HUMAN EXPLORATION OF PHOBOS AND DEIMOS: RADIOPROTECTION ISSUES.

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Radiation protection is a prime issue for extended missions to planets in our solar system (e.g. Phobos and Deimos), or for a return visit to the Moon. The radiation environment encountered by solar system missions mainly consists of the following components: 1) Trapped radiation in the Earth's Van Allen Belts and in the magnetosphere of Jupiter; 2) Galactic Cosmic Ray (GCR) background radiation and 3) Solar Proton Events (SPEs). Along with the continuous GCR background, SPEs constitute the main hazard for interplanetary missions. Up to now, prediction of SPE events is not possible. Potential Phobos and Deimos manned missions will need to consider solar activity (e.g. solar flares, coronal mass ejections, etc) very carefully due to the obvious detrimental effects of radiation on humans. Very high doses during the transit or surface activities can result in acute effects (radiation sickness). The risk of long-term effects such as cancer brain damage and other degenerative diseases during or after a mission is somewhat more difficult to quantify, but must also be considered in mission planning.

The radiation environment on the surface of Phobos and Deimos will probably be similar to that seen in Mars orbit. In addition, the lack of atmosphere to shield crews from protons and GCR and the presence of "albedo" neutrons produced in the upper layers of the surface, it poses a complex environment with characteristics similar to free space as well as planetary surface environments. The radiation hazard on Earth is reduced by the atmosphere, which provides 1030 gm cm-2 of shielding. The lack of atmosphere on Phobos and Deimos [0 gm cm^{-2}] and Mars [16 gm cm^{-2}] heightens the hazard but man-made structures and the planetary bodies will offer some protection. This radiation hazard will on average be slightly less on the surfaces of Phobos and Deimos and Mars than in deep space. However, human surface activities at the Martian moons posse's considerable risks somewhat equivalent to Moon activities.

The Phobos and Deimos radiation environment has not been fully characterized. Only a few space missions were able to begin the characterization of the plasma and radiation environment near Mars (Phobos-2, Mars Odyssey, etc). The primary objective of the Phobos-2 mission was to explore, Phobos. Phobos-2 operated nominally throughout its cruise and Mars orbital insertion phases, gathering data on the Sun, interplanetary medium, Mars, and Phobos. The Phobos-2 spacecraft arrived at Mars on January 1989, but was lost while maneuvering in Martian orbit to encounter Phobos on March 1989. Phobos-2 returned observations made by an Energetic Charged-Particle Spectrometer. During this period of the early rising phase of Solar Cycle 22, particles reaching energies of several tens of MeV were recorded close to Mars under disturbed interplanetary circumstances.

The Martian Radiation Environment Experiment (MARIE), a payload on the NASA's 2001 Mars Odyssey Orbiter, has collected data continuously from the start of the Odyssey mapping mission in March 2002 until October 2003. MARIE was designed to characterize aspects of the radiation environment both on the way to Mars and in the Martian orbit, using an energetic particle spectrometer. Gathered data showed that the accumulated total radiation dose equivalent in Mars orbit is about 2.5 times larger than that aboard the ISS. The dose equivalent from GCR agrees well with predictions based on modeling. Averaged over the 11-month period, about 10 percent of the dose equivalent at Mars is due to solar particles, although a 30 percent contribution from solar particles was seen in July 2002, when the Sun was particularly active. Starting on July 16 2003, the largest SPE was observed by MARIE with a dose rate > 1000 mrad/day . On Oct. 28, 2003, during a period of intense solar activity the instrument stopped working properly.

There is not sufficient data or knowledge to approve a mission to Mars or it's satellites at this time because of the lack of a well characterized radiation environment as well as of the poorly understood biological effects of GCR. Because of their shorter duration and majority of time is on lunar surface, Permissive Exposure Levels (PEL) have been drafted for Cancer and Acute Risks for Lunar missions, however there are still large uncertainties in cancer risks and potentially dose-rate effects and shielding should alleviate any acute risks. It is doubtful that shielding can reduce the risk from GCR to a sufficient level, therefore the primary research goal at this time is to establish risk models for future shielding and biological countermeasure development. For degenerative tissues and central nervous system damage new data needed to establish PEL's**.** Organ doses for a known SPE spectrum can be described with small uncertainties (<15%), but it will requires accurate monitoring, dosimetry and shielding. Risk assessment models are being developed for all risks however will require extensive data collection in accurate experimental models of human risks. Current research focus is evolving from risk assessment in the near term to mitigation strategies for long duration Mars and near-Mars missions in the long-term. Therefore, adequate radiation protection measures must be conceived for any lengthy Phobos or Deimos exploration endeavors.