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Prior Planetary Protection Reports

and

Mars Architecture

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Member of NASEM PP Studies in 2018 and 2020

Presentation to the NASEM
Committee on Planetary Protection
March 24, 2021

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Today's Talk – What is it about?

From NASEM – Nagasawa

"We are inviting you as a speaker to discuss prior planetary protection reports and Mars architecture.

- We encourage you to put your remarks in the context of the CoPP's newest statement of task as you much as you feel comfortable doing so. The CoPP's Statement of Task (is in) Appendix B."

From Appendix B

The Committee on Planetary Protection (CoPP) shall write a report that identifies criteria for determining locations or regions on Mars that are potentially suitable for missions of less restrictive bioburden than the current requirements for Category IV.

Additional Task – J. Alexander, D. Nagasawa

Please also include the various Special Region reports and Workshops

I have approached this task as the inverse of my usual astrobiology and Mars Program efforts to look for the "fingerprints of life"

Framing the Issues

- A future Mars Exploration Program (MEP) must deal with three major constituencies that are directly impacted by Planetary Protection Policy:
  - Science with new investigations, instruments and technologies
    - The Mars Architecture Strategy Working Group has recommended a Program of small science investigations, including landers
  - Commercial/entrepreneurial providers
    - SpaceX is clearly planning to send the Starship to Mars
  - Human spaceflight to the surface of Mars (which might be commercial)
    - HEOMD has announced a new preferred approach for Humans to Mars in the 2030's

- This talk will suggest tools, techniques, knowledge and methods that may help identify "exploration zones", commercial landing sites or other places where bioburden constraints may be reduced
  - I will not address the scientific issues raised by instruments that may be aboard a lander that does not meet Category IV

Prior Studies of Planetary Protection

2018 National Academies Policy Development Process

Review the history of planetary protection policy development, assess the current policy development process, recommend changes and improvements to deal with future issues and needs.

2019 NASA Planetary Protection Independent Review Board Report

Develop U.S. policies that properly balance the legitimate needs for planetary protection with the scientific, social, and economic benefits of public and private space missions.

2020 National Academies Comparison Report

Assess the consistency between the findings and recommendations in the 2018 SSB report (*Review and Assessment of Planetary Protection Policy Development Processes*) and those in the 2019 NASA Planetary Protection Independent Review Board report.

Assessment of the Report of NASA's PPIRB

Building the Scientific and Technical Foundations of Planetary Protection Policies for Human Missions to Mars

Recommendation: NASA should make the development and execution of a strategy to guide the adoption of planetary protection policy for human missions to Mars a priority, including:

1. A process to identify the most promising concepts for achieving planetary protection objective in the context of human missions, such as high-priority astrobiological zones and human exploration zones;

2. Establishment of an adequately funded program of research and development to answer questions and address challenges raised by the most promising concepts…for integrating planetary protection measures in human missions; and

3. A plan to develop planetary protection policy for human missions to Mars on a timeline that permits the integration of such research and development into mission planning and implementation at the earliest possible stages.

Mars Issues

PPIRB Major Recommendation: NASA should reconsider how much of the Martian surface and subsurface could be Category II versus IV by revisiting assumptions and performing new analysis of transport, survival and amplification in order to reassess the risk of survival and propagation of terrestrial biota on Mars (37)

NASEM 2020 Response: Categorization of Mars missions as either III, IV, or restricted sample return V (see Appendix E) is grounded in scientific data collected over the past 50 years, but particularly in the last 20 years of the "follow the water" Mars Exploration Program.

Now, however, Mars is an attractive object for not only scientific exploration but also commercial space ventures and human exploration. The 2018 report noted that commercial interests want to minimize uncertainty and expense and that human exploration faces particular planetary protection challenges.

That report did not recommend moving some missions (e.g., Mars landers) to Category II, but it did recommend that "NASA's process for developing a human Mars exploration policy should include examination of alternative planetary protection scenarios and should have access to the necessary research that informs these alternatives."

