Anticipating Challenges & Opportunities in Planning Human Mars Missions

ADDRESSING SCIENCE, TECHNOLOGY, PLANETARY PROTECTION & SOCIETAL ISSUES

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OVERVIEW

In recent strategic planning workshops & studies of long-duration human missions to Mars, experts in astrobiology, mission planning, technology and commercial communities have focused on important topics and issues that could adversely impact realization of long-term science exploration goals and human missions during the coming decades. **There is a clear need for pro-active, coordinated, cross-cutting efforts focused on:**

- ***Development of Planetary Protection (PP) policy requirements for Human Missions and filling key knowledge gaps*** that have implications for outbound and return mission phases, as well as science exploration and activities on Mars.
- ***Integrating information from multiple R&TD areas early in mission design to ensure science-supportive infrastructure beyond Earth orbit*** that also enables safe and reliable long-duration human transportation and habitation on the Mars surface (significantly different than human missions in LEO)
- ***Continue updating Science Information about Mars and Adopting advances in IT and robotics that may approach human-level capabilities***, thereby enabling improvements in science exploration, effective planetary protection, and ensured human health and safety during long duration missions.

THE PATH FORWARD

Planning for eventual human missions to Mars will require pro-active coordination across robotic and human spaceflight communities that have not worked together for decades. Except for the lunar missions of the Apollo Program, human space exploration has been done exclusively in Earth orbit for over 40 years, where conditions, activities and infrastructure are decidedly different from Mars.

- Human missions in LEO have been of relatively short duration with reliance on Earth for real-time communication and resupply of all essential materials,
- Equipment, systems and operations designed for orbital living and working conditions are significantly different from those likely needed for missions to distant planetary surfaces,
- In LEO, there has been no need to address planetary protection requirements or concerns about possible ET life

Based on recent scenario-building workshops and studies of future human missions beyond Earth orbit, there is growing recognition of the need to integrate experts across many disciplines—linking the human mission technologists, engineers, and medical experts with the robotic science exploration community and those addressing planetary protection policies and concerns.

NASA Policy Instruction: NPI 8020.7 (2013) outlines an incremental path forward for developing Planetary Protection Requirements for Human Extraterrestrial Missions

Accordingly NASA is facilitating work in key NPI Areas:

- Developing capabilities to comprehensively monitor the microbial communities associated with human systems & evaluate changes over time;
- Developing technologies for minimizing/mitigating contamination release, including but not limited to closed-loop systems; cleaning/re-cleaning capabilities; support systems that minimize contact of humans with the environment of Mars and other solar system destinations; and
- Understanding environmental processes on Mars & other solar system destinations that contribute to transport & sterilization of organisms released by human activity.

Other Considerations

While considerable cross cutting research, planning and coordination have been focused on the path forward for human missions to Mars, there remain several areas that could become problematic for science exploration if not addressed in the coming years. These include:

- ✓ Addressing and **updating Back Contamination Requirements & Preparations–whether for robotic sample return or human missions returning to Earth**. The Draft Protocol for Handling and Testing Returned samples should be updated, and attention focused on quarantine and facility requirements for astronauts returning as well.
- ✓ There will likely be a need to **assess the effects of oversight by other government agencies (e.g. CDC, USDA , etc.) with statutory mandates for controlling 'imports' of biological materials and organisms that may have uncertain risks.** Laws, institutions, and scientific categorization of risks have changed considerably in the decades since Apollo missions.
- ✓ There is currently **no framework or policy for decision making if and when ET life is discovered.** A lack of operating principles at the time of a possible discovery could raise legal or societal challenges about who, besides scientists should be involved in deliberations – raising complications that could challenge future science activities – on Earth as well as Mars.

NASA WORKSHOP (2015)

Workshop Objectives:

- ✓ Capture the State of Knowledge,
- ✓ Identify Key Knowledge Gaps
- ✓ Determine R&TD Needs

25 Knowledge Gaps & R&TD Needs in 3 areas:

- ✓ Many cross-cutting issues involve combinations of info on science, health, Mars environment, and technology & operations.
- ✓ Identified Issues address current COSPAR PP Principles and Guidelines for Human MIssions

Microbial & Health Monitoring

1. What **microbial sampling and collection technology & procedures** should be used?
2. What are **appropriate technologies for microbial monitoring to mitigate risks** to crew, ensure planetary protection & sci. integrity?
3. What **technologies and procedures** should be used **for sample processing** to reduce crew time and mitigate contamination concerns?
4. What **technologies and procedures** should be used **for data collection, storage, and interpretation during missions?**
5. What's needed to **understand spaceflight specific microbial responses & heritable changes** during extended spaceflight to planet **?**
6. What is needed to **monitor microbial populations of astronauts, vehicles and external environments?**
7. Develop **novel approaches** for **low toxicity disinfectants** and for **prevention/recovery from biofilm induced corrosion, fouling**
8. What **diagnostic & treatment options/studies** are needed **to understand crew health & biomedicine** related to microbial & contamination exposures?
9. What information is needed to **develop acceptable/appropriate, ethical & operational guidelines** for human missions to Mars?

Technology & Operations for Mitigating & Controlling Contamination

1. Does duration of surface stay matter to PP objectives of future missions? (What = relationship bet. human exploration time/duration & density and spread of contamination?)
2. What level of non-viable bioburden escape is acceptable? (If non-viability verified, does this address human microbial bioburden concerns? If not-vialbe, does this address concerns about external dissemination of microbes?).
3. Is there a need for using decontamination & verification procedures & protocols after releases? (nominal or otherwise). Are decontamination procedures needed both inside & outside the spacecraft?
4. What considerations should go into the design of quarantine facilities & methods (for use en route to Mars, on Mars ,or returning *from Mars*?)
5. How can contamination concerns be addressed during human missions given that definitions of Special Regions may vary in space& time (e.g. over diurnal & seasonal cycles)?
6. What research is needed to address gaps in questions about ISRU, Habitation and Testing –& in advance of planning/design of technologies, systems and operations?
7. What is 'acceptable containment' of wastes intentionally left behind (type, location, duration)? Also, what are acceptable constraints and procedures on vented materials?
8. What microbial contaminants would vent from an EVA systems/suit? what concentrations? What are implications for suit materials, cleaning tools, collection technology & procedures on Mars

Natural Transport of Contaminants

1. How do interactions of biocidal factors affect microbial survival, growth & evolution in Mars-type environments; What is the potential for survivability and replication of very hardy microbes (in dust environments? across Mars? In biofilms?)
2. What data or models needed to determine what happens to windblown dust, & where it might go. Also need understand meteorological conditions throughout several years at particular site(s)
3. What is the probability of transporting hardy terrestrial microbes to Mars via different pathways on a human mission?
4. What will leak and/or vent out of pressurized containers or human facilities? (Leak rate, size, biological diversity, organic molecules, cells, etc. vented during nominal operations?) After significant degradation (of materials)? During off-nominal situations? Differences between active venting vs. leaking?)
5. How will we study yet-uncultivable microorganisms? (methods? tools? etc.) What proportion of the entire community do they represent? How can we assess/monitor their viability?
6. Understand & establish acceptable contamination generation rates/thresholds for *human landing sites*—(consider sites as point sources of contamination (of microbes or organic particles); Model the minimum Aeolian contamination spread over distances, times and particular rates and conditions)
7. Understand & establish acceptable contamination generation rates/thresholds for *mobile-crewed systems* (pressurized vehicle or suited crew); study as point sources of contamination (of microbes & organic particles), and model minimum contamination spread (over time & distance)
8. Understand & establish acceptable contamination generation rates/thresholds for human landing sites in context of *subsurface contamination and ISRU of local water/ice*

Full Workshop Report http://hdl.handle.net/2060/20160012793

COSPAR WORKSHOP (2016)

