Explore Mars, Inc. Presents the Interim Findings and Recommendations of

The Eighth Community Workshop for Achievability and Sustainability of Human Exploration of Mars (AM 8)

Maximizing Crew Performance & Productivity for Missions to the Moon and Mars

Virtual Workshop: June 1 – 3, 2021

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

Was made possible thanks to the contributions of:

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This material is based upon work partially supported by the National Aeronautics and Space Administration Grant No. 80NSSC18K0836. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect those of the National Aeronautics and Space Administration.

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THE EIGHTH COMMUNITY WORKSHOP FOR ACHIEVABILITY AND SUSTAINABILITY OF HUMAN EXPLORATION OF MARS

Maximizing Crew Performance/Productivity for Missions to the Moon and Mars
Virtual Workshop: June 1–3, 2021

The eighth workshop (AM VIII) in this series hosted by Explore Mars, Inc., a 501(c)(3) non-profit, engaged a multi-disciplinary team of subject matter experts to investigate how lunar activities can be maximally leveraged to enable the human exploration of Mars. A subsequent in-person workshop (AM IX), to be held in early 2022, will follow up on key initial findings from AM VIII.

Summary of Interim Findings and Recommendations

The outcomes of the AM VIII workshop are summarized below, noting ways in which near-term activities in Low Earth Orbit (LEO), in lunar orbit, or on the Moon can retire risk and reduce costs for future human missions to Mars.

Planning for human missions to Mars

The Moon offers the opportunity to test many in-space/on-surface capabilities. It is important to demonstrate potential infrastructure approaches on the Moon to inform needed infrastructure/capabilities on Mars (e.g., habitat, surface space suits, robotic partners). In addition, initial Mars mission(s) will begin building infrastructure for subsequent missions. Therefore, a coordinated program that integrates currently disparate human and robotic programs for the Moon and Mars would enable collaboration across programs to achieve maximum efficiency.

> **FINDING:** NASA needs to establish a single **Moon and Mars office** with responsibility for coordination of the human exploration programs and robotic precursors for the Moon and Mars.

Preparing for transit to/from Mars

A coordinated program of analog studies on Earth, in LEO, and in the lunar vicinity (lunar surface and/or lunar orbit) is needed to minimize cost and risk for future human missions to Mars. Strong concerns were expressed about crew health and how to mitigate adverse effects associated with long-duration space travel. Near-term analog studies can help to identify and mitigate issues, including those related to neuro-ocular syndrome, gravity reconditioning/re-adaptation, psychological effects of reduced pressure and long-duration confinement far from home, and radiation exposure and associated cognitive decline.

> **FINDING:** NASA needs to establish a coordinated strategy and plan for analog studies that leverages the International Space Station (ISS) to investigate and mitigate crew health issues as well as operational hurdles that may arise during transit to/from and operations on Mars. Any findings should be socialized at both medical and Mars-focused conferences.

Human activities—especially science objectives—for human Mars missions are currently under-studied and offer enormous potential for a variety of scientific disciplines. Science objectives for surface stays could involve tasks such as studying the effects of the transition to a 1/3 gravity environment on human and other biology (e.g., microbes, plants). However, extended stays in space should also be capitalized on, as they may last up to approximately 3 years for orbital missions (or even longer if the crew is unable to land). Possible activities to consider for the in-space legs include teleoperation of pre-deployed assets at Mars (e.g., for sample assessment and collection); monitoring impacts of long-term exposure to the deep-space environment; and preliminary sample assessment of Mars samples during the return trip in order to capture ephemeral properties and as a back-up in case of equipment failure, recognizing potential planetary protection and sample contamination concerns.

Sample collection on the Martian surface will require careful selection. If this includes ice cores from mid-latitude sites on the red planet, it will necessitate cryogenic storage capabilities. Accessing potentially biologically sensitive areas like subsurface ice may need to be carried out by robots initially, with human crew to follow depending on TBD planetary protection requirements. Sample type (e.g., deep cores vs surface material) and science objectives, as well as containment and contamination-prevention requirements/equipment for cryogenic samples, may have a direct impact on Mars Transfer Vehicle (MTV) engineering requirements and crew activities. Either way, robotic or human drilling of ice or rock cores could be tested on the Moon prior to Mars.

The need for onboard spares (e.g. parts for suits, tools, etc.) and extra supplies, such as contingency food and water, adds mass and must be balanced against deployment as pre-positioned assets. Continued evaluation of in-space fabrication in analog environments is highly desirable. Lessons learned from repairs on the International Space Station (ISS), including responding to major malfunctions, are particularly valuable.

