Mars Atmospheric Dust As An Inadvertent Carrier of Potential Mars Microorganisms Back to Earth On the Return Human Mission

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Science and Planetary Protection in Advance of Human Missions
October 30-November 1, 2024

Outline of Talk

1. On Earth, atmospheric dust particles (e.g., desert-wind-blown dust) can transport Earth microorganisms.

2. The atmospheric dust can transport the microorganisms through the atmosphere for thousands of miles and the microorganisms are still living and viable when they fall back to Earth.

3. Mars is a planet with a dusty surface and atmosphere with wind-blown surface dust a regular feature of the atmosphere of Mars.

4. NASA Engineering and Safety Center (NESC) Workshop on Dust in the Atmosphere of Mars and Its Impact on Human Exploration, Lunar and Planetary Institute (LPI), Houston, Texas, June 13-15, 2017.

5. Can potential Mars microorganisms survive a 6-7 month trip through interplanetary space from Mars to Earth?

The United Nations Outer Space Treaty, 1967

The international consensus goals for planetary protection in the United Nations Outer Space Treaty (to which all spacefaring nations are signatories) are expressed as:

The conduct of scientific investigation of possible extraterrestrial life forms, precursors, and remnants must not be jeopardized. 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.

United Nations, 1967. Outer Space Treaty, Article IX, U. N. Document A/RES/2222 (XXI), 25 Jan. 1967; TIAS, No. 6347.

Human Missions to Mars: Planetary Protection-Some Definitions

Forward Contamination: The inadvertent transfer of Earth microorganisms to Mars that could potentially perturb possible indigenous life on Mars.

Backward Contamination: The inadvertent transfer of potential Mars microorganisms back to the Earth by the returning spacecraft, equipment, instrumentation or the astronauts themselves (e.g., The "Andromeda Strain" scenario).

Robotic missions to Mars "solved" the forward contamination of Mars issue by rigorous sterilization of the spacecraft prior to launch and obviously, did not have to consider the backward contamination issue.

Human missions to Mars must consider both forward contamination and backward contamination for the first time!

NASA/TM–2018-220084
NESC-RP-17-01263

The Dust in the Atmosphere of Mars and Its Impact on the Human Exploration of Mars: A NESC Workshop

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August 2018

NESC Mars Dust Report

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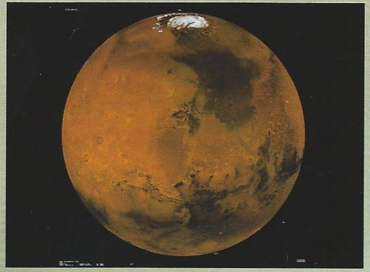
Dust in the Atmosphere of Mars and its Impact on Human Exploration



Edited by

Joel S. Levine, Daniel Winterhalter and Russell L. Kerschmann

NESC Mars Dust Report: Findings

7.1 Findings

F-1. There is insufficient knowledge on the possibility of extant life on Mars. It is especially important to know if there are microbes present in the globally circulating dust for the purposes of planetary protection for a returned human mission. It is inevitable that this material will interact with humans and systems on Mars and some will be returned to Earth by the return mission. ***(Panel 1)***

F-2. There is insufficient knowledge about the lethality of the Martian physical and chemical environment to terrestrial microbes. This information is critical for understanding the potential for forward contamination of Mars. ***(Panel 1, Panel 2)***

F-3. There is insufficient knowledge on the transport of potential viable organisms and its transport on atmospheric dust particles. ***(Panel 1, Panel 2)***

F-4. There is insufficient knowledge about how dust is lifted off the surface and how it moves through the lowest boundary layer of the atmosphere. This includes material mobilized by human activities. It will affect how far potentially contaminated material can spread from areas of human activities. ***(Panel 1, Panel 2)***

NESC Mars Dust Report: Highest Recommendations

7.3 NESC Recommendations

The following recommendations are priority ordered with: Very High.