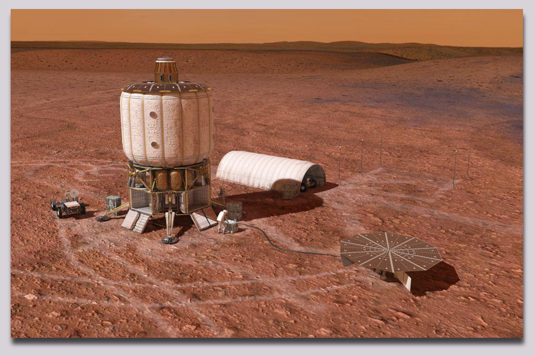
Workshop Objectives:

- ✓ **Review Identified Gaps**
- ✓ **List R&TD Needs *in Priority Order***
- ✓ **Assess Where/How R&TD can be done** (ISS, Earth,, Moon, Asteroids, Mars)

Workshop Report *Anticipated Mid 2017.*

AM IV (2016)

Achieving & Sustaining Human Exploration of Mars
The Fourth Community Workshop (AM IV)



65 Participants December 2016 – Monrovia CA

Continuing a series of community workshops --involving NASA, the science community, planetary protection, academia, consulting organizations, the National Academies, and potential international partners

Workshops Focus upon:

- ✓ Long-stay surface missions, key technologies/capabilities & characteristics.
- ✓ Develop plans(s) or options to make missions achievable by focusing on 'Long Poles"
- ✓ Assess Milestones, investment strategy, time requirements & and priorities for
  - Mars System Reconnaissance
  - Aggregation/Refueling/Resupply
  - Transit Habitation and Laboratory
  - Entry, Descent, and Landing
  - Surface Habitation and Laboratory
  - Surface Power
  - Mars Ascent Vehicle
  - Human Health/Biomedicine
  - Sustainability

Workshops III & IV also began considering how Planetary Protection requirements, related science and technology needs etc. will be integrated into the ongoing assessments of relevant 'long poles'

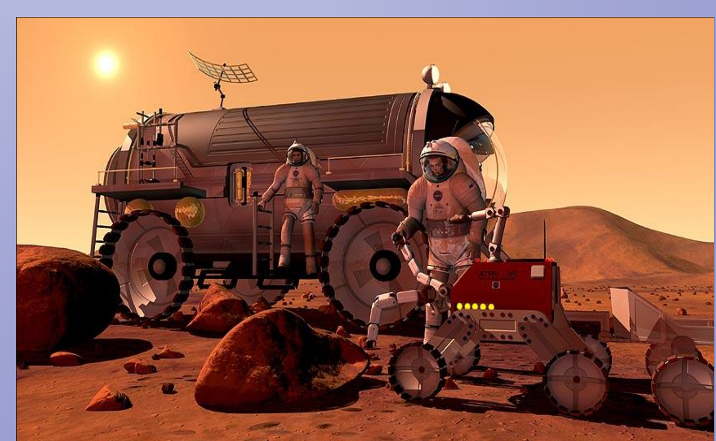
Workshop & Study Conclusions to Date:

- Human Mars surface mission could be accomplished by early to mid-2030s with sufficient funding (*Engineering & technology are not limiting factors)* .
- Human orbital missions are feasible by late 2020's & can inform later missions
- EDL systems are the major long pole for surface missions
- Robotic reconnaissance over the next 2 decades is essential for preparing for human missions, and also a source of priority science
- Need to study logistics support, supply nodes, refueling & aggregation needs in more detail to enable sustained human missions.
- There are significant interdependencies among the various habitation modules -- transit & surface– suggesting a priority need to assess the value of modularity
- Surface power looks very promising with the advent of small nuclear fission reactors.
- Lunar missions & operations not likely to add value to initial human missions to Mars.

AM IV Workshop Report ~Mid-March 2017 http://www.exploremars.org/

CONCLUSIONS

- **Stay the course --**
- Continue the incremental path forward as outlined in NPI 8020.7. Addressing the list of cross-cutting R&TD gaps will not only help develop effective Planetary Protection Requirements for Human Extraterrestrial Missions, in the long term it will enable more capable and effective science exploration on Mars and beyond, for robotic and human explorers alike.



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