a timed 300-yard shuttle run in which Marines are paired up by size and perform a series of combat-related tasks."[12]

Case Study: Hayley Arceneaux

Hayley Arceneaux is a childhood osteosarcoma (bone cancer) survivor. On September 16, 2021, she was one of the four members of SpaceX's *Inspiration4* mission—the world's first all-civilian spaceflight. Ms. Arceneaux has a titanium prosthesis in her left leg as a result of osteosarcoma in her femur as a child. Before the mission, she completed astronaut training with the goal to become FAA-certified commercial astronauts.[13] Ms. Arceneaux served as the medical officer for the flight. Her internal prosthesis handled up to 8 Gs during flight training and a month later, withstood the rigors of actual space flight.[14,15]

Through technological and medical advancements and policy revisions, service members that experience traumatic amputations can return to duty, and in some cases, return to active combat roles. In the two decades since 9/11, the DoD has treated more than 1,500 servicemembers with major limb amputations resulting from injuries while on deployment.[16] During the 1980s, roughly 2.3% of all US Army amputee soldiers returned to active duty (11 out of 469 soldiers).[17] Today returning to service after amputation is not a rare occurrence. Between 2001 and 2006, 16.5% of amputee soldiers returned to combat.[18] The majority of amputees that were able to return to duty experienced lower leg amputations.

As commercial spaceflight ventures increase, requirements concerning private astronauts and space flight participants are being developed. In contrast to policies dictated by NASA's Astronaut Corps, the Federal Aviation Administration (FAA) and private entity policies are in some cases less rigororous. In some cases, these policies are less rigorous than those required by NASA. Commercial entities view private spaceflight as less demanding compared to governmental space agencies aided by purview of different technological capabilities and see the role of their astronauts and space participants differently than NASA.

CONSIDERATIONS AND HURDLES

Safety and mission utility are a primary concern when developing and implementing health and medical standards. Therefore, understanding these considerations helps inform the feasibility and overall cost (e.g., time, funding, resources) required to realistically integrate parastronauts into a spaceflight mission. Technical, operational, and medical challenges all exist when including parastronauts. Short stature will likely require the most technical and operational developments, especially for emergency ingress/egress. Depending on the degree of impairment, leg length differences likely present the least difficulty for space flight. To date, there are no set criteria to determine whether those with lower limb deficiencies and differences and short stature are medically capable of space flight.

Technical

Technical components associated with spaceflight will need to be assessed and potentially re-designed or altered and re-evaluated in zero gravity, such as cockpit seats; Launch, Entry, Abort (LEA) and extravehicular activity (EVA) suits; interior spacecraft design; on-board equipment; and in the case of amputees, prosthetic devices.

Operational

While an initial look into relevant DoD policies concerning individuals with physical disabilities indicates that alterations to certification processes/requirements are not currently given (e.g., pilots must pass flight certification drills regardless of physical disability), the uniqueness of the spaceflight environment might warrant further investigation of NASA's policies and procedures. Operational considerations include mission requirements and roles, onboard safety protocols, onboard fitness regimes, and emergency ingress/egress. Functional testing should be carried out for each type of parastronaut, particularly in regard to egress.

Medical

The austere environments of space and interplanetary exploration include physical adversities such as microgravity and radiation. At the same time, the distance from Earth, cramped quarters of habitation, and isolation are social and psychological stressors. The goal of medical certification of parastronauts should be to meet the standards necessary to ensure safe and reliable mission performance.

Standardized objective outcome measures can serve as assessment tools for the medical examiner to establish medical readiness of the parastronaut.[19] While each disability explored has associated medical concerns common to that physical disability, each individual with a physical disability has a unique physical capacity to compensate for their disability and therefore, a tailored approach to medical screening should be applied.

Continued human space exploration, in terms of length of time and distance traveled, increases the chance that those individuals might experience an adverse medical condition or traumatic injury resulting in a temporary or permanent physical state analogous to that of a parastronaut. Regardless of the amount of terrestrial testing and training, the space environment and subsequent planetary gravity systems are different, which can lead to unanticipated challenges.[20]

These challenges can be viewed as opportunities to employ the human-centered design approach to spacecraft and equipment development with potential benefits including universal-design approaches to human system risk mitigation and increased diversity. Parastronaut inclusion may require redesign of current and future systems and rightfully challenges our notions of human spaceflight as they stand today. Implementing human-centered, inclusive design approaches on the front end could help alleviate some of these unknown hurdles.

