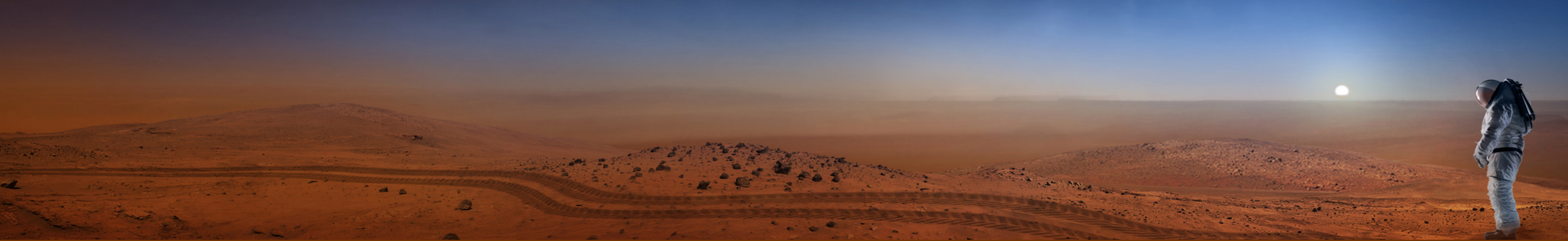


PLANETARY PROTECTION CONSIDERATIONS IN THE SELECTION OF LANDING SITES FOR HUMAN MARS MISSIONS

J. D. Rummel (SETI Inst), C. A. Conley (NASA HQ),

G. Kminek (ESA) and J. A. Spry (SETI Inst)

First Landing Site/Exploration Zone Workshop for Human Missions to the Surface of Mars

Oct 27th-30th, 2015

Overview

- Planetary Protection Overview
- Human Exploration Planetary Protection Paradigm
- Knowledge Gaps Workshop
- Paths Forward
- Summary

COSPAR Planetary Protection Policy: *Protect Science, Protect the Earth*

- "The conduct of scientific investigations of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized."
  - *avoid forward contamination: don't "discover" life we brought with us*
- "In addition, the Earth must be protected from the potential hazard posed by extraterrestrial matter carried by a spacecraft returning from another planet or other extraterrestrial sources."
  - *avoid backward contamination: don't contaminate the Earth*
- "Therefore, for certain space-mission/target-planet combinations, controls on organic and biological contamination carried by spacecraft shall be imposed in accordance with directives implementing this policy."
  - *tailor requirements by target location and mission type: don't require unnecessary measures*

What is Planetary Protection?

H.G. Wells
1898

And scattered about...
were the Martians–dead!
–slain by the putrefactive
and disease bacteria against
which their systems were unprepared; slain as the red weed was
being slain; slain, after all man's devices
had failed, by the humblest things that God,
in his wisdom, has put upon this earth.

...By virtue of this natural selection of our kind
we have developed resisting power; to no
germs do we succumb without a struggle...

International Agreements on Planetary Contamination/Protection

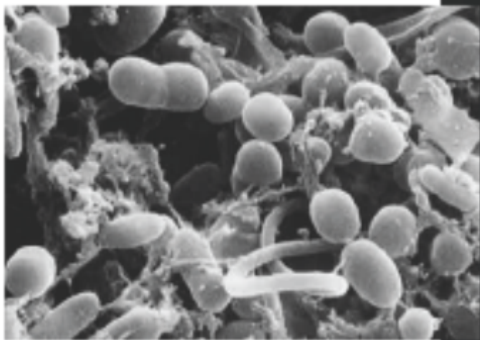
- The Outer Space Treaty of 1967:
  - Proposed to the UN in 1966
  - Signed by the US, UK and Soviet Union in January 1967
  - Ratified by the US Senate on April 25th, 1967
- Article IX:

  "...parties to the Treaty shall pursue studies of outer space including the Moon and other celestial bodies, and conduct exploration of them so as to avoid their harmful contamination and also adverse changes in the environment of the Earth resulting from the introduction of extraterrestrial matter and, where necessary, shall adopt appropriate measures for this purpose..."

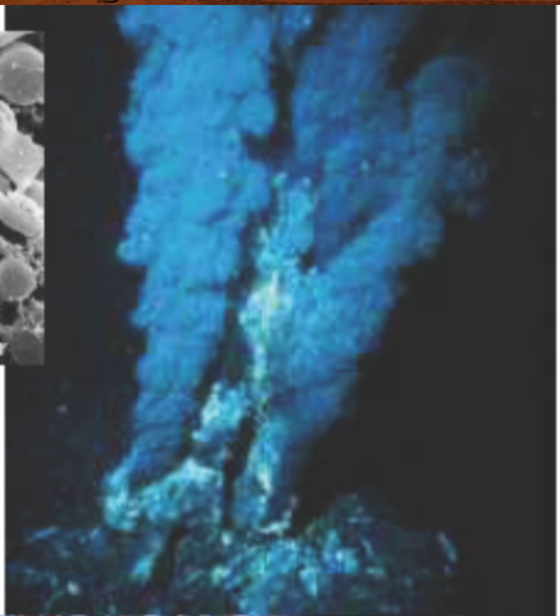
  "Treaty on Principles Governing the Activities of States in the Exploration and Use of Outer Space, Including the Moon and Other Celestial Bodies."
  (http://www.state.gov/t/ac/trt/5181.htm)

- COSPAR maintains an international consensus planetary protection policy under the Treaty

Surprising Life on Earth



Bacteria, maybe, but...



Nobody thought worms could live at the bottom of the ocean!

The Knowledge Dilemma

- Before *Deinococcus radiodurans,* we thought we knew how much radiation organisms could tolerate
- Before *Desulforudis audaxviator* (and their nematode predators), we thought we knew where organisms could live
- Organisms making do in 58 Million year old subsea sediments seem to wait around for a rather long time....

What is the actual range (and duration) of conditions under which Earth Life can grow? Can tolerate? Can survive?

Given that we know we keep learning more about life on Earth, how do we ensure that other planets are protected?

How do we compensate for what we don't know about life?
How do we compensate for what Mars is showing us?

Robotic Lander Missions to Mars

- Planetary Protection Category IV for Mars landers is subdivided into the three variants IVa, IVb, and IVc:

- Lander systems not carrying instruments for the investigations of extant martian life or entering special regions (Cat. IVa) are restricted to a biological burden no greater than 300 spores per square meter of surface area and 3x10^5 on exposed surfaces – e.g. MERs
- Lander systems searching for life (Cat. IVb) must reduce the IVa limits by 4 orders of magnitude, or to a level set by the life detection instruments, at least at subsystem level – e.g. ExoMars 2018
- Lander systems entering special regions (Cat. IVc) must reduce the IVa limits by 4 orders of magnitude; can be at subsystem level only if not landing in the special region.

Bioburden Occurrence - Robotic

Parameter	MSL Requirement	MSL Actual
S/C Total Spores	<500,000	278,000
Landed Hardware	<300,000	56,400
Impacting Hardware	Total minus landed	221,600
Spore Density (/ sqm)	300	22
Dry Mass (kg)		~900

Bioburden Occurrence - Crewed

Parameter	MSL Requirement	MSL Actual	Apollo 9 LM Ascent Stage	
S/C Total Spores	<500,000	278,000	ca.23,350,000	
Landed Hardware	<300,000	56,400		
Impacting Hardware	Total minus landed	221,600		
Spore Density (/ sqm)	300	22	775-11621	ca. x35
Dry Mass (kg)		~900	~2150	ca. x2.4

Sending crew (bioreactors) and their hardware to Mars "breaks" the robotic exploration PP paradigm – what then?

2005 NASA Life Support and Habitation and PP Workshop Findings

1 Planetary protection and science constraints may have a significant impact on mission architecture, technology trade options, operations and development costs.

2 Planetary protection and science requirements require definition early in the development cycle.
- Definition of "contaminants" is required.
- Establish forward and back contamination limits.
- Define waste containment and disposal requirements.
- Establish Earth return ops and quarantine requirements.