R-1. (priority: VERY HIGH) The question of life in the atmospheric dust on Mars can and should be addressed via Mars Sample Return. Because the atmospheric dust is globally mixed, the return and analysis of a single dust sample would be sufficient for this purpose. Life detection measurements (e.g., the lab on a chip, etc.) should also be included on a future Mars rover to search for extant life in near-surface materials that would be disturbed by human activities causing potential contamination. ***(F-1; O-1)***

R-2. (priority: VERY HIGH) It is recommended that future Mars missions should include instrumentation to obtain missing toxicologically relevant in-situ measurements, preferably at multiple locations, and especially for respirable dust <10 microns for both regolith-based and wind-borne dust. ***(F-7, F-8)***

R-3. (priority: VERY HIGH) Mars sample return materials should be examined to provide information on the missing toxicology (R-2), either by direct studies on the native material or indirectly through use of returned samples to validate authentic simulants. ***(F-7; O-8)***

R-4. (priority: VERY HIGH) Measure the size distribution and flux of the dust particles on the Martian surface in the ambient air, continuously for an extended period of time (multiple seasons), preferably on multiple platforms. A wide size range should be measured, from millimeter size downwards. Particularly important is the size range of 5nm–10μm. ***(F-4, F-18; O-4, O-17)***

R-5. (priority: VERY HIGH) Laboratory experiments should be performed under simulated Mars conditions to better constrain how long terrestrial microbes can survive and remain viable under these conditions. ***(F-2, F-3, F-4; O-2, O-3, O-4)***

Lifting of Mars Dust During Dust Storms Based on Viking Orbiter Photographs in 1977

Mass of atmospheric dust lofted into atmosphere associated with localized dust storm near Solis Planum: 13 million metric tons.

Mass of atmospheric dust lofted into atmosphere associated with regional dust storm: 430 million metric tons.

Reference: Martin, T. Z. (1995): Mass of Dust in the Atmosphere of Mars. J. Geophys. Res. Planets, 100, 7509-7512. DOI: 10.1029/95JE00414.

Dust in the Atmosphere of Mars Based on TES Measurements

Global annual amount of dust transported into the atmosphere: 400 million metric tons.

Atmospheric dust settling on the surface of Mars: A surface layer 50-100 micrometers.

Reference: Lopez-Cayuela, M. A., M.-P. Zorzano, J. L. Guerro-Rascado and C. Cordoba-Jabonero, 2024: Icarus, 409,DOI: 10.1016/j.icarus.2023.115854.