> **FINDING:** NASA needs to assess mission requirements for maintenance of astronaut and spacecraft health and identify/prioritize science objectives (for the transit, orbital, and surface legs) that impact the engineering requirements for the MTV or surface elements. Required technologies/capabilities should be tested in analog environments in LEO or on/near the Moon.

Preparing for surface activities on Mars

Planning planetary protection requirements for human missions to the martian surface introduces complexities beyond those for robotic missions, including:

1. habitat/laboratory performance (e.g., leakage),
2. flexible joints on suits that make movement easier, but are more likely to leak gas,
3. potential for hazardous Mars material to enter the habitat via suits during ingress or suit repair,
4. waste disposal/recycling systems to eliminate/repurpose human waste; and,
5. isolation and protection of collected specimens/samples.

Some aspects of planetary protection may be mitigated through judicious use of robotic partners, particularly in astrobiologically sensitive areas. Semi-autonomous or teleoperated robots that can core, capture, seal, and store samples can be tested on the Moon.

> **FINDING:** NASA needs to develop an understanding of what the planetary protection requirements for human missions to Mars should be and determine the impact on scientific return. Mitigating strategies to minimize both forward and backward contamination must be investigated. Where appropriate, such technologies and techniques should be tested in analog environments, such as on the Moon.

Robotic reconnaissance is needed at the Moon and Mars to characterize landing sites for science and resource potential. These efforts will in turn inform our pre-emplacement strategies.

Even for relatively short surface duration (~30 day) missions, pre-emplacement of infrastructure is critical for astronaut health and scientific exploration. Emplacement and testing of such infrastructure should be demonstrated in appropriate analog environments. Power generation is of the highest priority; systems can be tested and scalability assessed on the Moon. Communication and navigations capabilities for both human and robotic missions can also be improved. Pre-placement of a human-class rover is highly enabling, since mobility requirements are driven by topography, science investigation sites, and how far apart landed assets must be placed to avoid sandblasting during launch and landing. Habitat/laboratory design and robotic construction can be demonstrated on the Moon prior to emplacement on Mars. In-situ resource utilization (ISRU) and in-space manufacturing that can be partially demonstrated on the Moon will eventually be needed for long-stay missions.

> **FINDING:** NASA needs a plan for pre-emplacement of required infrastructure for the early human missions to Mars, including completing trades on habitation capability, mobility (pressurized vs. unpressurized), ISRU technology demonstrations, and power. Such elements should be tested on the Moon.

Partnerships between humans and robots are critical to exploration. Where possible, robotic partners should perform tasks to augment astronaut mobility and flexibility, such as enhancing EVA capabilities, thereby reserving astronaut EVAs for roles that are optimally performed by humans. For example, a robotic partner could carry the health monitoring equipment and Environmental Control and Life Support Systems (ECLSS). Concepts of Operations (conops) for optimal human-machine partnering can be tested on the lunar surface, including suit design and pairing with robotic partners, as well as contingency planning.

> **FINDING:** NASA needs to develop a conops plan for the first Mars human exploration mission(s), including human/robotic partnerships, and use the lunar environment to test and optimize that plan.

Challenges to Coordinated Human Exploration of the Moon and Mars

The Achieving Mars (AM) annual workshops, hosted by Explore Mars, Inc., a 501(c)(3) non-profit, bring together leading experts from disparate fields, and offer the opportunity for the broad community of technologists, scientists, engineers, and policy experts to contribute to the expansion of human presence beyond the Earth.

In June of 2021, a multi-disciplinary team of subject matter experts (SMEs) met to address how lunar activities can be maximally leveraged to enable the human exploration of Mars. Some of the critical questions asked included:

- What are the mission priorities for the in-transit, orbital, and surface elements that crews can achieve under different scenarios?
- How might crew preparation be optimized to enhance the performance of astronauts selected for these missions, whether orbital, short-stay, or long-stay, and in transit?
- What are the priority science and human exploration goals on the Moon and Mars that can be coordinated to enhance productivity for both worlds?
- How can human-robotic partnerships enhance human performance?
- How can operational experience on the International Space Station (ISS) as analog, and the return of humans to the Moon, be best applied to voyages to Mars?

Within the Artemis Program, many of these questions can be partially answered, while likely also generating new ones, and risks reduced.

