Radiation Assessment Detector (RAD)

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Linking SSP Scientific Interest with Exploration Goals and Objectives

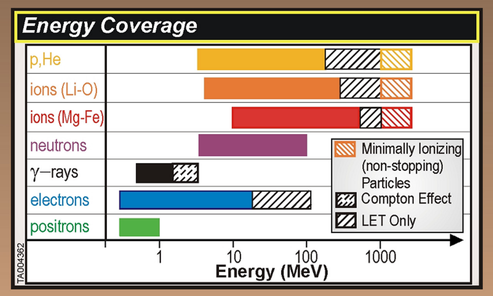
The Radiation Assessment Detector (RAD) is a simple, lightweight energetic particle spectrometer to fly as part of the NASA 2009 Mars Science Laboratory (MSL) Mission. RAD will detect and analyze all relevant energetic particle species (p, n, He, Fe, etc.) incident on the Martian surface, including direct and indirect radiation created both in the atmosphere and the regolith. Fully characterizing and understanding the radiation environment is fundamental to quantitatively assessing the habitability of Mars, and an essential precursor measurement for future manned Mars missions.

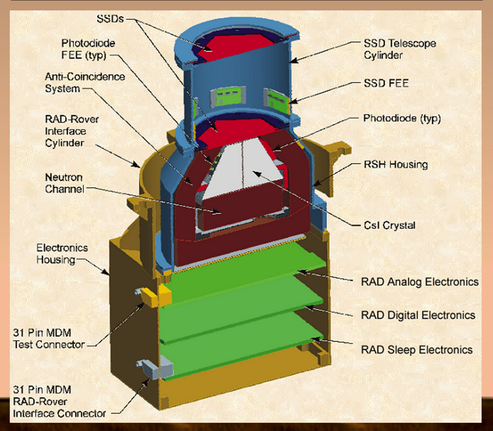
The RAD instrument consists of a solid-state detector stack and CsI calorimeter with active coincidence logic to identify charged energetic particles using the dE/dx vs E method. RAD also uses a separate plastic scintillator and anti-coincidence shield to detect neutrons and gamma rays. Each of these techniques and components have been used for radiation detection in space since the 1960s, but combined in this way, for the first time with RAD. The RAD project exemplifies the strong collaboration and cooperation between SMD and ESMD, and their common scientific and Exploration goals and objectives. *RAD is funded by NASA Exploration Systems Mission Directorate.*

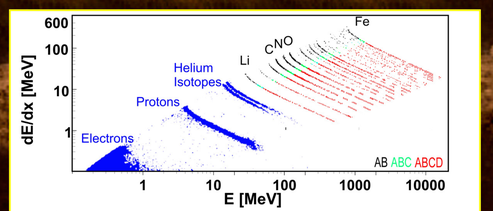
MSL RAD Scientific Objectives

To characterize fully the broad spectrum of radiation at the surface of Mars, measuring all of the relevant energetic particle species, including secondary neutrons and other particles both created in the atmosphere and the Martian regolith.