First Human Mars Mission Concept Overview

WHO

Current analysis includes 4 crew

Some could potentially remain in Mars orbit while others explore surface

WHAT

- Mars Transit
- Landing and Surface Exploration
- Mars Ascent and Earth Return

WHERE

- Cislunar, Deep Space and Mars orbit
- Mars Surface

WHEN

- As early as 2030s
- Crew away from Earth ~2 years
- ~30 sols on Mars

WHY

Science, Exploration, and U.S. leadership

HOW

1. *Pre-Deployed Cargo Phase*
2. *Crewed Surface Exploration Phase*

JACOB BLEACHER, NASA HQ
MICHELLE RUCKER, NASA JSC
January 27, 2021
MEPAG VM 11

Key Take-Away: First mission emphasis is a relatively short (~30 sol) surface stay for a ~2 year round-trip first mission, with pre-deployed cargo but minimal infrastructure build-up, leveraging systems developed for lunar exploration.

JACOB BLEACHER, NASA HQ
MICHELLE RUCKER, NASA JSC

January 27, 2021
MEPAG VM 11

Space X Goals

INITIAL MARS MISSION GOALS

2022: CARGO MISSIONS

Land at least 2 cargo ships on Mars

Confirm water resources and identify hazards

Place power, mining and life support infrastructure for future flights

2024: CARGO & CREW MISSIONS

2 crew ships take first people to Mars

2 cargo ships bring more equipment and supplies

Set up propellant production plant

Build up base to prepare for expansion

Issues of Concern in re-categorizing Mars Missions from IV to II

- Cat II: Any mission to locations of significant interest for chemical evolution and the origin of life, (*e.g.,* Moon, Venus, comets) but only a remote chance that spacecraft-borne contamination could compromise investigations. Requires simple documentation only, primarily to outline intended or potential impact targets, and an end of mission report of any inadvertent impact site if such occurred
  - Environments of the target objects are extreme (very cold, or very hot and/or airless)

Criteria for Mars might include (per Appendix B):

- Temperatures at the landing site and locations of mission activities are below -25C, or water activity is less than 0.5 (Note: water activity = water vapor pressure of a solution/vapor pressure of pure water),
- Proposed landing and/or mission activity sites do not contain geomorphological characteristics of flowing water, such as recurring slope lineae, etc (see Special Regions report)
- Mission activities will go no deeper than a certain distance below the surface,
- Landed spacecraft are not capable of melting the regolith, and

I would add one more:

- Activities at the landing site would avoid placing viable contaminants into Mars atmosphere

(Don't) Follow the Water (1/2)