OPPORTUNITIES

There are many unknown risks related to parastronauts, but this does not imply they are inherently "riskier." Rather, parastronauts face a different, unique type of risk that requires holistic analysis. Subject matter experts consulted by the Potomac Institute indicated there are no likely barriers due to feasibility; instead, the question revolves on whether there is significant motivation, allocation of resources (i.e., time and funding), and a thorough understanding of the overall mission risk (both to human and engineering systems) to change and evolve astronaut selection criteria for the modern era of human space flight.[21] Investment in technology and capabilities to enable parastronauts access to space could translate to advances in terrestrial medicine and health care. These advances could include novel reahabilitation methods, more evolved technologies, and increased safety, among other benefits, as detailed below.

Rehabilitation

Low Earth orbit (LEO) could enable "Space Rehab," that is, leveraging microgravity to conduct more effective physical therapy and rehabilitation. One expert noted that LEO rehabilitation could be beneficial to new amputees, enabling them to manage re-loading and weight bearing rehabilitation possibly more effectively than on Earth.[22] Further, technological innovations necessitated by parastronaut inclusion could be utilized in terrestrial care. Much like the DoD has been a driver for prosthetic device technology in recent decades,[23] NASA could see dual use in innovations for individuals with disabilities beyond the described criteria for parastronauts. The DoD advances have benefited not only veterans, but the greater disabled community. NASA has the opportunity to make a similar impact.

Evolving Technology

Understanding the feasibility of parastronauts is not only about shifting the work environment to view disability beyond the medical lens, but also understanding that disability is part of an individual's larger identity. Disability can add value to an individual's experiences and brings new perspectives to the table. While only three visible physical disabilities were studied for this report, it is likely that after the success of an initial parastronaut program, further physical conditions will be removed from the disqualification list such as deafness or blindness. NASA will need to consider the ever-evolving technologies and the implications that will have on further inclusion of the physically disabled.

Safety and Additional Benefits

Relevant updates to onboard training and procedures to accommodate parastronauts could, in fact, lead to an overall increase in safety and performance.[24] Not only does universal design facilitate inclusion, but it also inherently results in system redundancies and functionalities that could increase safety measures for the entire crew. For example, accessible instrumentation that has been adapted for a blind or visually impaired astronaut could be utilized by a sighted astronaut in the dark, or a temporarily blinded astronaut, as in the case of Canadian astronaut Chris Hadfield during a 2001 spacewalk.[25] Similarly, during the 1997 fire aboard the Russian Mir space station, the crew's vision was obstructed by smoke. A blind astronaut would not be impacted by the sudden lack of vision and would be able to locate the fire extinguisher based on their awareness of the cabin.[26] In the event of sudden temporary (or even permanent) hearing loss, a deaf astronaut knowledgeable in American sign language could continue non-verbal communication with their crew if properly trained.[27] Additionally, due to differences in the vestibular system, some deaf individuals are immune or resistant to motion sickness – during the famous Gallaudet 11 studies in the 1950s, NASA demonstrated that deaf individuals might be more adaptable to foreign gravitational environments.[28]

Further, individuals with disabilities can bring many desirable skillsets and unique perspectives to NASA's astronaut pool. Improved inclusivity can positively impact a team by increasing innovation, motivation, and a sense of individual value.[29] SMEs highlighted positive characteristics of individuals with disabilities that would likely be considered for parastronaut selection, including being highly motivated,[30] less risk adverse,[31] adaptable and perseverant,[32] resilient,[33] and possessing strong mental fortitude.[34] Many individuals with disabilities have high problem solving skills, due to having to adapt daily to a world not always designed for them.[35] Further, individuals who have experienced a traumatic amputation could be calmer in emergency situations, as they have likely demonstrated this ability upon experiencing the traumatic amputation.[36]

In recent decades, advances in technology and medical care have improved access for those with disabilities. Scientific advancements have assisted in shifting societal views on diversity and inclusivity by removing many physical barriers for disabled individuals and societal views have subsequently increased scientific research and technological development. Already commercial space ventures are beginning to remove certain disqualification criteria to ensure broad access to their space missions, and have demonstrated leveraging their knowledge gained from more inclusive practices.

PATH FORWARD

For NASA and the international space agencies to keep pace with societal and commercial advances, understanding the feasibility of inclusion of parastronauts in space is encouraging. In the past decade, societal attitudes towards diversity and inclusivity have shifted along with a shift in technological capabilities and accommodations. While no individual with a known disqualifying physical and/or mental disability has yet flown in space, commercial space ventures are already beginning to lessen restrictions on who qualifies for human spaceflight. The likelihood of an individual with an amputation or other physical disability traveling to space will increase in the upcoming decades with increased space flight participation from commercial entities. The technology and health/medical standards necessary to fly them safely must also increase and evolve with changing astronaut medical standards and policies.

