

## LUNAR SURFACE INSTRUMENTATION FOR SAMPLE SELECTION

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**Introduction:** Some of the most intriguing scientific opportunities made possible by renewed lunar exploration require selection of appropriate samples for subsequent analysis on the Moon or in Earth-based laboratories. Therefore, it is important that the architecture for future lunar field science by astronauts maximize the efficiency of sample selection.

For example, one of the major unresolved scientific legacies of the Apollo era is evidence of a spike in the impact rate around 3.9 Ga. This “late lunar cataclysm”, first postulated by Tera et. al. [1] and subsequently reviewed by Ryder [2], may have had profound consequences for the timing of the origin of life on Earth and its early evolution. However, the chronology and even the existence of the cataclysm has been questioned, in part because the sampling of impact breccias and melts during the Apollo and Luna missions took place in terrain that was significantly affected by Nectarian Period impact events, which might result in an age bias in the dated samples. Therefore, a key to better constraining the bombardment history is to select samples that are most likely to represent the diversity of lunar geology. Such sample selection requires careful geological characterization of landing sites, to include searching for materials anomalous for a given field area and hence likely to be derived from diverse locales.

The search for locally-anomalous materials is also important because they might be ancient samples of the Earth, Mars, or Venus. The analysis of such samples would be very valuable scientifically. The challenge is that while it is certain that such extra-lunar materials exist on the Moon their distributions are entirely unknown.

The high costs of working on the Moon, and of returning samples to the Earth, places a particular premium on selecting samples quickly and correctly. It will therefore be critical to equip future astronauts with tools that facilitate rapid reconnaissance of field sites, as well as mineralogical and chemical characterization of outcrops and hand specimens. To do this, a number of remote sensing and contact instruments could be employed. The technology for such instruments has evolved drastically since the Apollo era. Some such

instruments already exist as robust, off-the-shelf commercial hand-held devices for geological exploration on Earth that might be straightforwardly adapted for lunar field science. Instruments could also be derived from technologies that have proven themselves in robotic planetary exploration.

**Remote Sensing Instrumentation:** The first step in sample selection is site survey, in which conventional visual imaging could be augmented by instrumentation such as lidar and 3D artificial vision systems.

Calhoun and Spray et. al. [3] have worked with Optech Incorporated on evaluating lidar technology as a classification tool for lunar geology. Laboratory testing with an ILRIS (Intelligent Laser Ranging and Imaging System) originally developed to inspect the Space Shuttle’s heat shield tiles has shown that using lidar to differentiate between mafic and felsic samples is feasible provided proper characterization and calibration are done. Characterization must also address the effects of specular and diffuse reflection. Further development will be required to improve reproducibility, resolution, and speed.

An artificial vision system developed by MDA called Instant Scene Modeler (iSM) uses images from a hand-held or vehicle-mounted camera to produce photorealistic 3D images. This system has been demonstrated in terrestrial mining applications [4]. Results are available within minutes of acquisition, and sample surface texture is captured in the 3D models.

An ability to remotely quantify rock size, distance, and type using systems such as lidar and iSM, which are capable of accuracy and resolution superior to that obtained from orbital imagery, could be a significant advantage in field exploration by reducing time and risk. For example, one could envision a robotic “field assistant” equipped with remote sensing instrumentation to evaluate rocks and provide terrain data to an augmented reality display inside an astronaut’s visor. These data could then be used by the astronaut to decide whether it is scientifically valuable and safe to venture into an unknown region.

Once promising samples have been tentatively identified by remote sensing, further screening can be performed using contact instrumentation.

**Contact Instrumentation:** X-ray techniques are a powerful way to determine the elemental composition of geological samples. In the past decade devices based on such techniques have been flown and have also been integrated into hand-held devices for field exploration.

A key contact instrument that could be employed for lunar sample selection is the alpha particle x-ray spectrometer (APXS). This sensor is placed in contact with a sample that is irradiated with alpha particles and x-rays from a radioactive source. The composition of the sample is then determined from the backscatter spectra.

The APXS that will be flown on the Mars Science Laboratory (MSL) mission, for which MDA is the prime contractor, employs a  $\text{Cm}^{244}$  source that emits alpha particles as it decays to  $\text{Pu}^{240}$ . In turn, x-rays are produced by  $\text{Pu}^{240}$  decay. Particle induced x-ray excitation (PIXE) produces lines for low Z elements from Na to Ti, and x-ray fluorescence (XRF) produces lines for higher Z elements from Cr to Br, with weaker returns for Rb and Sr. Figure 1 shows the sensitivity of APXS in the PIXE and XRF domains.

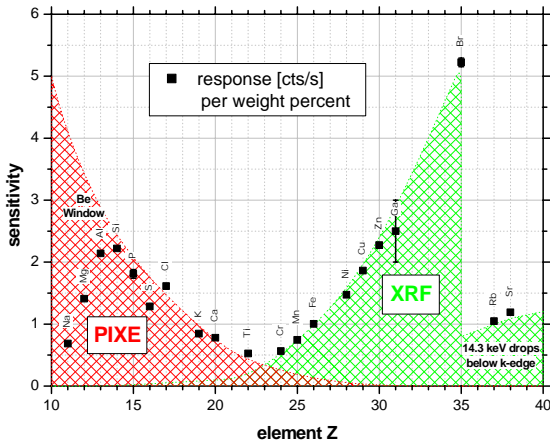


Figure 1: Elemental Sensitivity of APXS

APXS has significant heritage in robotic exploration, having flown previously on the Mars Pathfinder and Mars Exploration Rover (MER) missions [5], with a third unit now being prepared for the MSL rover in 2009. While APXS has never been used on the Moon, there are no constraints that would preclude its operation in the lunar environment, either

on a robotic assistant or integrated into a hand-held device.

The potential utility of hand-held, astronaut-operated x-ray devices for in-situ elemental analysis of lunar samples can be seen in the Field Portable X-Ray Fluorescence (FP-XRF) instruments originally developed by NITON, LLC. These devices can quantify the abundances of elements from Mg to U. Also referred to as handheld XRF, the instruments may be optimized for elements of interest without opening the housing or carrying extra tools. Miniaturized x-ray tube sources allow for an adjustment to the energy of the beam which can focus analysis in specific areas of the spectrum. Radioisotope sources ( $\text{Fe}^{55}$ ,  $\text{Am}^{241}$ , and  $\text{Cd}^{109}$ ) are also available for excitation of a range of elements. Recent advances in calibration methods obviate the need for site-specific standards and calibrations, automatically compensating for differing mineralogies, densities, and other sample characteristics. As a result, accurate results can be obtained rapidly in the field.

**Conclusion:** The scientific returns from lunar exploration can be enhanced by efficient sample selection, which in turn requires rapid geological and geochemical exploration of lunar field sites. Remote sensing instrumentation such as lidar and iSM, and contact instruments like APXS and handheld XRF, can play a crucial role in this exploration. Significant heritage exists for these technologies that can be leveraged in developing new tools for lunar surface science.

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