AM 8 in the Context of NASA's Artemis and Mars Exploration Programs

The AM 8 workshop (see Appendix A, the list of participants) built upon our previous workshops (particularly AM workshops V, VI, and VII; https://www.exploremars.org/affording-mars/), which emphasized that both the Moon and Mars are intrinsically compelling in their own right.

Our sixth and seventh workshops (held in-person during August 2018 and November 2019, respectively) critically assessed how operations, technologies, and facilities for the Moon and its vicinity may simultaneously be used to enable human missions to the martian surface before the end of the 2030s.

Our next series of workshops was structured differently from our previous seven stand-alone workshops. Planned as a two-part event, the initial workshop (AM 8) took place virtually in early June 2021 and will be followed by a planned in-person workshop (AM 9) that is tentatively scheduled for late November/early December 2021. **The June 2021 virtual workshop yielded the initial findings and recommendations listed in this report.** These findings and recommendations are only preliminary in nature, however, and will be subject to further review at the larger, in-person workshop later this year.

Coordinated Moon and Mars Exploration Architecture Elements That the AM 8 Workshop Assessed

Attendees at the June 2021 workshop used the assumptions listed below to guide their discussions

- » Both the Moon and Mars are profoundly important scientific and human space flight goals in their own right and additionally are extremely attractive for coordinated exploration and development of technological capabilities.
- » That said, there has been relatively little integration to date of jointly developed science programs and other Moon+Mars activities.
- » If astronauts are to be capable of achieving major science and operations goals on Mars, they will have to deal with the effects of radiation [solar and galactic cosmic (GCR)], microgravity, and isolation in a high-stress environment during transit times that will last between 6-8 months and possibly longer (depending on the trajectory used).

- Astronauts on orbital missions or those unable to land on the surface of Mars (due to technical malfunctions or other risks), may experience these effects for up to 37 months.

» Unless mitigated, this extended transit time will require adjusting physically and mentally to perform adequately under these conditions. A lengthy readjustment to the martian gravity suggests that it will be advantageous for much of the initial infrastructure to be put in place in advance of a human landing.

» Comprehensive programs of astronaut activities during the long transit times between Earth and Mars (and return) are essential, but have yet to be developed.

The three-day June workshop identified priorities and initiated subsequent assessments that will lead to a more in-depth, in-person workshop in late autumn/early winter 2021. The results of our work have formed a solid foundation for subsequent in-depth assessment of technology investment priorities and will be presented to NASA for consideration of integration into the Agency's exploration architecture.

TOPIC AREAS FOR EACH DAY

DAY ONE: Crew Health and Performance

- What facilities and conditioning in the confined environment of the Mars transit vehicle will be essential to mitigate the effects of zero g and remote isolation to prepare astronauts for surface activities?
- What activities, including achieving science goals, will be important during transit to keep the astronauts actively engaged?
- How can the surface space suit design be optimized, including preparation overheads and improved egress/ingress procedures, to make EVAs more efficient, less demanding, and more frequent? What are dominant suit design issues that limit their broad acceptability?
- What are priority crew health issues and strategies to mitigate the effects of long-duration space travel?
- What are the most-effective Mars analogs/simulations on ISS, in the Gateway, or on the lunar surface?

DAY TWO: Enabling Surface Infrastructure, Including Robot Partners

- What are the key elements of the surface infrastructure for the initial human mission(s) and how are they optimized for the first crew(s)? What elements are most important for subsequent sustained human presence?
- What are the options for Rovers/Remote Operated Vehicles (ROVs) that can maximize the productivity of the crew?
- What are the essential roles for lunar and martian robotic partners and precursors, especially to achieve science goals?
- What risks to martian exploration can be retired by lunar operations and technology development?
- How best can the lunar experience with the Artemis base camp benefit the establishment of the martian base camp?
- Make or take: How can increasing capabilities for in-space fabrication and use of resources offer the potential for significant mass and complexity savings?

DAY THREE: Science Goals from the Lunar Surface to Mars

- What are the science priorities and their commonalities for the transit, orbital, and surface phases of human missions to Mars, including tools, instruments, and mobility systems?
- What kind of tools, instruments, modules, and mobility elements need to be included for each phase of the mission? What technology developments are required for these capabilities?
- What are the capabilities offered by the Gateway and lunar surface operations as proposed by the Artemis Program that could be evolved to support future human missions to Mars?
- What are the key technology development programs necessary in advance of or during lunar exploration that will be most useful for human and robotic exploration of Mars?