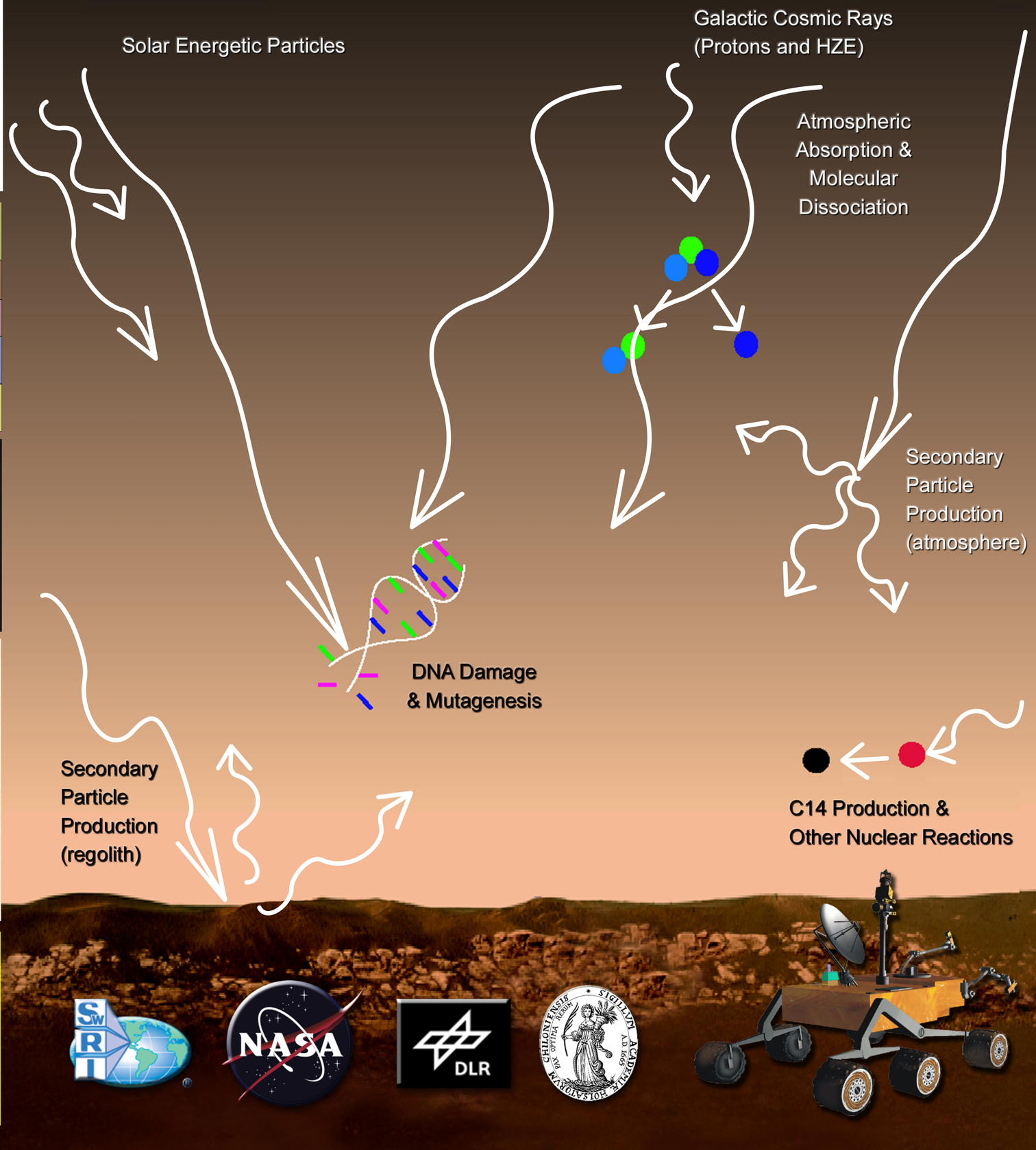
- Characterize the energetic particle spectrum incident at the surface of Mars, including direct and indirect radiation created in the atmosphere and regolith.
- Determine the radiation Dose rate and Equivalent Dose rate for humans on the Martian surface.
- Validate Mars atmospheric transmission models and radiation transport codes.
- Determine the radiation hazard and mutagenic influences to life, past and present, at and beneath the Martian surface.
- Determine the chemical and isotopic effects of energetic particles on the Martian surface and atmosphere.



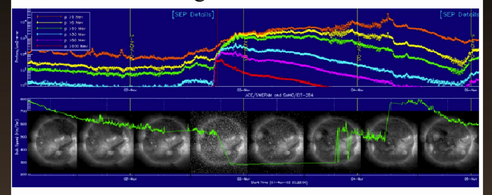




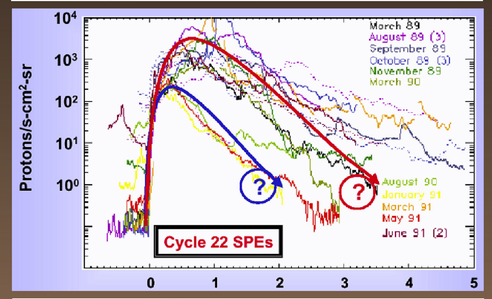
The RAD energy loss matrix spans from electrons to protons to Fe ions. COSTEP observations of e-, p, and He are merged with a RAD heavy-ion simulation, based on actual instrument and data compression parameters, demonstrating RAD's critical capability of resolving energy spectra for low- to high-Q Z=26 ion species individually.

