Health threat from cosmic radiation during manned missions to Mars

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Introduction

Data Collection Instruments

Radiation Assessment Detector (RAD)

RAD is on board the Mars Scientific Laboratory (MSL) spacecraft.

Martian Radiation Experiment (MARIE)

MARIE is on board the Mars Odyssey satellite.

High Energy Radiation - Galactic Cosmic Rays (GCRs)

- Chronic source of high energy radiation.
- GCR flux made up of highly charged nuclei (HZE).
- Modulated by solar wind’s magnetic field.

High Energy Radiation - Solar Energetic Particles (SEPs)

- Fluctuate drastically in response to strength, duration and location of solar energetic particle events.
- Solar energetic particle events occur at random intervals.

Benchmark Transfer Orbit

Hohmann Transfer Orbit

An elliptical orbit used to transfer between the two circular planet orbits using the lowest possible amount of propellant.

Kepler’s 3rd Law

The Hohmann orbit semi-major axis is 1.262 AU, so total mission time is 978 days (259 days of travel each way, 460 days on Mars).

Synchronized Alignment of Planets

Launch and landing must happen within a specific window of time.

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Radiation hazards on space missions

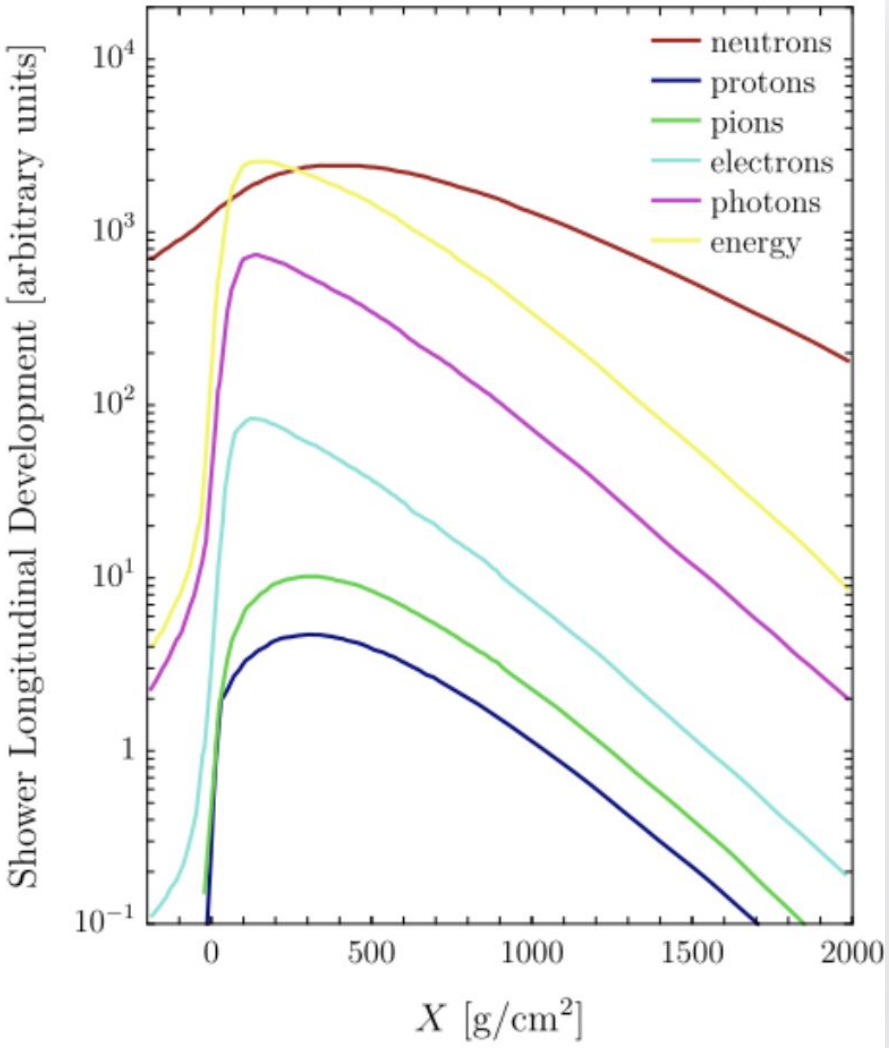
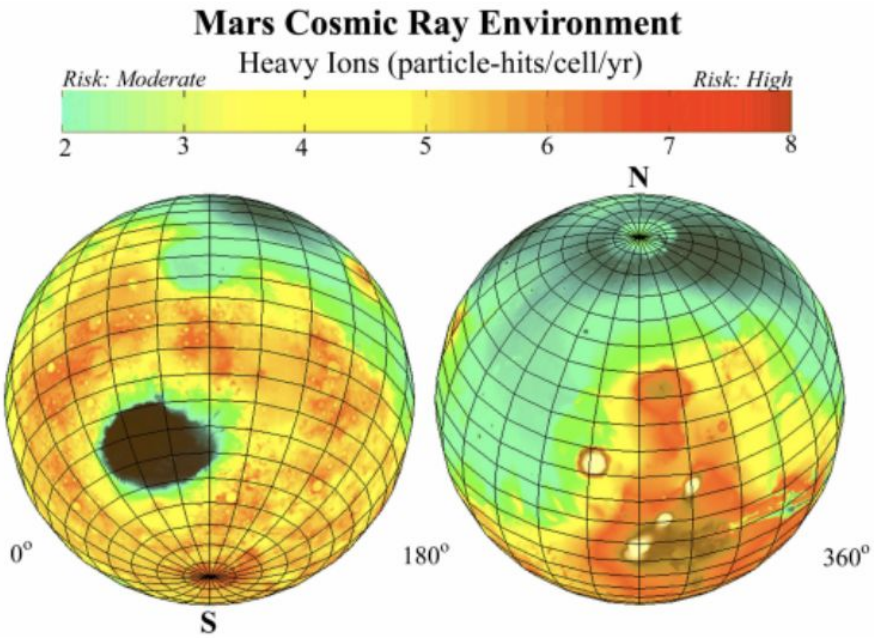
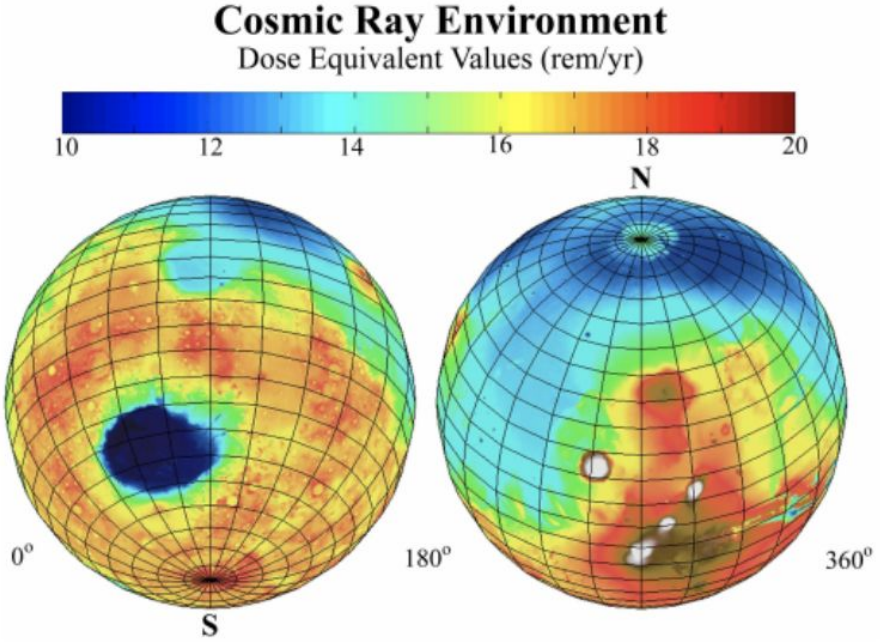


