THE IMPORTANCE OF DIVERSITY AND GROUND TRUTH IN LUNAR EXPLORATION.

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Introduction. Remote sensing, in-situ assessment, and returned samples will always be three essential and interrelated elements of planetary exploration. Over the last 50 years since a human first stepped on the surface of the Moon, remarkable insight as well as science challenges have evolved considerably with each of these components.

It is well to reflect on lessons learned as we enter the next several decades during which we will be able to employ increasingly more sophisticated instruments. Significant advancements will be made 1) in orbit to identify resource location and characterize the geologic context of targets, 2) on the ground to assess local properties and environment, and 3) in Earth-based laboratories to document details of crustal/mantle properties from purposefully selected new samples. All three elements are directly and cyclically interrelated. Here we highlight two areas for discussion with needs and requirements for targeted lunar sample collection.

Diversity: A thorough assessment of the diversity of materials at a landed site is essential in order to a) understand what is *typical* or representative of the region as well as to b) identify *unusual* or pristine components that provide links to understanding the complex evolution of the local crust. A good example of the latter is the discovery and sampling of the unexpected 'orange soil' by astronaut H. Schmitt at Apollo 17. At every landed site, assessment of what is typical and what is unusual is essential (either by trained astronauts or by in-situ instruments). The particularly valuable <1% of rock lithologies that have escaped extensive reprocessing can be identified, targeted, and collected as hand specimens.

Most areas on the Moon have experienced multiple impact events that redistributed and mixed crustal elements. One sound approach to establishing a statistical assessment of different components that contribute to a site is one proposed by MoonRise SPA sample return [1, 2]. Based on Apollo knowledge of lunar regolith evolution, a well-developed (mature) regolith contains regional lithologic components in a processed mixture that has evolved over millions of years. Nature + time has prepared a representative mixture for us. High-grading a large amount well-developed soil and collecting its population of small rock fragments provides a statistically significant (unbiased) record of the lithologic diversity of the region.

Ground Truth: We recognize that a special weathering environment exists across the Moon, and that materials on the lunar surface have been systematically altered with time by complex space weathering processes [3]. Apollo samples have documented how soils from a single site are not all alike. To link with remote measurements [e.g. 4], soils representative of (undisturbed) regions need to be collected from areas unaffected by (or shielded from) recent geologic events, including human or robotic presence.

In addition to establishing the ground truth link for local lunar soils, the use of advanced remote sensing now can extend detailed information from sampled rock lithologies to small un-sampled outcrops exposed across the Moon. As we move forward, remote compositional analyses need to again be validated with direct analyses of appropriate samples. In other words, 'ground truth' needs to also be confirmed between remote measurements of rocky outcrops and direct measurement of lithologic samples as would be found in their natural lunar environment. Several well documented Apollo rocks collected with their exposed surface may meet this requirement.

Compositional remote sensors continue to improve in spectral and spatial resolution (and coverage). The remarkable ability to remotely identify and explore important but challenging lunar areas that are difficult for humans to access (such as rough terrain across large craters) will become increasingly valuable, and are excellent examples of human-robotic partnership in the years ahead.

References: [1] Jolliff et al., 2017, LPSC48 #1300. [2] Jolliff and Korotev, 2019, LPSC50 #2706. [3] Pieters and Noble, 2016, JGRP. 121, 1865–1884, [4] Pieters 1999, Workshop New Views of the Moon, #8025