3 Define material inventory and characteristics, process products, and release mechanisms.

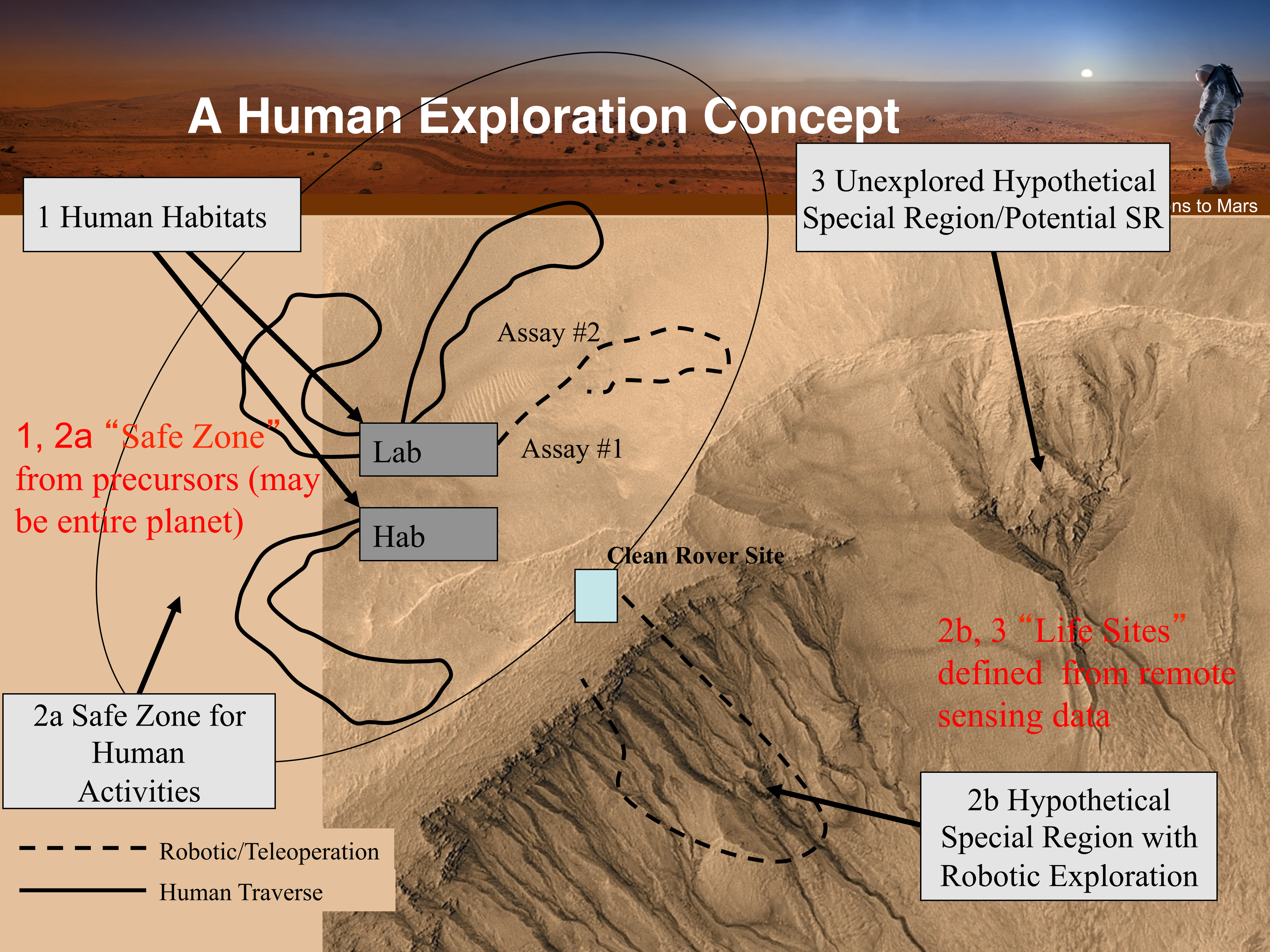
4 Establish detection standards, response times and back contamination identification methods.

5 Currently not possible to provide quantitative planetary protection guidelines.

6 Current proposed approach: Do not affect or otherwise contaminate "Special Regions" of Mars (via cleaning, prudent landing site selection).

7 Lunar operations should serve as a test-bed for Mars missions with respect to planetary protection and science operations.
- Testing can occur without penalty.
- Avoid developing two distinct and expensive technology pathways.