Figure 1: Longitudinal development of a 100 GeV proton shower on lead as a function of depth X.

Estimated Radiation Dose from GCRs





The absorbed radiation dose during a round trip to Mars for a Hohmann transfer would be between **906 mSv - 1, 554 mSv**, whereas the absorbed radiation dose during the stay on Mars would be between **97 mSv - 115 mSv**.

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Astronaut career radiation dose limits and prospects for space exploration

Evolution of Radiation Dose Limits

Table 1: Comparison of effective dose limits over 10 yr period. The last row corresponds to never-smokers.

Sex	Female				Male			
Age (yr)	25	35	45	55	25	35	45	55
NCRP 1989	1.00 Sv	1.75 Sv	2.50 Sv	3.00 Sv	1.50 Sv	2.50 Sv	3.25 Sv	4.00 Sv
NCRP 2000	0.40 Sv	0.52 Sv	0.75 Sv	1.35 Sv	0.75 Sv	1.00 Sv	1.48 Sv	2.98 Sv
NSCR 2012	–	0.48 Sv	0.51 Sv	0.59 Sv	–	0.70 Sv	0.75 Sv	0.81 Sv
NSCR 2012	–	0.70 Sv	0.75 Sv	0.85 Sv	–	0.79 Sv	0.85 Sv	1.15 Sv

A Hohmann transfer would yield a total estimated radiation dose between **1.003 Sv** and **1.669 Sv** ... over the course of **~ 2.7 years**.

Conclusion

Long Stay Time Manned Missions Could Be Possible!

- Shortened interplanetary travel time to 180 days each way instead of 259 days each way.
- Incorporating BNNT shielding into spacecrafts.
- Building underground shelter structures in lava tubes on Mars.
- Investing in space weather architecture to detect the onset of SEP events and provide a sufficient warning for astronauts to seek additional protection/shelter.

Thank You!

Additional Images for Discussion