A DIGITAL ARCHIVE FOR MARS SCIENCE LABORATORY DYNAMIC ALBEDO OF NEUTRONS PASSIVE MODE RESULTS. **C. G. Tate[1]**, N. J. Cagle[1], J. Moersch[1], I. Jun[2], A. C. Martin[1], and L. M. Martinez Sierra[2]. [1]**Department of Earth and Planetary Sciences, University of Tennessee, Knoxville, TN, USA, ctate10@vols.utk.edu**, [2]Jet Propulsion Laboratory/California Institute of Technology, Pasadena, CA, USA.

Introduction: The Dynamic Albedo of Neutrons (DAN) instrument onboard the Mars Science Laboratory rover, *Curiosity*, is capable of detecting neutrons escaping from the shallow Martian subsurface with the purpose of estimating the amount of water equivalent hydrogen (WEH) present in the Martian regolith [1,2]. Here, we introduce a digital archive of interpreted DAN passive results, which are intended to augment and complement the calibrated count rates and other DAN measurements archived in NASA's Planetary Data System (PDS).

DAN is composed of a pulsed neutron generator (PNG) and two ^{3}He proportional counters [1]. One of the proportional counters (CTN) detects neutrons of energies up to 100 keV, though detection efficiency is low at higher energies [1]. The other proportional counter (CETN) is shielded with a cadmium jacket, which absorbs neutrons below 0.4 eV, and thus detects only neutrons with energies above 0.4 eV [1].

DAN has two modes of operation, active mode and passive mode. The active mode of operation uses the PNG to produce a high intensity pulse of high energy (14 MeV) neutrons and then measures the neutron leakage flux at the detectors as a function of time since the pulse [1]. The passive mode of operation, however, does not use the PNG. There are two sources of neutrons that contribute to the Martian neutron leakage flux that are relevant to MSL passive mode data. The first source is the interaction of Galactic Cosmic Rays (GCRs) with nuclei present in the Martian regolith and atmosphere, which produces neutrons. The second source is the Multi-Mission Radioisotope Thermoelectric Generator (MMRTG), which is the rover's power source. The MMRTG contains a plutonium oxide fuel, which produces alpha particles through radioactive decay and these alpha particles interact with oxygen within the fuel to produce high energy neutrons of around 14 MeV [3].

Once neutrons are created they will move within the subsurface and interact with the nuclei of the regolith through inelastic and elastic scattering. These interactions will moderate the neutron energies from high energy to lower energies [4]. The amount of moderation that takes place is dependent on the amount of hydrogen in the regolith [4]. A greater amount of WEH will lead to more neutron moderation and thus a greater proportion of low energy (thermalized) neutrons in the neutron leakage flux [4]. Another factor to consider is that elements with high thermal neutron absorption cross sections will remove thermalized neutrons from the leakage flux [5]. However, DAN is sensitive to the neutron leakage flux and uses this to infer the amount of WEH present in the shallow regolith.

Methods: Numerical simulations are necessary to analyze DAN passive mode data. We use the Monte Carlo radiation transport code MCNPX [6] to simulate the Martian neutron leakage flux relevant to MSL DAN passive mode and the instrument's response to it [7]. In large scale, this involves simulating GCR transport through the Martian atmosphere by keeping track of the relevant GCR and secondary particles and their energy and angular distributions. The results from this step are used as input for a rover-scale simulation that includes the Martian regolith, the rover, and the DAN detectors. In a separate simulation, the MMRTG-source is also simulated within in the same rover-scale geometry. The composition of the Martian regolith within these simulations contains varying amounts of WEH and absorption equivalent chlorine (AEC). The results from both of these rover-scale simulations are in neutron counts per source particle and thus must be scaled by source strength and combined to produce the estimated DAN count rates for a given composition of the Martian regolith. The MMRTG source simulations are scaled by a factor derived in [3]. The GCR-source simulations are scaled using a factor derived from calibration of DAN passive in combination with DAN active results and MSL Radiation Assessment Detector (RAD) data [7], which measures the high energy particle environment at the surface of Mars [8]. DAN passive data are compared to these simulation results in order to determine the composition that best models the data [7].

Archive: The digital archive of DAN passive results is meant to be offered to the planetary science community as part of the Data Management Plan of our Mars Data Analysis Program project for interpreting DAN passive data. It is hosted by the University of Tennessee's open repository, (the Tennessee Research and Creative Exchange) (TRACE, www.trace.utk.edu).

NASA's PDS serves as the primary archive for planetary science mission data; however, the PDS is for raw and reduced or calibrated data. The DAN passive reduced data (without WEH results) are available in the PDS: https://pds.nasa.gov/ds-view/pds/viewProfile.jsp?dsid=MSL-M-DAN-3/4-RDR-V1.0. The purpose of the TRACE archive described here is to make the results/interpretations of our

DAN passive analysis, including best estimates of WEH from the passive-mode measurements, available to the community.

