ENABLING GLOBAL LUNAR SAMPLE RETURN AND LIFE-DETECTION STUDIES USING A DEEP-SPACE GATEWAY. B. A. Cohen[1], J. A. Eigenbrode[1], K. E. Young[2], J. E. Bleacher[1], M. E. Trainer[1]. [1]NASA Goddard Space Flight Center (barbara.a.cohen@nasa.gov), [2]UTEP/Jacobs-JETS Contract/NASA Johnson Space Center

Introduction: Sample studies underpin the foundation of our knowledge of the origin and evolution of the Moon and other planets [1]. The Moon is the best understood extra-terrestrial object because of the samples returned by the Apollo program. Samples provide a unique perspective based on the high spatial resolution and high analytical precision capabilities of terrestrial laboratories. Even relatively small samples record planetary- and solar system-scale processes. Combined with orbital and ground-based measurements, samples provide ground truth and enable interpretation within a planetary context.

Samples also help prepare for human lunar return and in situ resource utilization for commercial exploitation. Samples help validate orbital observations in unvisited terrains, enabling prospecting for similarly-sited deposits, as well as providing detailed evaluation of the composition (and contamination) of potential resources, e.g., Ti in pyroclastic deposits and lunar polar volatiles.

There are many more sites representing the Moon's rich geologic diversity than we have visited. Sites that would benefit from sample return include (but are certainly not limited to) impact-melt flows in lunar basins such as the South Pole-Aitken Basin, Nectaris and Crisium, key benchmark craters such as Copernicus, young volcanic materials with a range of compositions, felsic extrusive provenances, resource-bearing deposits, and places where orbital remote sensing has identified lithologies that are not present in the current sample collection [2-4].

Lunar Sample Return: The Deep-Space Gateway (DSG) could uniquely enable a lunar robotic sampling campaign that would provide incredible science return for a drastically reduced cost, compared with traditional approaches of single-launch robotic sample return to earth. In this scenario, the DSG would be the base of a cycler system for lunar landers, each of which would be refueled at the DSG and redeployed to different landing sites. