GLACE (GEANT4 LUNAR ALBEDO COMPUTED ENVIRONMENT): A MODEL OF LUNAR ENERGETIC-PARTICLE SECONDARY RADIATION IN THE PRESENCE OF REGOLITH HYDROGEN. M. D. Looper[1], J. E. Mazur[1], J. B. Blake[1], H. E. Spence[2], N. A. Schwadron[2], J. K. Wilson[2], A. P. Jordan[2], C. Zeitlin[3], A. W. Case[4], J. C. Kasper[5,6], L. W. Townsend[7], T. J. Stubbs[8], and P. H. Phipps[8,9], [1]The Aerospace Corporation (corresponding author: mark.d.looper@aero.org), [2]University of New Hampshire, [3]Leidos Innovations Corporation, [4]Harvard-Smithsonian Center for Astrophysics, [5]BWX Technologies, Inc., [6]University of Michigan, [7]University of Tennessee, [8]NASA Goddard Space Flight Center, [9]University of Maryland.

Introduction: When energetic ions from space strike the lunar surface, secondary energetic particles are produced. The subset of these particles that escape back into space are conventionally called "albedo" particles. They are continuously produced by the steady influx of galactic cosmic rays (GCRs), and can also result from strong solar energetic particle events.

Since the 2009 launch of the Lunar Reconnaissance Orbiter (LRO), the science team of its Cosmic Ray Telescope for the Effects of Radiation (CRaTER) sensor has used the Geant4 energetic-particle radiation transport code [1] to model the lunar albedo in order to help us understand our observations (e.g., [2], [3], [4]). We would like to make the results of our modeling available to the community. In our presentation, we will describe the content that we will be providing and will show some examples of its use.

Simulations: We model the full energy and angular distribution of albedo particles, starting from an isotropic, monoenergetic incident flux of a single ion species from Z = 1 to 28 (H to Ni). We will provide result files for all such sets of initial conditions, so that others can use these data as a "kernel" to convolve with any desired incident cosmic-ray or solar-particle spectrum. At present, we plan to release our GLACE model on Zenodo.

Albedo distributions have been calculated for each of a set of target regolith compositions that include dry ferroan anorthosite (FAN) and a range of layered geometries with hydrogen- or water-bearing FAN on top of a dry base. The layers range from 1 mm to 10 m deep and have either 10% or 1% hydrogen by weight or 9% water by weight (which includes 1% hydrogen).

Energy and angular distributions of all albedo particles except neutrinos are tabulated at the surface and at 20 km altitude. The latter is necessary for modeling spacecraft observations because unstable particles can decay on the way up.

Example of Results: The figures below are from an earlier version of this calculation [5]. The upper figure shows the proton albedo at the lunar surface produced from dry FAN, integrating over all GCR species for a particular model of their modulated spectra, and with a colorscale indicating the logarithm of flux in protons per (m^2 sr sec MeV). The lower figure shows the fractional enhancement or depletion of proton fluxes vs. energy and angle when a 1 cm layer with 10% hydrogen by weight is placed on top.

Not shown is the distribution of the depths of origin for albedo protons and neutrons, which is also logged in our simulations. This information can be used to find the depth beneath the lunar surface to which a particular set of observations can probe (e.g., 10s of cm for protons at the energies observed by CRaTER).

References: [1] Allison J. et al. (2016) *Nucl. Inst. And Meth. In Phys. Res. A, 835,* 186-225. [2] Looper M. D. et al. (2013) *Space Weather, 11,* 142-152. [3] Schwadron N. A. et al. (2016) *Icarus, 273,* 25-35. [4] Schwadron N. A. et al. (2017) *Planetary and Space Sci., 162,* 113-132. [5] Looper M. D. et al. (2018) *AGU Fall Meeting,* Poster #P23C-3449.