DAN passive data analysis is computationally expensive. To some, this can be a prohibitive step in using the acquired data. Therefore, this archive provides a path forward for those looking to utilize results from the passive mode of the experiment without having to recreate in detail the analysis already performed. Furthermore, the analysis performed in [6] requires many assumptions about the simulations and regolith composition in order to produce WEH interpretations. For an end-user, it may not be necessary to revisit these assumptions. for use of the results contained in this archive. If one wanted to use different assumptions or simulation procedures, they would start with the data available on the PDS. An example user of the archive described here would be someone wanting to compile interpreted results from all or some MSL instruments for a specific location, time period, or traverse segment of MSL's investigation. This archive allows for the acquisition of the DAN passive component of such an undertaking.

The archive contains WEH estimates along traverse (*e.g.*, Figure 1) and DAN Passive Geochemical Index (DPGI, described in [7]) estimates (Figure 2), and their uncertainties from both fixed locations and traverse segments in CSV format. Plots of WEH versus odometer position for each individual traverse segment the rover has made (*e.g.*, Figure 3) are also included. Traverse plots are organized by the sol on which the data were acquired. The archive will be updated as new results are peer-reviewed and published. However, previous versions of the archive are also retained.

The initial analysis and WEH estimates for sols 0 to 200 are described in detail in [9]. Revisions have been made to this analysis, involving an updated RAD/DAN active calibration and derivation and addition of the DPGI index, while also describing the results from sols 201 to 753 of the mission in [7]. Work currently in progress will extend the analysis of DAN passive data to sol 1292. This work will also include revisions to make use of the latest RAD data, DAN active results, and additional processing on traverse segment data to include spatial binning within the footprint of the instrument to better leverage the fact that the instrument over-samples within its footprint [10].

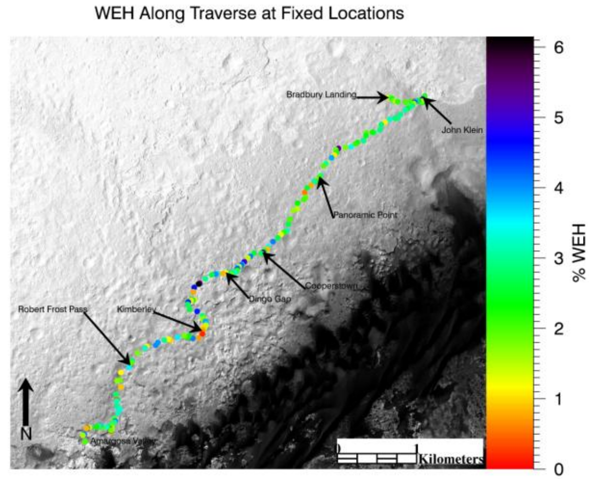

Figure 1. DAN passive WEH estimates at fixed locations along *Curiosity's* traverse [6] are shown. WEH estimates are included in the digital archive.

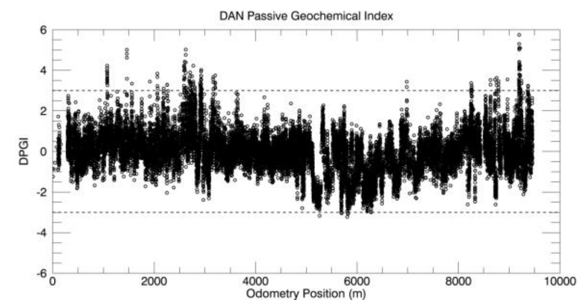

Figure 2. DPGI values along *Curiosity's* traverse [6] are shown. DPGI values are included in the digital archive.

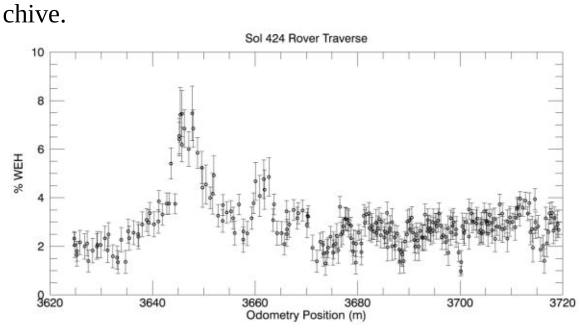

Figure 3. An example of DAN passive WEH estimates from a traverse segment [6] is shown. Corresponding plots for each sol are included in the digital archive.

References: [1] Litvak M. *et al*. (2008) *Astrobiology*, 8. [2] Mitrofanov I. *et al*. (2012) *Space Science Re*views, 170, 559-582. [3] Jun I. *et al*. (2013) *Journal of Geophysical Research, Planets,* 118. [4] Drake D. *et al*. (1988) *Journal of Geophysical Research*, 93. [5] Hardgrove C. *et al*. (2011) *Nuclear Instruments and Methods in Physics Research A*, 659, 442-455. [6] McKinney G. *et al*. (2006) Los Alamos LA-UR-06-6206. [7] Tate C. *et al*. (2018) *Icarus,* 299. [8] Hassler D. *et al*. (2014) *Science*, 343. [9] Tate C. *et al*. (2015) *Icarus,* 262. [10] Tate *et al*., in prep.