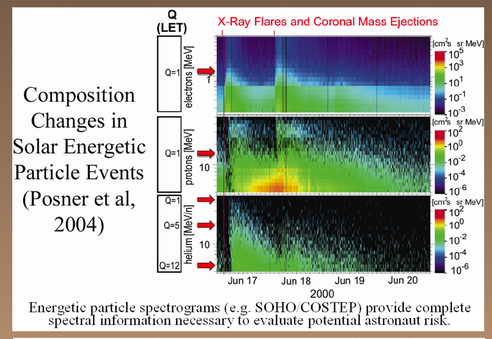


Solar Energetic Particles Events



Massive Solar Energetic Particle Events (SPEs) from Oct/Nov 2003 created havoc on satellites and spacecraft throughout the heliosphere. Earlier in the month, a similar SPE knocked out the MARIE instrument on Mars Odyssey after recording radiation does rates in excess of 1200 mrad/day. Shown are GOES proton fluxes and ACE/SWEPAM solar wind data superposed on SOHO/EIT images.





Energetic particle spectrograms (e.g. SOHO/COSTEP) provide complete spectral information necessary to evaluate potential astronaut risk.

Preparation for Human Exploration of Mars:
Astronaut Safety Requires Monitoring Certain Particle Species

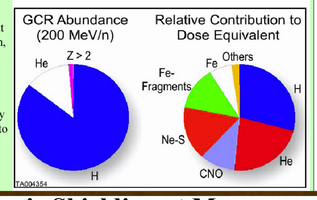
Table A1-2: Requirements for Complete Characterization of Radiation Environment.
Full characterization requires measuring ALL of these relevant species.

Particle Species	Quality Factor (Q)	Relevance (Biological Importance and Need for Measurement)
Protons	1-7	Largest flux, large contributor to total dose (>90% of GCR, >98% of SEP)
He (alphas)	2-30	Large flux, high Q at low energies thus large contributor to equivalent dose
C, N, O	5-30	High Q with large probability of reaction in body tissue, significant contributor to equivalent dose, relevance to carbon provenance, carbon cycle from $^{13}C/^{12}C$ ratio
Fe	6-30	High Q factor with largest probability of reaction in body tissue, large contributor to equivalent and effective dose, *primary astronaut safety concern*
Neutrons	3-10	High Q factor, relevant near regolith and within tenuous atmospheres, high probability of reaction in tissue at 10-100 MeV, highly penetrating, *high astronaut safety concern*
γ-rays	1	Solar flare indicator, relevant to Mars geology: saline γ-line (^{40}K) detection
Electrons	1	SEP precursor, highly penetrating, large fluence during SEP events (even with Q=1, large fluence contributes to large equivalent dose)
Positrons	1	GCR cascade by-product, required for radiation transport model validation

Astronaut Safety: Determining the Radiation Dose Rate for Humans on Mars

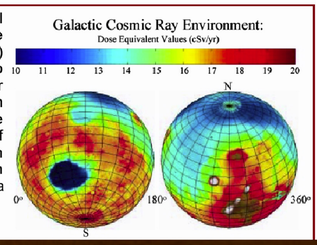
GCRs produce near-constant background flux of radiation, modulated by solar cycle.

Composed mostly H^+ and He^{2+}, but heavy ions contribute disproportionately to the Dose Equivalent due to their high quality factor, Q. (Wilson et al. 1997)



Atmospheric Shielding at Mars:
Strong dependence on atmospheric column mass

Figure FO1-5. Model prediction of Dose Equivalent (health risk) from exposure to GCRs, calculated for solar maximum conditions. Note the strong dependence of radiation exposure on the Martian topography. (Cucinotta et al. 2004)



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