Atmospheric Dust Shielding of Incoming Solar Radiation

$F = F_{top}e^{-tau}$

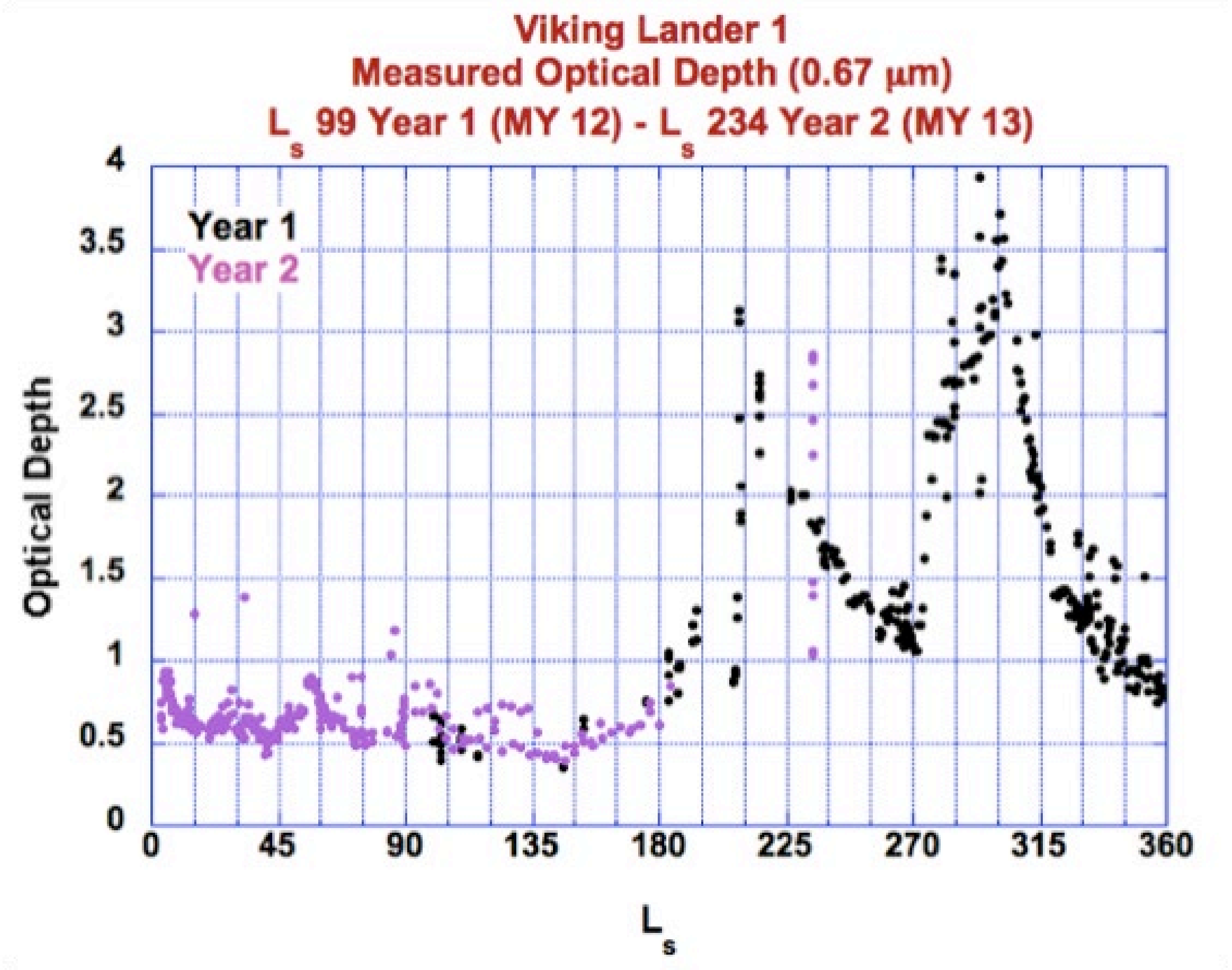
F= UV flux at any altitude, z

F_{top} = UV flux at top of atmosphere

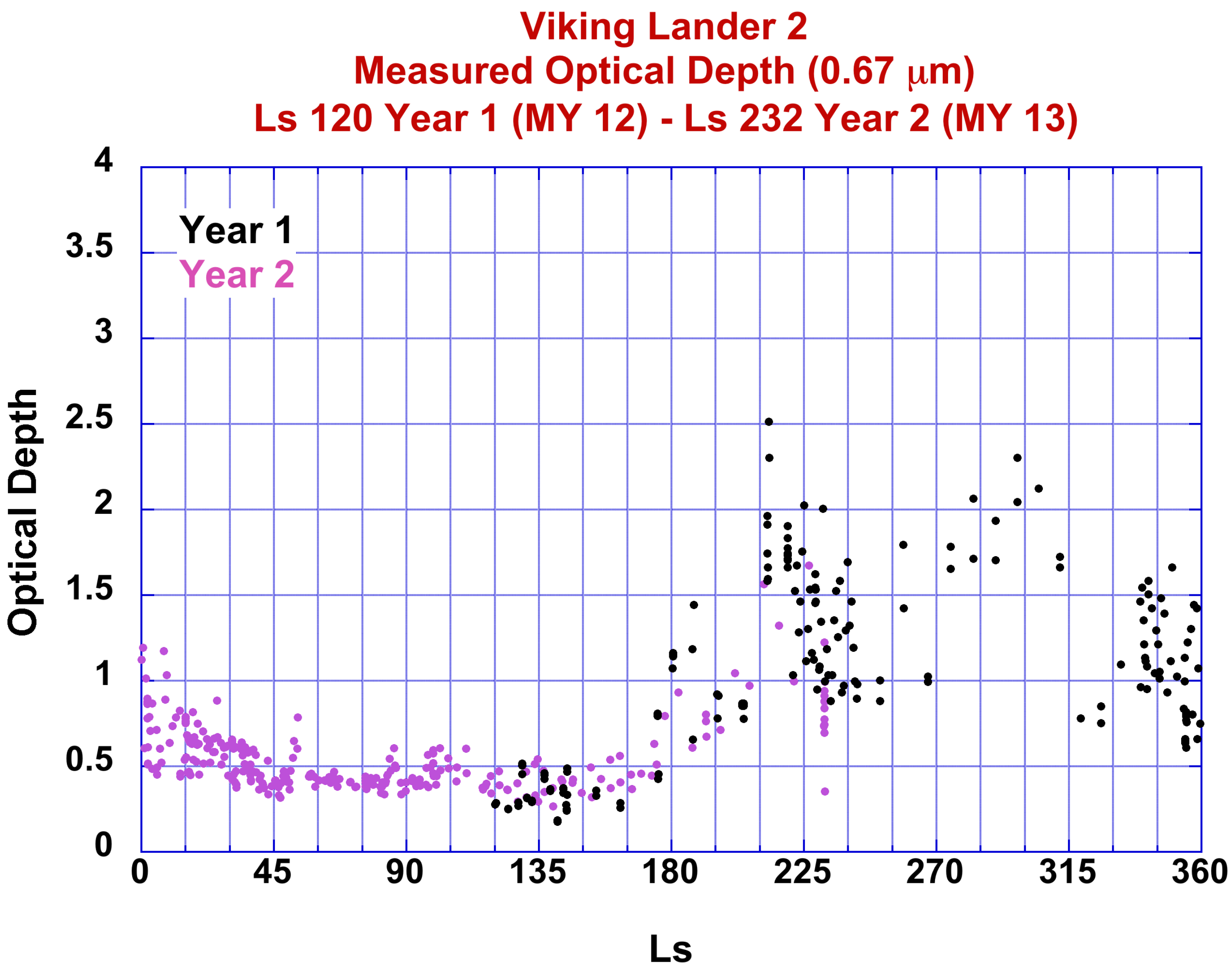
tau = Atmospheric dust optical depth, a measure of the concentration of atmospheric dust above altitude, z

tau	F
0.5	0.693
1.0.	0.367
2.0	0.135
3.0	0.049
4.0	0.018

Viking Lander 1 Measured Optical Depth (Tau): Years 1 and 2



Viking Lander 2 Measured Optical Depth (Tau): Years 1 and 2




Tau Values
Opportunity
Spirit
Tau
6
5
4
3
2
1
0
1236
1238
1240
1242
1244
1246
1248
1250
1252
1254
1256
1258
1260
1262
1264
1266
1268
1270
1272
1274
Sol (Spirit, Opportunity +20)
Data from Mark Lemmon - MER Science team - http://www.lpl.arizona.edu/~lemmon/mer_dd.html

Microbial Transport by Atmospheric Dust on Earth

On Earth, microbial cells transported by atmospheric dust can travel thousands of miles and retain their viability.

The typical airborne dust particle on Mars in “clear” skies

(tau = 0.5) is in the size range of 1-2 microns. During a regional or global dust storm, the particle size reaches 8 microns.

On Earth, the typical size of a Bacillus Subtilis spore is 1.07 microns x 0.48 micron.

During a typical regional or global dust storm, the UV flux can decrease by 95% helping to protect the microbial cell and keeping it viable.

Microbial Transport by Atmospheric Dust on Earth: Selected References

Aquilera, A. et al., 2018: Microbial Ecology in the Atmosphere: The Last Extreme Environment. DOI: 10.5772/intechopen.81650. https://www.intechopen.com/chapters/64400.

