Lunar ISRU Prospecting with BECA. A. M. Parsons[1], M. Ayllon Unzueta[1,2], and R. D. Starr[1,3], [1]NASA Goddard Space Flight Center, Greenbelt, MD, [2]Oak Ridge Associated Universities, Oak Ridge, TN , [3]Catholic University of America, Washington DC. (Contact: Ann.M.Parsons@nasa.gov)

Introduction: The Bulk Elemental Composition Analyzer (BECA) is a new instrument that has been matured through NASA's Development and Advancement of Lunar Instrumentation (DALI) program and has great potential for use in lunar In Situ Resource Utilization (ISRU) activities [1]. BECA employs nuclear techniques to measure the in situ near-surface bulk elemental composition on planetary bodies without the need to make physical contact with the surface. BECA's lunar ISRU capabilities are extensive with its ability to determine the elemental content of lunar regolith down to ~30 cm below the surface. BECA would thus be a valuable ISRU prospecting tool when placed on a rover where it could measure the lunar subsurface composition as the rover traverses the lunar surface. The resulting map of the locations and concentrations of key elements for ISRU would make the recovery of these resources much more efficient.

BECA Capabilities: Since BECA uses both gamma ray and neutron information, it can detect a significantly larger number of elements than available from instruments measuring only neutrons. BECA will measure hydrogen down to ~30 cm depth with gamma rays and down to ~60 cm depth with neutrons. Using the gamma ray and neutron information together, BECA may achieve H sensitivity at the100 ppm level allowing it to measure H abundances both inside and outside Permanently Shadowed Regions (PSRs). BECA will easily measure regolith oxygen content. Additionally, BECA will also be able to measure the regolith's Fe and Ti content thus allowing users to infer the presence of ilmenite ($FeTiO_3$) useful for oxygen extraction. BECA is also sensitive to carbon as well as the metals available in common lunar minerals. In fact, BECA can measure the concentrations of a wide variety of elements such as Al, Ca, Cl, Fe, O, K, Mg, Mn, Na, Si, U, Th, Ti and C.

Concept of Operations: As shown in Figure 1, BECA contains a Pulsed Neutron Generator (PNG) [2] that emits isotropic pulses of 14 MeV neutrons that irradiate the lunar regolith. Subsurface nuclear interactions in the lunar material produce gamma rays at energies characteristic of the isotopes that produced them. BECA's Gamma Ray Spectrometer (GRS) measures the energies and intensities of the gamma rays emitted by the lunar surface to determine the bulk elemental composition of the lunar regolith beneath the instrument.

BECA also includes Neutron Detectors (NDs) to measure rate and energy of the neutrons emitted from the surface to provide H and bulk property information. There are many advantages to having both GRS and NDs measuring the same volume of lunar regolith. The GRS detects a wide range of specific elements including H while the NDs measure H as well as bulk neutron transport properties of the regolith. Having two independent measurements of H improves sensitivity and reliability. Bulk regolith neutron transport properties measured by the NDs also provide a consistency check on the GRS results and the combination of gamma ray and neutron data should improve element depth inferences.

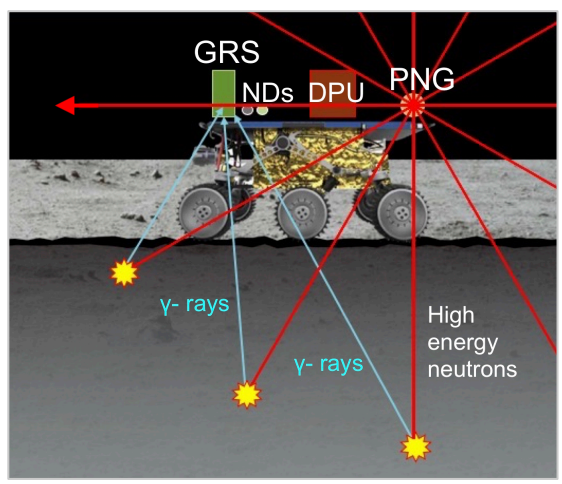

Figure 1: BECA can perform ISRU prospecting over the lunar surface.

Results: As a demonstration of BECA's lunar ISRU prospecting capabilities, we will present the experimental results of composition measurements of a monument of Columbia River basalt. This large (0.91m x 0.91m x 1.82 m) basalt sample has been independently chemically assayed and is located at a dedicated testing facility at NASA Goddard Space Flight Center (GSFC) [3].

References: [1] Ayllon-Unzueta, M. *et al.* (2022) *LPS LIII*, Abstract #2674, [2] Radtke, R. J. *et al.,* (2012) *SPWLA 53rd Ann. Logging Sym.* [3] Parsons, A. M. *et al.* (2016) *LPS XLVII,* Abstract #2476.