CONCLUSION

Inclusion of parastronauts, while considered technologically feasible, will require additional research and development (R&D) and alignment of human systems and engineering risk stratification. Successful inclusion warrants a comprehensive understanding of overall mission risk comprising of both engineering and human systems risks, particularly in the areas of emergency procedures and spacesuit and spacecraft design. Some of the proposed solutions will require explicit experiments in space to validate safety and performance. Further, NASA will need to consider the degree to which some mission delay is acceptable, particularly in light of upcoming timelines for Artemis missions.

NASA's Flight Opportunity Program also offers individuals who have not met the astronaut requirements the opportunity to enter space and fly with NASA. These researchers are able to conduct human-tended studies in austere environments including zero gravity, extreme radiation, and extreme temperatures through this program.[37] While policy alterations to the Astronaut Corps selection requirements would be required to allow individuals with physical disabilities to fly, the Flight Opportunity Program does not pose the same hurdles. Therefore, it could be an avenue to explore this possibility.

Shifting societal views and policies have led to emergence in R&D of technological and medical advances related to individuals with disabilities, and vice versa. Increasing human access to space is being pursued in private industry and non-profit organizations.

Technical and operational considerations that surround parastronauts highlight the importance of employing human-centered design approaches to spacecraft and equipment development. However, there are potential benefits to inclusion of parastronauts from more universal-design approaches to human system risk mitigation and advantages associated with increased diversity. Integrating parastronauts into NASA's Astronaut Corps requires a thorough understanding of the technical, operational, and medical hurdles, relevant policy implications, and effective alignment between the human systems needs and engineering systems requirements. The possibility of increasing access to space is inspiring and aligns with NASA's overarching vision to "reach for new heights and reveal the unknown for the benefit of humankind."[38]


STS-121
KELLY

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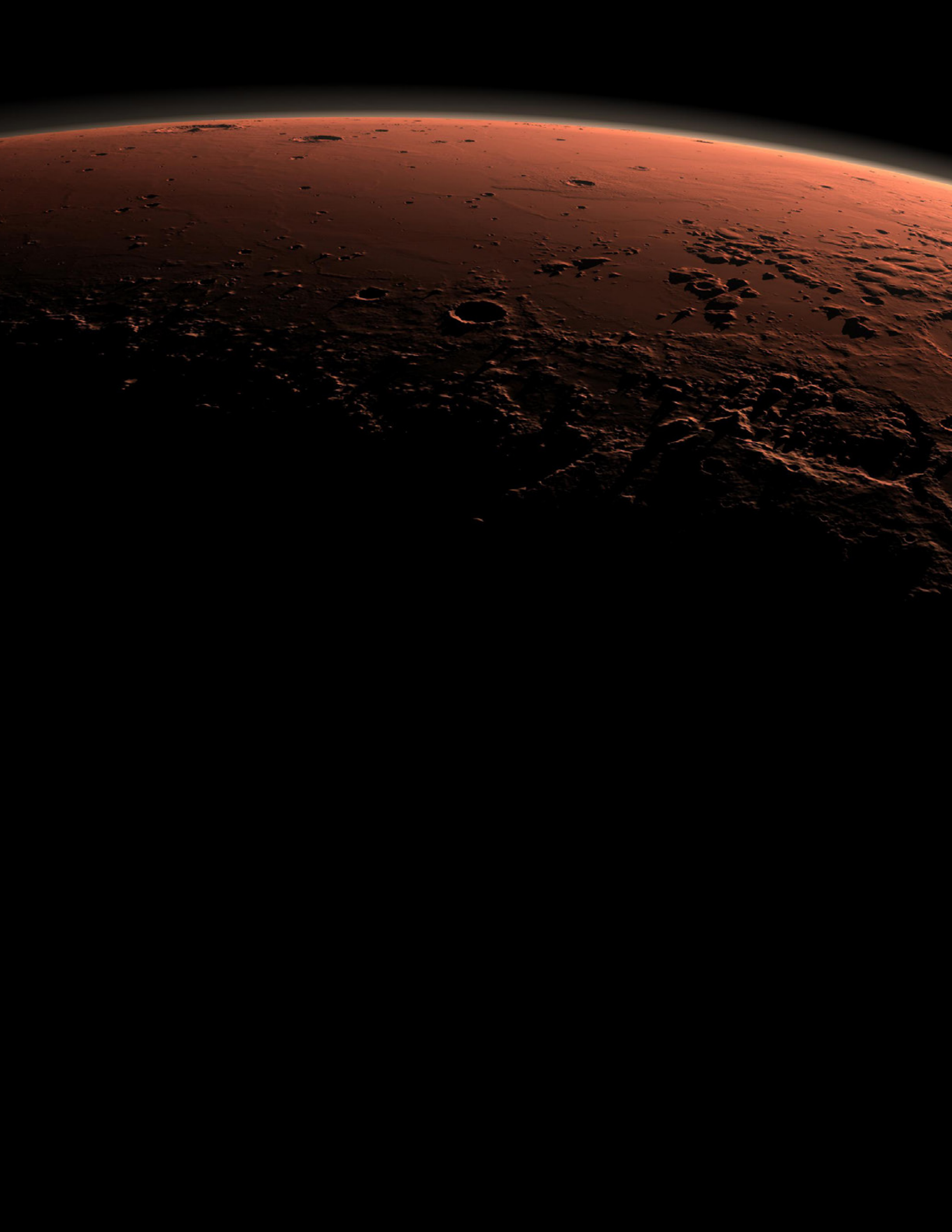