Hogan, J.A. *et al.* (2006) NASA Technical Memorandum NASA/TM-2006-213485 Life Support and Habitation and Planetary Protection Workshop Final Report


A Human Exploration Concept
1 Human Habitats
3 Unexplored Hypothetical Special Region/Potential SR
Assay #2
Assay #1
Lab
Hab
1, 2a "Safe Zone" from precursors (may be entire planet)
Clean Rover Site
2b, 3 "Life Sites" defined from remote sensing data
2a Safe Zone for Human Activities
2b Hypothetical Special Region with Robotic Exploration
Robotic/Teleoperation
Human Traverse

Human Exploration PP Principles

From COSPAR Policy*:

“The intent of this planetary protection policy is the same whether a mission to Mars is conducted robotically or with human explorers. Accordingly, planetary protection goals should not be relaxed to accommodate a human mission to Mars. Rather, they become even more directly relevant to such missions—even if specific implementation requirements must differ.”

General principles include:

- *Safeguarding the Earth from potential back contamination is the highest planetary protection priority in Mars exploration.*
- *The greater capability of human explorers can contribute to the astrobiological exploration of Mars only if human-associated contamination is controlled and understood.*
- *For a landed mission conducting surface operations, it will not be possible for all human associated processes and mission operations to be conducted within entirely closed systems.*
- *Crewmembers exploring Mars, or their support systems, will inevitably be exposed to martian materials.*

* Developed following joint ESA-NASA Workshop; Kminek, G., Rummel, J., & Race, M. (2007). Planetary Protections and Human System Research & Technology. In ESA-NASA Workshop Report, ESA WPP-276, ESTEC, Noordwijk, The Netherlands.

Human Exploration PP Guidelines

Specific implementation guidelines for human missions to Mars include:

- Human missions will carry microbial populations that will vary in both kind and quantity, and it will not be practicable to specify all aspects of an allowable microbial population or potential contaminants at launch. Once any baseline conditions for launch are established and met, continued monitoring and evaluation of microbes carried by human missions will be required to address both forward and backward contamination concerns.
- A quarantine capability for both the entire crew and for individual crewmembers shall be provided during and after the mission, in case potential contact with a martian life-form occurs.
- An onboard crewmember should be given primary responsibility for the implementation of planetary protection provisions affecting the crew during the mission.

Human Exploration PP Guidelines

Specific implementation guidelines for human missions to Mars include:

- A comprehensive planetary protection protocol for human missions should be developed that encompasses both forward and backward contamination concerns, and addresses the combined human and robotic aspects of the mission, including subsurface exploration, sample handling, and the return of the samples and crew to Earth.
- Neither robotic systems nor human activities should contaminate "Special Regions" on Mars, as defined by this COSPAR policy.
- Any uncharacterized martian site should be evaluated by robotic precursors prior to crew access. Information may be obtained by either precursor robotic missions or a robotic component on a human mission (see also the US NRC recommendations given in the 2002 Safe on Mars report: http://www.nap.edu/books/0309084261/html/)

Human Exploration PP Guidelines

Specific implementation guidelines for human missions to Mars include:

- Any pristine samples or sampling components from any uncharacterized sites or Special Regions on Mars should be treated according to current planetary protection category V, restricted Earth return, with the proper handling and testing protocols.
- Planetary protection requirements for initial human missions should be based on a conservative approach consistent with a lack of knowledge of martian environments and possible life, as well as the performance of human support systems in those environments.
- Planetary protection requirements for later missions should not be relaxed without scientific review, justification, and consensus.

NPI 8020.7 for Human Missions

NPI for NASA Policy on Planetary Protection Requirements for Human Extraterrestrial Missions

NPI describes the intention on the part of NASA to facilitate:

a) Developing capabilities to comprehensively monitor the microbial communities associated with human systems and evaluate changes over time;

b) 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;

c) Understanding environmental processes on Mars and other solar system destinations that would contribute to transport and sterilization of organisms released by human activity.

