Lunar Cosmic Ray Albedo Measurements Using the Cosmic Ray Telescope for the Effects of Radiation on the Lunar Reconnaissance Orbiter. H. E. Spence[1] and the CRaTER Science Team, [1]Space Science Center, Institute for the Study of Earth, Oceans, and Space, Morse Hall, 8 College Road, University of New Hampshire, Durham, NH; harlan.spence@unh.edu.

Abstract: We describe early results from a new instrument, the Cosmic Ray Telescope for the Effects of Radiation (CRaTER), which is providing measurements of energetic particles while in orbit around the Moon onboard the Lunar Reconnaissance Orbiter (LRO) mission [1]. CRaTER measures the effects of ionizing energy loss in matter due to penetrating solar energetic protons (SEP) and galactic cosmic rays (GCR), specifically in six silicon solid-state detectors and after interactions with tissue-equivalent plastic (TEP), a synthetic analog of human tissue [2]. The CRaTER investigation quantifies the linear energy transfer (LET) spectrum in these materials through direct measurements with the lunar space radiation environment, particularly the interactions of ions with energies above 10 MeV. Combined with models of radiation transport through materials, CRaTER LET measurements constrain models of the biological effects of ionizing radiation in the lunar environment as well as provide valuable information on radiation effects on electronic systems in deep space. In addition to these human exploration goals, CRaTER measurement capabilities provide new insights on the spatial and temporal variability of the SEP and GCR populations and their interactions with the lunar surface. We present an overview of the CRaTER instrument, its exploration and science goals, and results from flight observations obtained since LRO's launch in June 2009 until present, an interesting interval during this historic solar minimum accompanied by record high GCR intensity.

The CRaTER Instrument and LRO: CRaTER is an ionizing radiation instrument on the Lunar Reconnaissance Orbiter spacecraft. The exploration-enabling objectives of CRaTER are to characterize the lunar radiation environment and to study how dose rates evolve as a function of shielding and depth in the human body. LRO is a three-axis stabilized lunar pointing spacecraft, and the two ends of the CRaTER telescope are continuously pointed with unobstructed fields of view of deep space and the lunar surface.

Effects of the Moon on Galactic Cosmic Rays: We present observations with CRaTER from cruise phase to the Moon through the first nine months of operations with a focus on identifying how the Moon affects the flux of galactic cosmic rays that reach the spacecraft. We examine event rates as a function of altitude above the Moon and compare our results with a simple geometric model.

First, we show how the rates drop as LRO approaches the Moon owing to a geometric effect. The Moon acts as an efficient absorber of GCR particles. As LRO nears the Moon, a larger portion of the unit sphere of the sky is blocked; very close to the Moon approximately half of LRO and CRaTER's field-of-view is subtended by the Moon. Consequently, the portion of the sky filled by the Moon blocks access from GCR in that direction, and so the overall detection rates decrease.

Second, we show that the decrease in rates is slower than predicted from a pure geometric lunar absorption of GCR. In other words, with decreasing altitude from the lunar surface, the measured rates fall off systematically more slowly relative to those expected from being near to an absorbing spherical object whose apparent diameter is changing with distance.

We explore one explanation for this excess of GCR rates as we approach the Moon: secondary sources of radiation caused by primary GCR interactions with the lunar regolith. When sufficiently high energy GCR particles strike the lunar surface, they can produce through spallation a wealth of secondary particles liberated from the regolith. Some of these secondaries will forward scatter deeper into the surface. Some may backscatter into space. And other primary interactions of GCR at grazing incidence with the lunar surface can forward scatter into space as well. For our purposes, any secondary source of ionizing radiation coming up from the lunar surface is deemed cosmic ray albedo.

Finally, we use radiation transport codes to model the interaction of primary GCR particles with the lunar surface to identify unique signatures of cosmic ray albeo interactions in the CRaTER data. We use a GCR spectrum appropriate for the current solar cycle conditions and the GEANT4 model to show expected responses within the CRaTER instrument to primary GCR and lunar cosmic ray albedo, focusing on light ion interactions (protons and alpha particles). We explore the properties of the albedo cosmic rays in order to remotely sense the interactions of the GCRs with the lunar surface.

References: [1] Chin et al., (2007) *Space Sci. Reviews*, 129 [2] Spence et al., (2009) *Space Sci. Reviews*, in press.