Maki, T. et al., 2019: Aeolian Dispersal of Bacteria Associated With Desert Dust and Anthropogenic Particles Over Continental and Ocean Surfaces. Journal of Geophysical Research: Atmosphere, 124, 101, pp.5579-5588.

Smets, W. et al., 2016: Airborne Bacteria in the Atmosphere: Presence, Purpose, and Potential. Atmospheric Environment, 139, pp.214-221.

Ulrich, R., 2021: Bacteria in the Wind. Nature Reviews Earth and Environment, 2, p. 823.

The Dual Roles of Atmospheric Dust in the Transport of Microorganisms: Transport and Shielding

1. Wind-blown atmospheric dust is a vehicle

for the transport of microorganisms through the atmosphere.

2. In addition, wind-blown atmospheric dust shields the microorganisms from biologically-lethal solar ultraviolet radiation.

Experiments on the Survival of Microbes in Low Earth Orbit (LEO)

1. The NASA Long Duration Exposure Facility (LDEF): April 6, 1984 to January 12, 1990-69 months in LEO.

2. The Japanesse Exposure Facility on the International Space Station (ISS)-Japanese Experiment Module (JEM) in LEO.

NASA Langley Research Center Long Duration Exposure Facility (LDEF): 69 Months in Orbit

Launched: April 6, 1984

Recovery: January 12, 1990

2076 days in orbit

Distance travelled: 1,374,052,506 km (853,796,644 miles)

Orbits completed: 32,422

Perigee altitude: 473.0 km (293.9 miles)

Apogee altitude: 483.0 km (300.1 miles)

Orbital period: 94.2 miles

Website:
crgis.ndc.nasa.gov/historic/Long_Duration_Exposure_Facility_(LDEF)

Conclusions from the LDEF Microbial Experiment
"Long-term Survival of Bacteria in in Space"

The NASA Long Duration Exposure Facility (LDEF) "Long-term Survival of Bacteria in Space" experiment conducted by G. Horneck, H. Bucker and G. Reitz (1994) spent nearly 6 years in orbit and was probably the longest running microbe experiment to-date.

Spores of Bacillus subtilis monolayers (10^6/sample) or multilayers (10^6/sample) were exposed to the space environment for nearly 6 years.

The experimenters found up to 80% of the spores in multilayers survived in space if shielded from solar ultraviolet radiation. They found that exposure to solar ultraviolet radiation reduced survival by 4 orders of magnitude or more.

The experimenters concluded that their experiment added to the discussion of the likelihood of panspermia.

Reference: Horneck, G. H. Bucker and G. Reitz (1994): *Advances in Space Research*, Vol.14, No. 10, pp. 41-45 DOI: 10.1016/0231177(94)90448-0

Conclusions from the Microbe Survival Experiments Using the Exposure Facility on the International Space Station-Japanese Experiment Module (JEM) (Kawaguchi et al., (2013)

Microbial Cell-Aggregates as a Form for Interplanetary Transfer of Microbes

Our results suggest that the aggregated cells of D. radiodurans, D. aerius and D. aetherius are highly resistant to environments of LEO. We would like to emphasize the possible importance of microbial cell-aggregates as an ark for interplanetary transfer of microbes. We call this concept 'massapanspermia' ('Massa' stands for mass in Latin).

Reference: Kawaguchi et al., (2013). The Possible Interplanetary Transfer of Microbes: Assessing the Viability of Deinococcus spp. Under the ISS Environmental Conditions for Performing Exposure Experiments of Microbes in the Tanpopo Mission. *Origins of Life and Evolution of Biospheres*. 43, 411–428. https://doi.org/10.1007/s11084-013-9346-1

Future Research

Conduct research on the survivability of microbes both on the Moon and on the journey to the Moon under the Artemis Program since the majority of existing experiments have been conducted in Low Earth Orbit.

Using a Mars sample return mission, obtain samples to Mars atmospheric dust to better understand the chemical properties and characteristics of these potential carriers of potential Mars microbes to Earth.