INTERIM FINDINGS AND RECOMMENDATIONS

This section is divided into 3 parts, as follows:

1. *KEY FINDINGS*
2. *AREAS OF GENERAL AGREEMENT*
3. *IMPORTANT TOPICS WHERE MORE WORK, INCLUDING TRADE STUDIES, APPEAR NECESSARY*

KEY FINDINGS

1. If NASA intends a coordinated program that integrates disparate human and robotic programs for the Moon and Mars, **there must be a single office** with this responsibility. This will allow easier integration across programs to achieve maximum efficiency.
2. There was strong support among the participants for analog studies on Earth, in Low Earth Orbit (LEO), and in the lunar vicinity (lunar surface and/or lunar orbit).
3. There is a need to establish and investigate differences in re-adaptation to gravity (e.g., some humans recover sooner than others) and ways to mitigate the negative effects of zero g (e.g., exercise, diet, robotically enhanced surface suits or robotic partners on surface).
4. It is expected that planetary protection requirements will be significantly different for human missions than those used for robotic missions. Some of the reasons include:
   a. Habitat/laboratory performance (e.g., leakage, waste disposal)
   b. Flexible joints make movement easier, but are more likely to leak gas from inside the suit
   c. Can/should suits be brought inside the habitat/laboratory, for example, to perform repairs?
   d. Potential for Mars microbes to enter the habitat during ingress
   e. Isolation and protection of collected specimens/samples
   f. Other issues yet to be determined
5. Tutorials or seminars on human health and physiology in space for non-specialists should be scheduled. Many results of studies of the human body in space are published in medical journals and presented at non-planetary science conferences. Thus, many individuals in the space community may be unaware that certain studies have already been performed.
6. Humans are needed for exploration in addition to the critical role of robotics, although humans may possess complicating factors (e.g., psychological, physical, etc.).
7. Science objectives are highly dependent on the phase of the mission.
   a. In-space: Human activities during in-space legs of Mars missions are currently under-studied. However, some initial considerations include human research, microbial research, astrobiology, botany and sample collection, processing, and storage. Extended stays in space may last up to 1100 days (37 months) for orbital missions or if the crew is unable to land. Therefore, assessing activities to keep the crew productively engaged throughout extended periods is essential.
      i. Teleoperation of pre-deployed assets should also be investigated. Teleoperation of pre-emplaced assets may make the most sense on the outbound leg.
      ii. There must be close monitoring of how humans and other types of biology (e.g., microbes, plants) aboard the Mars Transfer Vehicle (MTV) change in response to long-term exposure to a deep-space environment (e.g., zero-g, radiation, isolation, etc.).
      iii. Consideration should be given as to whether preliminary sample assessment should or should not be performed by the astronauts during the return trip. In order for such preliminary assessments to be made before the return to Earth, planetary protection concerns must be addressed. In addition, such assessments on the return flight will require additional equipment and therefore additional mass on the MTV.
      iv. Mission objectives, as well as sample type, will determine how samples are handled and stored during the return trip (i.e., not all samples are created equal: deep cores vs surface material).
      v. The definition of “cryogenic sample return” needs to be explicit as it has direct impact on the engineering requirements for the MTV.
      vi. Other issues (to be determined)

b. Surface: Sample collection will require the careful selection of the sample regardless of up-mass.
   i. **Sample collection:** Selection of quality samples is key.
      1. Sample collection and storage priorities may affect surface infrastructure and MTV designs.
      2. Sample collection and storage plans will depend on what the samples will be used for.
      3. Mid-latitude locations may offer access to subsurface ice, which is an ideal target for ice coring. As such, it is recommended that ice coring expertise be represented at the subsequent (AM IX) workshop.
      4. Access to and operation in astrobiologically sensitive areas, including drilling and capturing/sealing ice cores, may initially have to be done robotically and followed up by humans depending on planetary protection protocols that are still being developed.
   ii. **Human research:** human body reactions to extended stays in 1/3 gravity environments
   iii. **Microbial research:** examining microbial samples collected inside the MTV to assess the effects of changes in gravity on microbes.
   iv. **Astrobiology:** including the need to better define and explain how human explorers will accelerate the search for life on Mars
   v. **Botany:** understanding plant growth in 1/3g
   vi. Other ideas (to be determined)