Provided the starting point for the March 2015 "Workshop on Planetary Protection Knowledge Gaps for Human Extraterrestrial Missions" and feed-forward to a future NPR

WORKSHOP

Planetary Protection Knowledge Gaps for
Human Extraterrestrial Missions

- Held at ARC March 24-26, 2015
- Interdisciplinary group of engineering, programmatic, planetary protection and microbial ecology specialists
- 2½ days of plenary "get everyone up to speed" sessions
- Final ½ day in 3 breakout sessions
- Report pending…

Knowledge Gap Areas

1st EZ Workshop for Human Missions to Mars

Study Area 1 GAPS: Microbial & Human Health Monitoring	Study Area 2 GAPS: Technology & Operations for Contamination Control	Study Area 3 GAPS: Natural Transport of contamination on Mars
1.1 ID Sampling collection technology & procedures	2.1. Does the Duration of human surface stay (30 days v. 500 day) matter? Does it change objective of PP during mission? What is the relationship between human exploration time and the density and spread of contamination?	3.1. Understand the current level of knowledge of microbes in dust environments; What is the potential of a very hardy microbe to survive across Mars? Biofilms?
1.2. ID technol for microbial monitoring to mitigate risks to crew, PP & science integrity	2.2. What level of non-viable bioburden escape is acceptable? (if non-viability can be demonstrated, does this significantly address human microbial bioburden concerns? does it address concerns about external dissemination of microbes?)	3.2. Data or Models to determine what happens to windblown dust, where it might go; understanding meteorological conditions throughout several years at particular site(s)
1.3. ID sampling processing tech. and procedures (automated?)	2.3. What microbial contaminants would vent from a EVA suit? & what concentrations?	3.3. What is the probability of transporting hardyterrestrial microbes to Mars from a human mission?
1.4. Organize Data Collection, storage & Interpretation for on-site use	2. 4. What is acceptable containment of wastes intentionally left behind? Constraints on what is acceptable to vent? (assume yes). Duration? (e.g., its not just how well you contain something, but for how long you need to guarantee containment).	3.4. What is leaking &/or venting out of pressurized containers/human facilities (rate, size, biological diversity, organic molecules, cells etc) during nominal operations , after significant degradation and off nominal situations? What are differences between active designed venting vs. leaking?
1.5. Understand spaceflight specific microbial responses & heritable changes	2.5. do the supplemental science requirements (beyond PP concern of viable microbes) exceed constraints on what is acceptable to vent? (assume yes)	3.6.Need Quantitative data on interactions of biocidal factors on microbial survival, growth and evolution-- or combinations of these factors. How does microbial association with biofilms effect biocidal effectiveness (habitability)?
1.6. Understand astronaut, vehicle, and external envmt. microbial populations to be monitored	2.6. does local environment acceptably kill off escaped viable bioburden in vented gaseous products? And at what rate/probability of survival.	3.5. How to study uncultured microorganism? Do they represent the entire community? How assess /monitor viability?
1.7. Protect vehicle systems from microbial induced corrosion, system fouling.	2.7. Is there a need for a decontamination & verification procedure after releases (nominal or otherwise)? And is one needed for inside the spacecaft and outside?	3.7. Study human landing site as point contaminant (of microbes and organic particles), then determine the minimum contamination that matters and allows for spread (distance and time)

