^{3}He Prospecting Challenges. R. S. Miller, C. Hibbitts, Y. M. Abul-Huda[1], [1]Johns Hopkins Applied Physics Laboratory, 11100 Johns Hopkins Rd., Laurel, MD, 20723 (Richard.s.miller@jhuapl.edu).

Introduction: ^{3}He is one of the most valuable resources identified on the Moon to date. This isotope of helium promises a "clean"nuclear fuel for fusion reactors, as well as medical imaging, cryogenic, and national security applications. Identification of ^{3}He at or near the lunar surface, including localized abundance and depth profiles, will aid an evaluation of accessibility, inform extraction technologies, and refine the economic viability of this potential resource.

Prospecting Motivation: ^{3}He has been continuously implanted into the lunar regolith by the solar wind for billions of years; its presence on the Moon was confirmed in returned Apollo samples [1]. Parts-per-billion (ppb) abundance levels were found to be correlated with the TiO_2 and optical maturity of those samples [2, and references therein]. It is important to note to limited geologic rand global range over which those samples were collected. A true global lunar survey based on ^{3}He detection signatures that are agnostic to geologic (or other model-based) assumptions is therefore well-motivated. The viability of such an approach is the focus of our efforts.

Orbital Geochemistry. Neutron and gamma-ray detection from orbit is a well-established remote sensing technique for airless planetary bodies [3]. These orbital geochemistry techniques have revealed detailed information regarding global elemental abundance distributions, as well as the presence of bulk hydrogen at the lunar poles; the latter likely in the form of water within permanently shadowed regions (PSRs) [4]. As noted. these nuclear orbital geochemistry techniques are sensitive to bulk elemental deposits, rather than mineralological proxies.

The remote sensing process is initiated by cosmic ray bombardment of the lunar regolith. Fast neutrons produced by these interactions may be moderated, and ultimately captured by nuclei in the regolith. Characteristic secondary de-excitation and/or capture gamma-rays that escape the lunar surface provide one of the key remote sensing detection channels; energy-dependent neutron suppression signatures are another.

^{3}He has a non-trivial likelihood of interaction with cosmic-ray induced neutrons. Neutron interactions include ^{3}He(n,n)^{3}He (elastic scattering), ^{3}He(n,p)^{3}H, ^{3}He(n, d)^{2}H, and ^{3}He(n,γ)^{4}He (radiative capture); each is characterized by an interaction cross-section and branching ratio, i.e. the fraction of into a given interaction channel. The total ^{3}He cross section across all channels is relatively large at thermal neutron energies.

^{3}He Radiative Capture Our initial interest is the radiative capture channel due to its unique 20.578 MeV gamma-ray signature; this signature is a "smoking gun" for the presence of ^{3}He. The detectability of this secondary signature was evaluated by leveraging the thermal neutron flux measured in-situ in lunar orbit [5] and known ^{3}He abundance levels at the lunar surface. Macrosopic (energy-dependent) cross-sections incorporated tabulated nuclear cross-sections and regolith density.

The derived flux of secondary 20.578 MeV gamma-rays from ^{3}He(n,γ)^{4}He is $\leq 10^{-11}$ γ cm^{-2} s^{-1} for abundance levels $\lesssim 10$ ppb by weight. Detection therefore requires a large (meter-class) gamma-ray spectrometer, long dwell times, or a combination of both. The small signature is the product of the low ^{3}He abundance and small radiative capture branching ratio.

A similar analysis shows that surface-based prospecting based on radiative capture is also impractical, even when an artificial source of thermal neutrons (e.g. neutron generator or radiological source) is employed. Again, the small signature is the product of the low ^{3}He abundance, small radiative capture branching ratio, and the assumption that surface-based prospecting employs a detector more modest in size than those deployed to orbit.

^{3}He Knowledge Gaps The viability of ^{3}He remote sensing depends on inputs, the most critical of which is the abundance level of this isotope. Apollo samples provide important, but limited, information in this regard. New lunar samples, including depth profile measurements, may change the calculus; laboratory measurements, of ^{3}He implantation, retention, adsorption, migration, etc, may also be important. Absent information that fills these knowledge gaps, or the presence of ^{3}He abundances at ppm-levels, prospecting based on radiative capture will remain impractical. Other approaches are currently under study.

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