8. The initial Mars mission(s) will begin building infrastructure for subsequent missions. Therefore, it is important to demonstrate infrastructure approaches on the Moon.
9. Early infrastructure and technology demonstration requirements for Mars include:
   a. Power: Power generation is of the highest priority, and we can develop and assess scalability on the Moon that will feed forward to Mars.
   b. Infrastructure (roads, landing/launch pads, etc.): It is assumed that detailed mapping and site characterization will be available. Current understanding is that the landers must be spaced one kilometer apart from one another and other critical infrastructure, such as habitats, in order to avoid sandblasting in the absence of additional infrastructure (e.g., landing pads, protective berms, etc.).
   c. In-situ resource utilization (ISRU) systems will eventually be needed for other than short-stay missions. However, we need to investigate how short-stay missions, in addition to pre-emplacement, could support subsequent ISRU.
   d. Mobility requirements are driven by topography, science investigation sites, and distance from landing and launch pads. Pre-placement of human-class rover should be considered. (This includes performing a cost benefit analysis of whether to send a pressurized or unpressurized rover.)
   e. Habitat/Laboratory design and construction can be demonstrated on the Moon and pre-emplacement on Mars may be an enabling capability.
   f. Waste disposal/recycling systems are necessary to eliminate/repurpose human waste on Mars. This might be demonstrable by comparable systems on the Moon.
   g. Ingress/egress systems and operations: Dust considerations must be included for the Moon and Mars and must factor in the differences between regolith/dust on the Moon vs. that on Mars.
10. Radiation is a concern, more so on the Moon but nevertheless also on Mars. Suits could be augmented with mobile robotic partners, e.g., health monitoring, Environmental Control and Life Support Systems (ECLSS).
    a. Can one type of surface suit (and its derivatives) be developed for both the Moon and Mars?
11. Options for the partnering of robots and humans must be assessed.
    a. Ingenuity helicopter demonstrated a new type of partner to augment current concepts of operations.
12. The Moon allows opportunity to test many in-space/on-surface aggregation, assembly, and fabrication capabilities: Many aggregation approaches demonstrated for the Moon could feed forward to Mars and options for pre-emplacement can be assessed.
    a. Techniques for pre-emplacement and construction can be evaluated on the Moon (e.g., habitat, surface space suits, robotic partners).
13. Reuse capability could be demonstrated on the Moon, which can begin with Commercial Lunar Payload Systems (CLPS) for autonomous operations. Are lessons learned from terrestrial mining industry (e.g., assume everything will break) applicable to the Moon and Mars?
14. Learn lessons from examples of repairs on ISS, especially those that were not anticipated but nevertheless occurred and had to be made immediately.
15. A limiting factor may be the substantial limitations to the volume of Mars Transfer Vehicle.

AREAS OF GENERAL AGREEMENT

1. During initial missions, emphasis must be placed on driving requirements that will keep crews safe while at the same time enabling success in as many mission objectives as possible.
2. Both Moon and Mars remain a NASA priority.
3. There is a deep concern over re-adaptation to gravity and how it will affect an astronaut's performance on the martian surface. There was much agreement that we need to understand the effects more and find ways to mitigate them. As such, there was widespread support for more analog missions utilizing the ISS (see first two bullets in "Important Topics" section that follows).
4. Strong concerns were expressed about crew health and how to mitigate adverse effects:
    a. Spaceflight-Associated Neuro-Ocular Syndrome
    b. Psychological issues
    c. Gravity re-conditioning/re-adaptation: challenges and limits to mitigation in transit
    d. Radiation exposure
    e. Physiological effects of reduced pressure
5. Missions must provide capabilities not only for human survival but also for scientific research.
6. Surface duration drives decisions about infrastructure/capabilities.
7. What exactly is meant by NASA's, and the space community in general, use of the words, "sustainable," "sustained," and "sustainability? You can have one without the others, so which is it?
8. Make or Take: There will be a need for spares (e.g., contingency food and water; parts for suits; tools; etc.), although this must be balanced with the cost of added mass mitigated by inclusion as pre-positioned assets. Evaluation of in-space fabrication is highly desirable.
9. Diversity of lunar activities, some of which cannot be predicted today, will provide experience for Mars.
10. The Moon is a great place to practice Concept of Operations (conops) including contingency management. That is both good science and good systems engineering.
    a. Operational analog studies can be / have been useful for outlining science support for science conops for human Mars missions.
    b. Examples: https://www.liebertpub.com/toc/ast/19/3
    c. Robotic or human drilling of ice or rock cores must be tested on the Moon prior to Mars. Teleoperations of robots from ISS, Gateway, or lunar base camp may simulate such operations from Mars orbit or the Mars Habitat.
    d. Teleoperations on the Moon of robots for potential sample selection is also important to optimize robot design and capabilities.