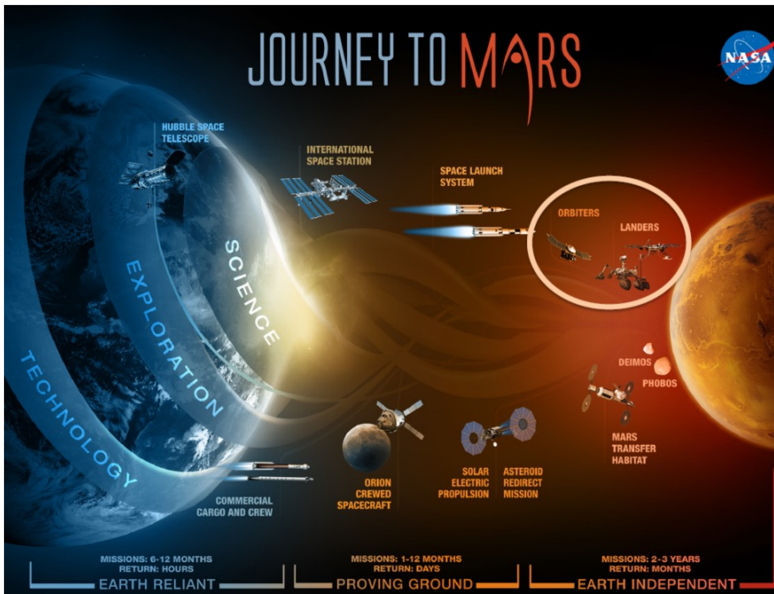
KEY

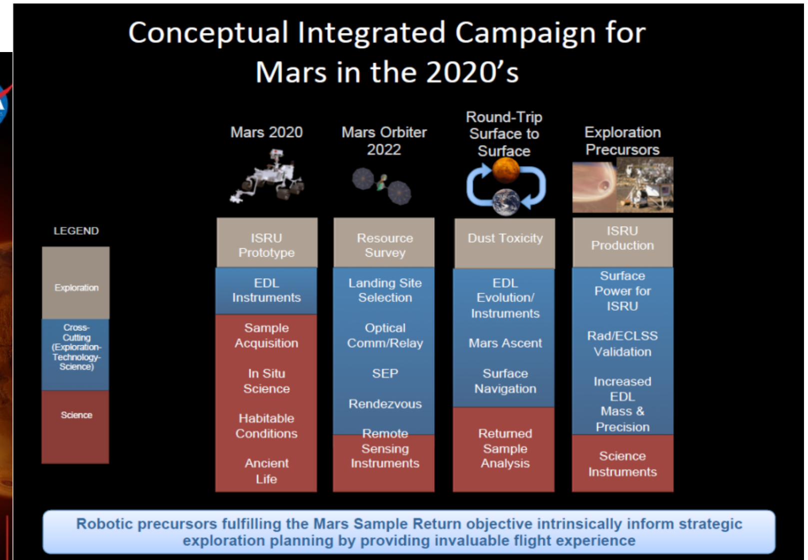
Microbial Capability at Mars, inc. Survey & Monitoring

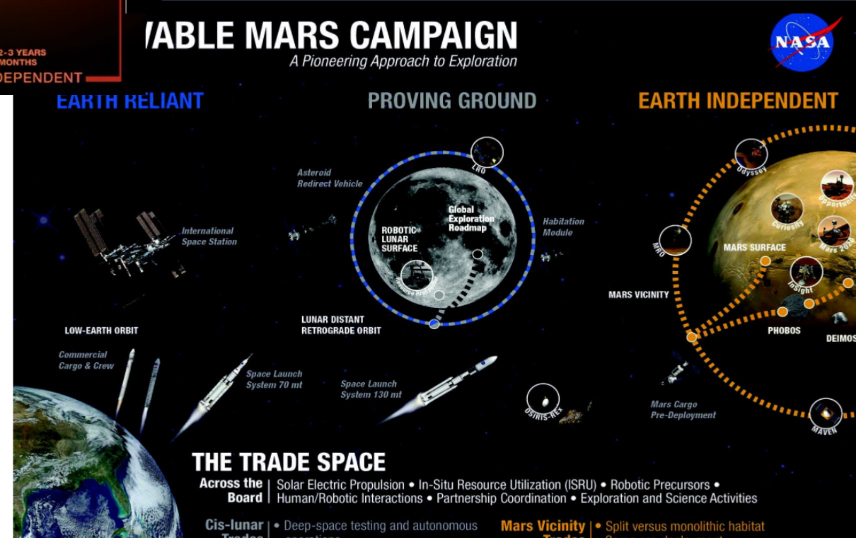
Mission Technology & Ops

Dispersal-Transport

Path Foward







The knowledge gaps address the extent and nature of the viable organisms carried by missions that can be tolerated in the martian environment

Key Message

If we are ever going to answer humanity's fundamental questions as described in the "*NASA's Journey to Mars: Pioneering Next Steps in Space Exploration*":

> *"Was Mars home to microbial life? Is it today?*
>
> *Could it be a safe home for humans one day?*
>
> *What can it teach us about life elsewhere in the cosmos or how life began on Earth?*
>
> *What can it teach us about Earth's past, present, and future?"*

… then we had better protect our ability to answer those questions.

Planetary protection is a required part of 'The Journey'

Summary

Planetary protection issues need to be resolved for human exploration missions to Mars

Guidelines are in place, but new data is required to inform what should be the specific/numeric planetary protection requirements

NPI for Human Extraterrestrial Missions is a guide for NASA mission planning going forward, on a path to producing an NPR

- Look out for the Workshop report when its published

Early integration of planetary protection considerations/ requirements into mission planning is essential for crew safety and mission success