

MODELS FOR THE RADIATION ENVIRONMENT OF PLANET MARS.

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Introduction: Radiation protection is one of the two NASA highest concerns priorities [1]. In view of manned missions targeted to Mars [2], for which radiation exposure is one of the greatest challenges [3], it is fundamental to determine particle fluxes and doses at any time and at any location and elevation on, below and around Mars [4]. With this goal in mind, models of radiation environment induced by Galactic Cosmic Rays (GCR) and Solar Particle Events (SPE) on Mars have been developed [5]. The work is described [6] as models of incoming cosmic ray [7-9] and solar events [5-6] primary particles rescaled for Mars conditions then transported through the atmosphere down to the surface, with topography and backscattering taken into account, then through the subsurface layers, with volatile content and backscattering taken into account, eventually again through the atmosphere, and interacting with some targets described as material layers. The atmosphere structure has been modeled in a time-dependent way [10-11], the atmospheric chemical and isotopic composition over results from Viking Landers [12-13]. The surface topography has been reconstructed with a model based on Mars Orbiter Laser Altimeter (MOLA) data at various scales [14]. Mars regolith has been modeled based on orbiter and lander spacecraft data from which an average composition has been derived [4-6]. The subsurface volatile inventory (e.g. CO₂ ice, H₂O ice), both in regolith and in the seasonal and perennial polar caps, has been modeled vs. location and time [15-16]. Models for both incoming GCR and SPE particles are those used in previous analyses as well as in NASA radiation analysis engineering applications, rescaled at Mars conditions [4-6]. Preliminary models have been developed for the surfaces of the Martian satellites Phobos and Deimos.

Results: Particle transport computations were performed with a deterministic (HZETRN) code [17] adapted for planetary surfaces geometry and human body dose evaluations [4]. Fluxes and spectra for most kinds of particles, namely protons, neutrons, alpha particles, heavy ions, pions, muons etc., have been obtained. Neutrons show a much higher energy tail than for any atmosphereless bodies [4]. Results have been obtained for different surface compositions: only at the latitudes closer to the equator the soil is mostly silicatic regolith, whereas for northern or southern locations a suitable mix, with variable ice concentration with time, of ices of water and carbon dioxide needs to be used [4-6]. Results have been calculated

for different locations and atmospheric properties models [4-6]. The results obtained with these models differ from those from other models obtained with a simplified model of the Martian atmosphere (single composition, single thickness, no time dependence) and with a regolith-only (no-volatiles) surface model [18]. This Mars Radiation Environment Model will be tested against spacecraft data (e.g. LIULIN-PHOBOS instrumentation onboard the PHOBOS-GRUNT spacecraft from the Russian Space Agency RKA).

Conclusions: Models for the radiation environment to be found on the planet Mars have been developed. Primary particles rescaled for Mars conditions are transported through the Martian atmosphere, with temporal properties modeled with variable timescales, down to the surface, with altitude and surface backscattering patterns taken into account. The work is being extended to the Phobos and Deimos surfaces. The Mars Radiation Environment Model will be tested with the data from spacecraft instruments in the future.

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References: [1] O'Keefe, S. (2002)

- <http://www.spaceflightnow.com/news/n0203/27okeefe>
 [2] Cucinotta F.A. et al. (2001) *Radiat. Res.*, 156, 682-688. [3] Hoffman S. J. and Kaplan D. L. (1997) NASA SP-6107. [4] De Angelis G. et al. (2004) *Adv. Space Res.*, 34, 1328-1332. [5] De Angelis G. et al. (2006) *Radiat.Meas.*, 41, 1097-1102. [6] De Angelis G. et al. (2007) *Nucl.Phys. B*, 166, 184-202. [7] Badhwar G. D. et al. (1994) *Radiat. Res.*, 138, 201-208. [8] Badhwar G. D. and O'Neill P. M. (1996) *Adv. Space Res.*, 17, 7-17. [9] Wilson J. W. et al. (1999) NASA TP-209369. [10] Justus C. G. and D. L. Johnson (2001) NASA TM-2001-210961. [11] Justus C. G. et al. (1996) NASA TM-108513. [12] Owen T. K. et al. (1977) *JGR*, 82, 4635-4639. [13] Levine J. S. (1985), *The Photochemistry of Atmospheres*, Academic Press, New York. [14] Smith D. E. et al. (1999) *Science*, 284, 1495-1503. [15] Christensen P. R. and Zurek R. K. (1984) *JGR*, 89, 4587-4596. [16] James P. B. et al. (1987) *Icarus*, 71, 298-305, 1987. [17] Wilson J. W. et al. (1995) NASA TP-3495. [18] Saganti P. B. et al. (2004) *Space Scie. Rev.*, 110, 143-156.