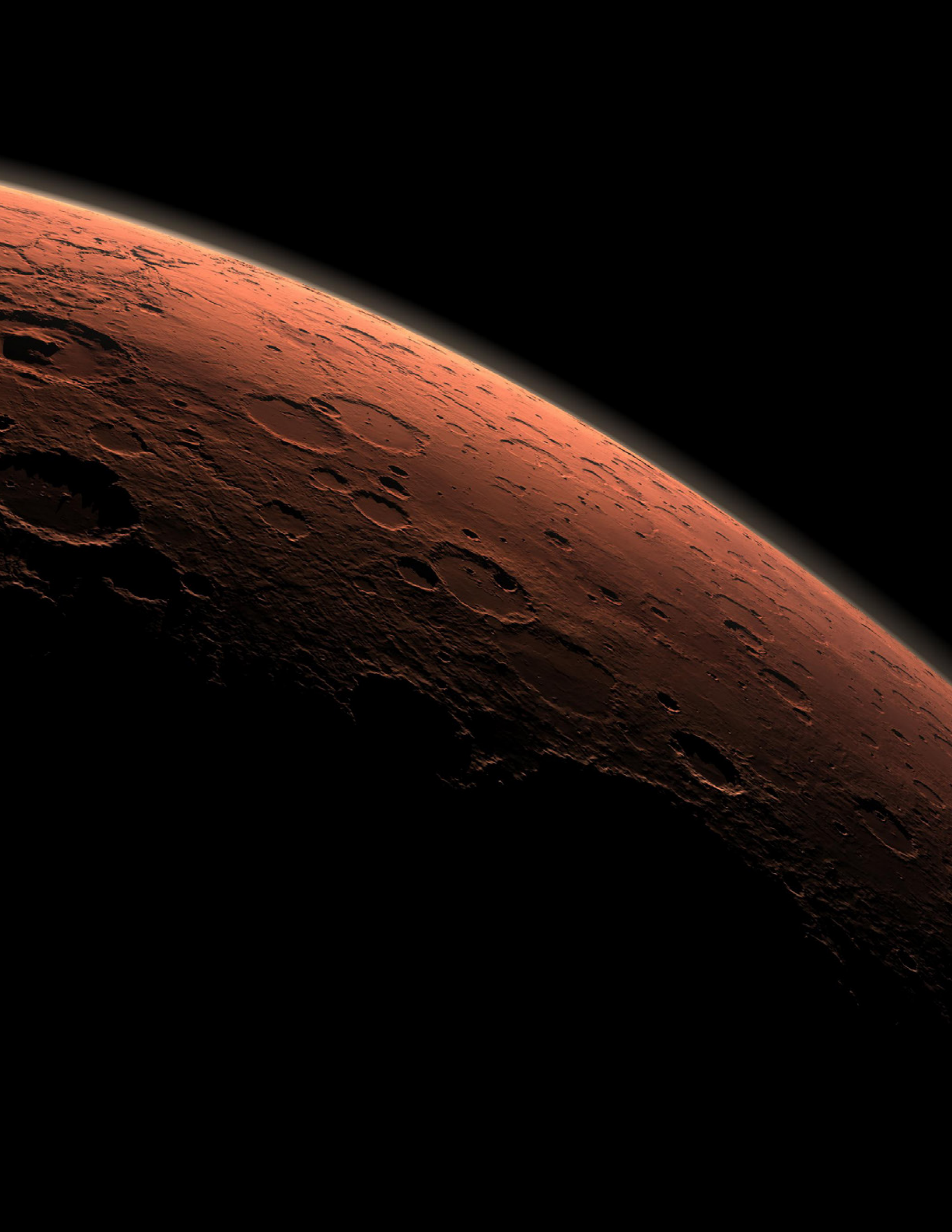

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