IMPORTANT TOPICS WHERE MORE WORK, INCLUDING TRADE STUDIES, APPEARS NECESSARY

1. Analog missions are suggested: ones that use astronauts staying in orbit for 200+ days, landing on Earth, and immediately performing tasks (e.g., putting on suit, collecting samples, deploying scientific instrumentation), then returning to ISS for another 200+ days, followed by return to Earth).
    a. Same type of analog missions as above, but with landing on the Moon instead of Earth to perform tasks.
    b. Such missions could establish which humans more easily re-adapt to gravity.
        i. Need larger dataset of variations in gender, race/ethnicity, age
    c. There is a need to establish trades of maintenance time, spares, maintainability of suits vs. need for a suit that will not restrict the astronauts as they decondition.
    d. How much does the human body change after longer-term exposure to microgravity, and will that generate a requirement for suits of different sizes or that can be modified for each astronaut?
    e. Meaningful activities, including science objectives, should be established for astronauts to pursue while traveling to and from Mars.
    f. How do diet and exercise play a role in reasonable re-adaptation to gravity?
    g. In order to establish a good analog, it is necessary to know the volume of the Mars Transfer Vehicle.
2. Analogs on Earth and Moon and using ISS and Gateway to establish procedures for some items and to test others:
    a. Egress and ingress to keep dust out [also for planetary protection (PP)] and to reduce fatigue

    b. Dealing with psychological problems of isolation in a stressful environment: Can be done to varying degrees in Earth orbit (i.e., on the ISS), on the Moon, and on Earth. For example, Earth has a safety net of physicians nearby, whereas the Moon does not and will add in another psychological factor.
    c. Contingency scenarios must be developed for injuries.
        i. Simulated medical emergency
    d. Advancements are needed in communication technology.
        i. Induce time-delay in communications between ground control and crew.
    e. Radiation shielding may be tested on the Moon.
    f. Physiological effects of human body at reduced pressure environments
3. The Moon as a testbed for human activities on Mars:
    a. Concept of Operations
    b. Dress rehearsal of Mars operations
    c. Practice on the Moon to drive down risk at Mars (e.g., fabrication and deployment of pre-emplaced infrastructure)
    d. Study how plant, bacteria, algae, and fungi grow in partial gravity; establish food system (see the LEAG Lunar Exploration Roadmap)
    e. Examine mutations and gene expression
    f. Send Mars Transfer Vehicle to lunar orbit to test
    g. The initial Mars mission(s) will begin building/deploying/testing infrastructure for future missions. Therefore, it is important to demonstrate infrastructure approaches on the Moon.
    h. Power systems can be tested on the Moon: solar, fuel cells, fission
    i. ISRU capabilities (e.g., drill ice cores) can be demonstrated.
    j. Fabrication capabilities can also be demonstrated.
    k. High-bandwidth teleoperation of robotic assets and capabilities of robotic partners in immediate vicinity can be tested/demonstrated.
4. More detailed examination of science goals, objectives, and tasks at each phase of the mission will require focused discussions for each phase (outbound, surface, return).
5. Criteria must be established for balancing science and human exploration goals during the various trajectories/missions (i.e., orbital, short-stay, long-stay).
6. Human-robotic partnerships
    a. When are robots most useful?
    b. Should robots be pre-emplaced if they are of limited value during transit?
    c. A trade must be made between the need for spare parts for critical equipment versus the mass penalties that result from the transport of those spares.
    d. Help with astronauts' re-adaptation to gravity
7. NASA should assess risk to humans to Mars program depending on success, or failure, of lunar program.
8. A Moon+Mars Program office will allow system engineering across programs, similar to the robotic Mars Exploration Program. It will bring elements together that now appear to be disconnected.
9. Autonomous construction capabilities and ground mapping are required before ISRU systems can be designed effectively.
10. Potential locations must be assessed where contaminating payloads could land for initial missions, possibly downgrade from Cat 4 to Cat. 3 on Mars. There is an opportunity for precursor missions to make planetary protection more robust.
11. The potential to aggregate capabilities that address multiple capability needs must be assessed (e.g., maintainable, low g, hard vacuum bulldozer to create landing pads, and which could also be used to create roads, flat areas for construction, berms for radiation shielding, etc.).

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