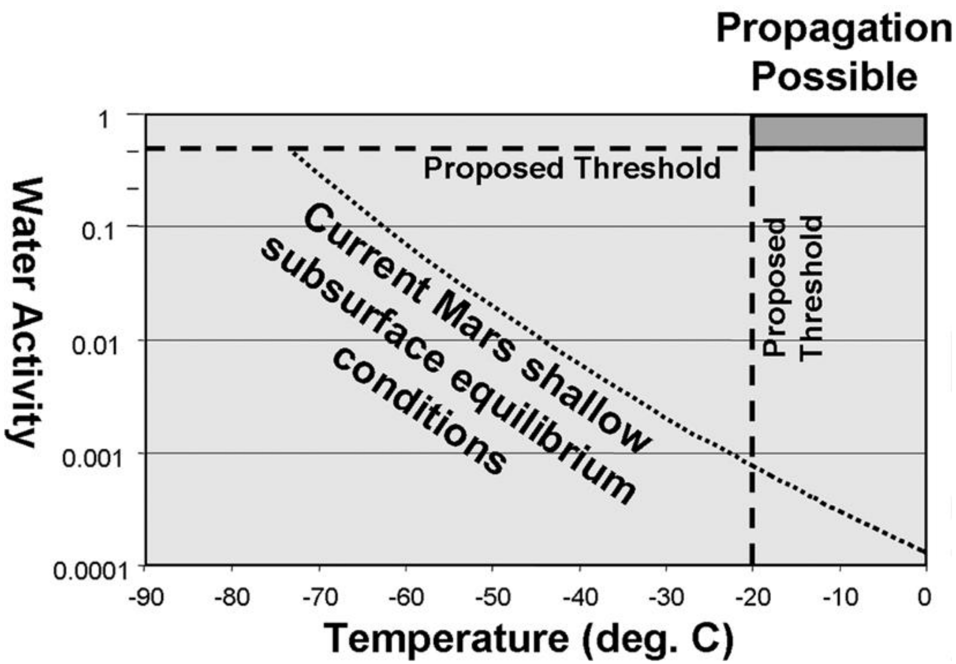


Fig. 8, Beaty et al., 2006, MEPAG Special Regions
Also: NASEM Review of the MEPAG Report on Special Regions (2015)

- *Two relevant concepts: 1) chemical activity of any water present at a locality, and 2) total inventory of water present.
- Conditions are too severe everywhere on the surface of Mars to enable life to 'propagate,' namely to become metabolically active, repair itself, and replicate.
- Attached diagram from an earlier Special Regions report summarizes the situation.
  - Near the equator where temperatures might be favorable, water is so tightly bound that its chemical activity is too low to be chemically useful for life.
  - In polar ice, water activity is much higher but it exists as solid ice at temperature that are way too low to enable life to propagate.
  - Conditions could become more favorable if temperatures could be raised sufficiently either to melt polar ice or to heat chemically bound water to free it from hydrated minerals.

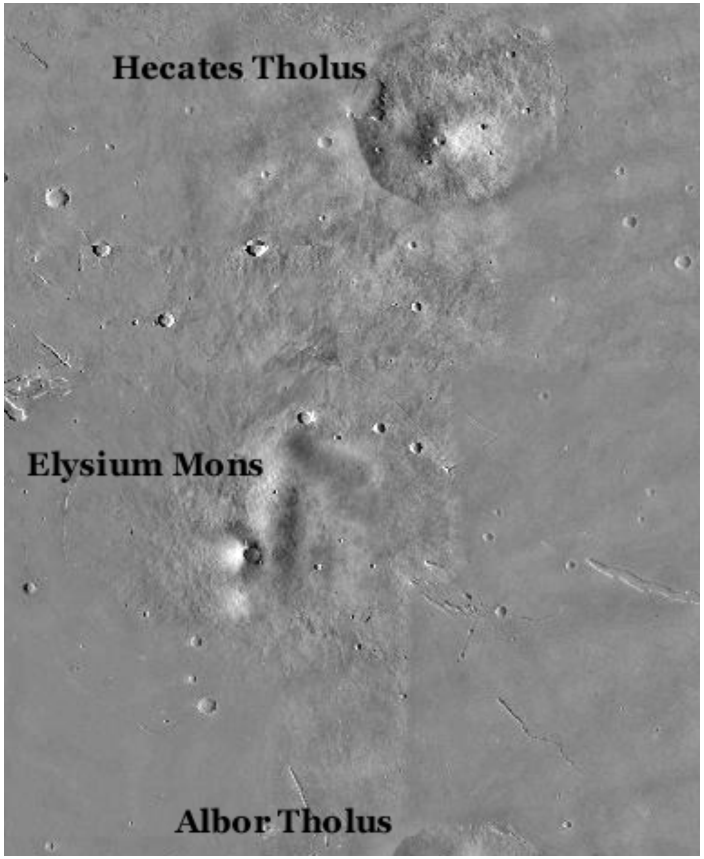
*Personal communication from Dave Desmarais

