Mars Science Laboratory Radiation Assessment Detector (MSLRAD) Modeling Workshop Proceedings

Introduction

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The Radiation Assessment Detector (RAD) (Hassler et al., 2012) onboard the Mars Science Laboratory (MSL) *Curiosity* rover (Grotzinger et al., 2012) has been making detailed measurements of the radiation environment on the surface of Mars since landing on 6 August 2012 (Hassler et al., 2014; Zeitlin et al., 2016). These measurements are the first of their kind on the surface of another planet and are providing essential measurements of the radiation environment on Mars in preparation for a human mission in the coming decades.

The objectives of RAD are; 1) to characterize the energetic particle spectrum on the surface of Mars as a function of time in the solar cycle, including direct (galactic cosmic rays and solar energetic particles) and indirect (neutrons, etc.) radiation created in the atmosphere and regolith, 2) to determine the dose and dose-equivalent rates as a function of time in the solar cycle, and 3) to use these observations to test and validate space radiation transport models. Initial results of the charged particle spectra (Ehresmann et al., 2014) and neutral particle spectrum (Köhler et al., 2014), as well as dose and dose-equivalent during cruise (Zeitlin et al., 2013) and on the surface (Hassler et al., 2014) have been reported, and with almost five years of continuous measurements, RAD continues to characterize the radiation environment as solar minimum is approached.

Although the radiation environment on Mars has been estimated and modeled by many groups using different numerical models and codes (Gronoff et al., 2015; Kim et al., 2014; McKenna-Lawlor et al., 2012; Simonsen et al., 1990; Townsend et al., 2011), particle spectral predictions have rarely been published, and until the observations from RAD became available there was no definitive way to test or validate these models. One of the first attempts to validate space radiation transport models with experimental data from RAD, was performed by Matthiä et al. (2016a), who compared calculated particle spectra and dose rates from four different models to RAD data during its first six months on the Martian surface.

To expand this effort and extend the comparison of RAD data with as many models as possible, including as many teams working on modeling the radiation environment on planetary surfaces as possible, a "blind challenge" workshop was held in Boulder, Colorado on June 28-30, 2016. Forty scientists, engineers, modelers and instrumentalists from the United States and Europe participated in the workshop, and seven different transport codes (Geant4, Geant4 Hybrid, PHITS, HZETRN, FLUKA, HETC-HEDS, MCNP6) were discussed and compared with RAD data. These codes are used by space agencies such as NASA, the German Aerospace Center (DLR), and the Japanese Aerospace Exploration Agency (JAXA). The structure of this “blind challenge” was for each modeling team to predict the particle spectra and dose rates for a two month period of time (15 November 2015 to 15 January 2016) before the MSLRAD data had been released to the public, and submit and present their results and predictions at the workshop. In addition to the time frame, certain other boundary conditions for the model calculations were provided to the workshop participants in advance, such as the amount of atmospheric shielding to be used. Other variables, such as the composition of the atmosphere and the composition of the soil or regolith, as well as the GCR input spectrum were left up to the individual modeling teams to choose. Note however, that the paper by Slaba and Stoffle (2016), shows that different choices have a minor effect on the results. The first day of the workshop included general presentations about each of the different models from each of the modeling teams, as well as a presentation on RAD and how it works. The second day of the workshop included presentations of the modeling teams' results, as well as the observations from RAD for this time period. The third day of the workshop included the detailed comparison and discussion of model results with the RAD data.

As expected, results were mixed, due in part to different assumptions and normalization factors each of the modelers used, but also in part due to different physics assumptions used in the models. However, there was optimism and enthusiasm in the group that the variances between the different models and between the models and the data can be understood and worked out with cooperation and activities like this workshop. Obvious simple mistakes, such as geometry factors, were easily corrected, yet differences remain as can be seen in the results presented here in these Proceedings.

The papers in these Proceedings include contributions from each of the groups concerning the details of their models and the procedures used in comparing their results with RAD data. The paper by Matthiä et al. (2016b) contains a summary of the results of each group. Importantly, it is shown that there remain significant differences between models and in comparisons to RAD data. Differences of factors of two are not uncommon with some differences an order of magnitude. Dose-equivalent rates and quality factors also show a significant spread between the different codes and compared to RAD data. Resolving these discrepancies is important, because such variations could possibly determine whether astronauts do or do not exceed dose limits.

This Workshop was the first-of-its-kind, and as such enormous progress and improvement was made by getting both the instrumentalists and the different modeling teams together to discuss and compare their results in a collegial and open manor. These Proceedings reflect this spirit of cooperation and team work and a second workshop is tentatively scheduled for Spring 2018.

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