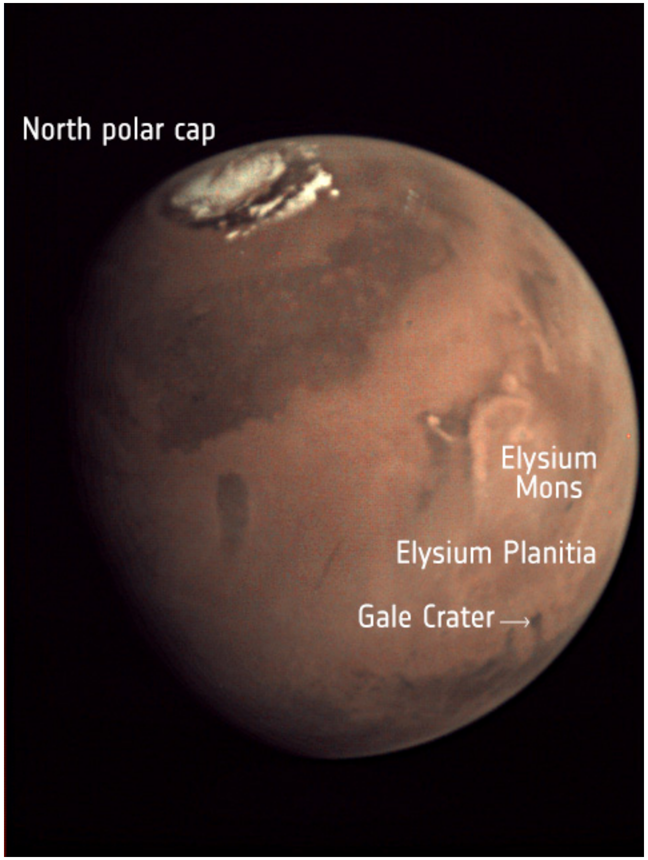
(Don't) Follow the Water (2/2)

- Where is the safe landing place re: water activity
  - To avoid sites where conditions might be habitable, identify regions where H_2O abundances are too low to increase with heating.
- Possibly use GRS and HiRISE/CRISM data to locate the water-poor areas. However, the Curiosity rover found abundant clay minerals at localities where CRISM did not identify the presence of hydrated minerals.
  - It is now generally accepted that surface mineralogy is often hidden beneath the very shallow depth (a few wavelengths of near-IR radiation) at which CRISM can detect water or hydrated minerals.
- Accordingly, probably the most assuredly water poor areas to visit would be basaltic lava flows.
  - The outgassing of basalts erupting on the Martian surface is very efficient, so the basaltic plains that formed are probably the most assuredly water-poor regions on the Martian surface today.

Example: Water Poor Area on Mars

- **Elysium Planitia** ***(a volcanic region on Mars)***
  - *Landing site for Insight*





Report of the Joint Workshop on Induced Special Regions

- The Joint Workshop on Induced Special Regions convened scientists and planetary protection experts to assess the potential of inducing special regions through lander or rover activity. An Induced Special Region is defined as a place where the presence of the spacecraft could induce water activity and temperature to be sufficiently high and persist for long enough to plausibly harbor life.
- The questions the workshop participants addressed were:
- (1) What is a safe stand-off distance, or formula to derive a safe distance, to a purported special region?
- (2) Questions about RTGs (Radioisotope Thermoelectric Generator), other heat sources, and their ability to induce special regions.
- (3) Is it possible to have an infected area on Mars that does not contaminate the rest of Mars?

Life Sciences in Space Research
Volume 23, November 2019, Pages 50-59

Report of the Joint Workshop on Induced Special Regions

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- The workshop participants reached a consensus addressing the posed questions, in summary:
- (1) While a spacecraft on the surface of Mars may not be able to explore a special region during the prime mission, the safe stand-off distance would decrease with time because the sterilizing environment, that is the Martian surface would progressively clean the exposed surfaces. However, the analysis supporting such an exploration should ensure that the risk to exposing interior portions of the spacecraft (i.e., essentially unsterilized) to the Martian surface is minimized.
- (2) An RTG at the surface of Mars would not create a Special Region but the short-term result depends on kinetics of melting, freezing, deliquescence, and desiccation. While a buried RTG could induce a Special Region, it would not pose a long-term contamination threat to Mars, with the possible exception of a migrating RTG in an icy deposit.
- (3) Induced Special Regions can allow microbial replication to occur (by definition), but such replication at the surface is unlikely to globally contaminate Mars. An induced subsurface Special Region would be isolated and microbial transport away from subsurface site is highly improbable.

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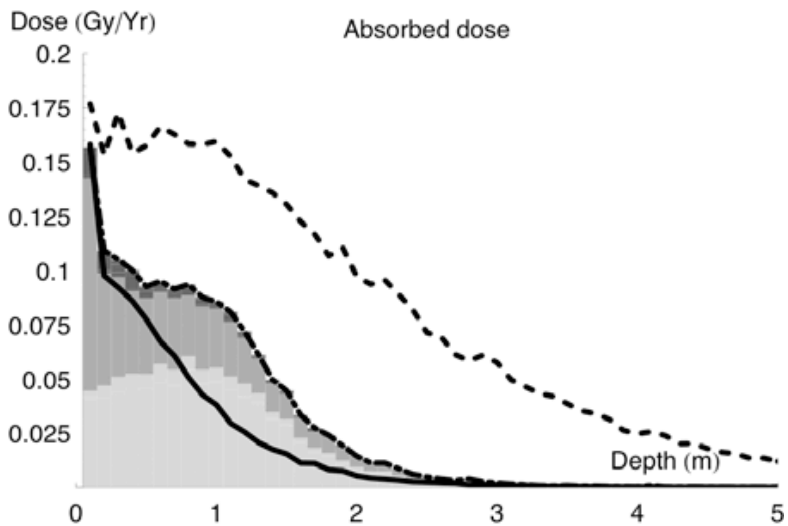
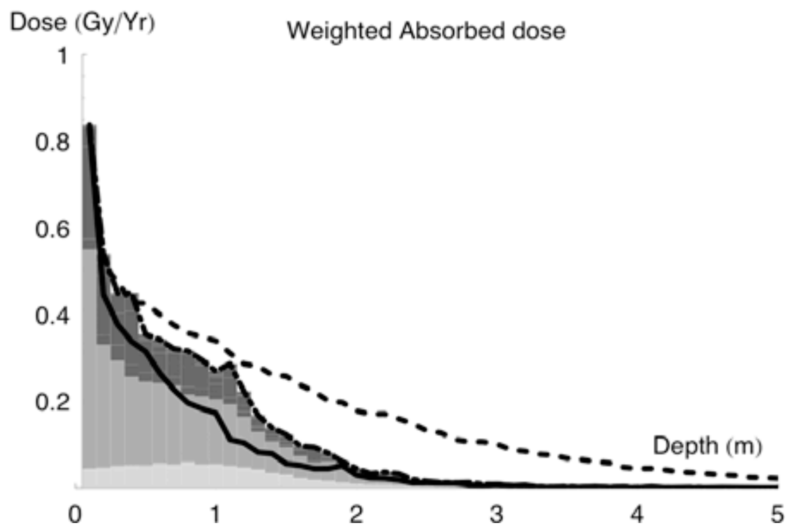
Cosmic-Ray and Solar Proton Radiation and Microbial Survival





- **With a peak biologically-weighted dose rate of 0.85 Gy/year at no point is the ionizing radiation environment on or beneath the Martian surface immediately lethal to even radiosensitive terrestrial bacteria.**
- **Over geological time-scales, though, even the most radioresistant populations are inactivated.**
- **For the prospects of finding viable Martian microbes then, cells must either have been brought to the surface only recently, by outflow of deeper meltwater or exposure by impact excavation, for example, or else be able to periodically revive to repair radiation damage and reproduce,**

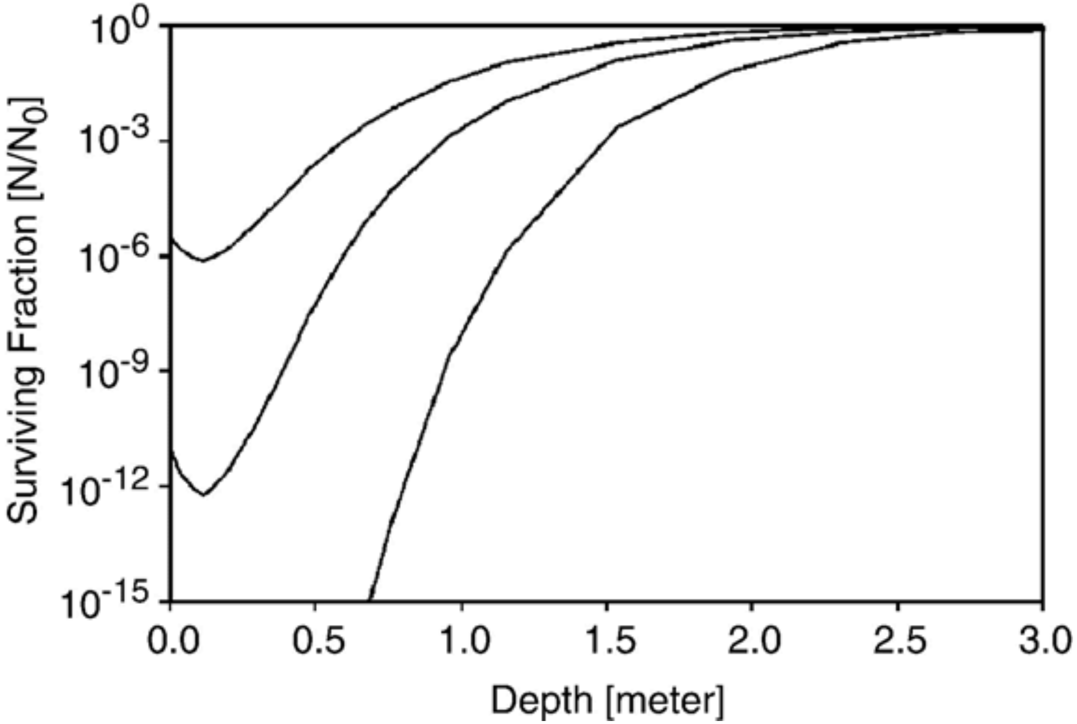
Modelling the surface and subsurface Martian radiation environment: Implications for astrobiology

L. R. Dartnell,1 L. Desorgher,2 J. M. Ward,3 and A. J. Coates4

GEOPHYSICAL RESEARCH LETTERS, VOL. 34, L02207, DOI:10.1029/2006GL027494, 2007

The effect of ionizing radiation on the preservation of amino acids on Mars*

- Ionizing radiation from space affects the long-term preservation of amino acids associated with extinct Martian life or meteorites. This is particularly severe in the first meter of the Martian subsurface.
- However, below a shielding depth from space radiation of 400–500 g/cm2, amino acids will not be degraded substantially.
- These results show clearly the need to access the Martian subsurface in the range of meters in the search for biomarkers of extinct Martian life.

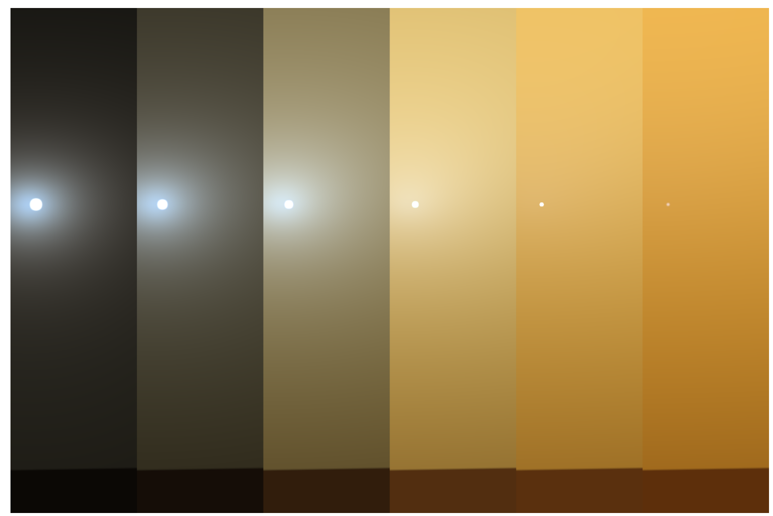


*Gerhard Kminek ⁎, Jeffrey L. Bada
Earth and Planetary Science Letters 245 (2006) 1–5

Contamination and Mars winds

- The distance that dust travels from its source region depends strongly on the type (and location) of dust storm
- Martian atmosphere is generally efficient at mixing trace gases, very small particles, etc.
- Majority of dust particles raised by local storms likely fall near their source region on fairly short timescales (hours to days)
- Larger storms can certainly spread dust far and wide rapidly due to strong positive radiative/dynamic feedbacks.

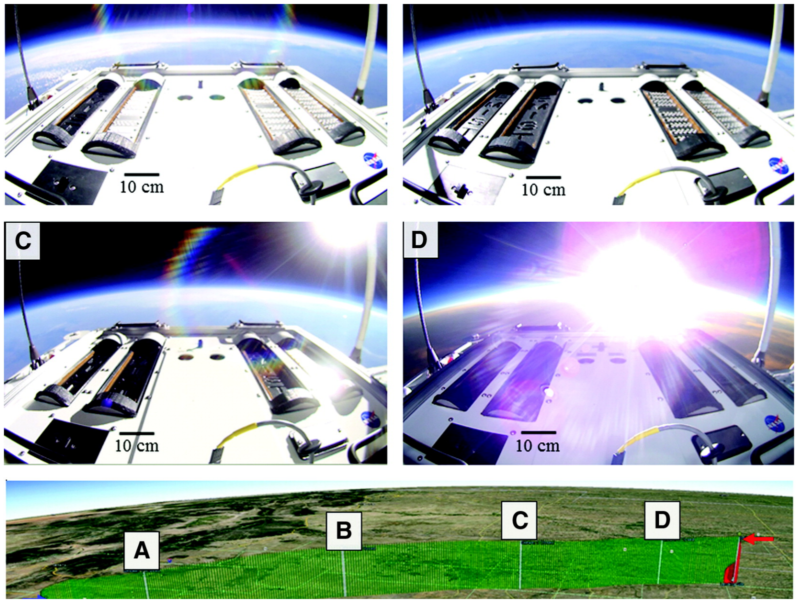
Melinda Khare* NASA Ames



Global dust storm ~once per decade

*Kahre, M., Murphy, J., Newman, C., Wilson, R., Cantor, B., Lemmon, M., & Wolff, M. (2017). The Mars Dust Cycle. In R. Haberle, R. Clancy, F. Forget, M. Smith, & R. Zurek (Eds.), The Atmosphere and Climate of Mars (Cambridge Planetary Science, pp. 295-337). Cambridge: Cambridge University Press. doi:10.1017/9781139060172.010

Mars Contamination and Aerobiology – UV exposure*



- >99.9% inactivation for Sun-illuminated bacterial spores exposed to Mars-like conditions in the stratosphere for 8 h.
- Our starting concentration of viable spores was substantially higher than contamination levels typical for Mars-bound spacecraft
- Used one of the most radiation-resistant bacterial strains known to be in clean rooms;
- B. pumilus SAFR-032 spores were rapidly killed by sunlight in the stratosphere.

- "Based on our experimental observations, it seems unlikely that a fully exposed, sunlit bioburden sent to Mars could perpetually withstand the effects of UV radiation at the Red Planet's surface".

*Stratosphere Conditions Inactivate Bacterial Endospores from a Mars Spacecraft Assembly Facility
Christina L. Khodada, et al
https://www.liebertpub.com/doi/10.1089/ast.2016.1549

Mars Airborne Contamination and Aerobiology

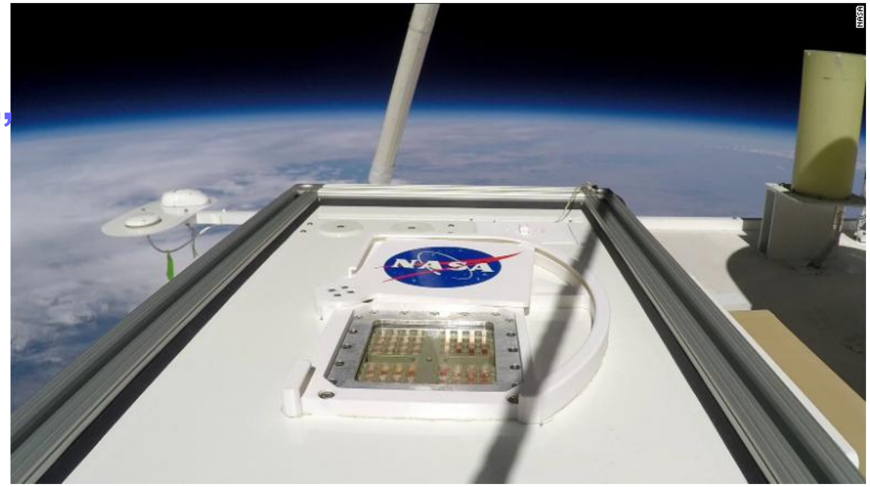
A Martian experiment in our sky: Earth microbes could temporarily survive on Mars, study says: CNN Tue February 23, 2021*

- **The surviving species included Staphylococcus capitis and Salinisphaera shabanensis. The first is a bacteria associated with human skin and the second is a bacteria that can be found in deep-sea brine pools.**
- **Aspergillus niger, a fungus that is used in the production of antibiotics, was dried to send it on the experiment, and it was also able to be revived once it returned from Earth's stratosphere.**

"If a microbe can hack it up there, above much of the protective ozone layer, it just might be able to survive -- however briefly -- on a journey to the surface of Mars," said study coauthor David J. Smith, MARSBOx co-principal investigator and researcher at NASA's Ames Research Center, in a statement.

"The question you're asking strikes at the heart of what we do in the Aerobiology Lab." David J. Smith, Ph.D. (On loan to NASA HQs)

- **Program Officer for PDART, ISFM, HEC**
- **Deputy Program Scientist for Europa Clipper**



- Balloon research was funded by PPR (https://www.cnn.com/2021/02/23/world/marsbox-balloon-microbes-scn-trnd/index.html
- Front. Microbiol., 22 February 2021 | https://doi.org/10.3389/fmicb.2021.601713

Summary Science and Technical

- Some future Mars explorers (especially human, commercial) question Category IV Planetary Protection constraints
  - Is it possible, they ask, to extract resources in one region while "looking for life in another"
- A reduction in Category IV guidelines might be met on Mars, especially for the initial human/commercial landing by the following:
  - Designate an extremely water-poor landing site such as that for InSight
    - Elysium Planitia is one example
  - Limit any subsurface exploration to << 2 meters
  - Avoid Special Regions (Induced Special Regions do not appear to be an issue)
  - Winds on Mars are very effective at mixing small particles worldwide
  - Examine the findings of the NASA Ames Aerobiology Lab that some viable organisms might survive albeit briefly
    - Evaluate whether those species be carried by Mars winds
    - A mitigation may be to avoid landing in a dust storm season and allow the surface UV to "sterilize" the spacecraft.
- Future work will be required to evaluate the engineering and spacecraft and instrument design issues

Suggestion: Programmatic

Risk probability	Risk severity: Catastrophic A	Hazardous B	Major C	Minor D	Negligible E
Frequent 5	5A	5B	5C	5D	5E
Occasional 4	4A	4B	4C	4D	4E
Remote 3	3A	3B	3C	3D	3E
Improbable 2	2A	2B	2C	2D	2E
Extremely improbable 1	1A	1B	1C	1D	1E

- **Mars exploration is about to enter a new phase with more participants landing at more sites.**
- **For Planetary Protection, ongoing risk management is crucial and a multi-Agency responsibility (NASA and FAA)**
- **I suggest the OPP maintain a standard risk management matrix for all missions and**
- **Be certain this is shared with the FAA Office of Commercial Space Transportation**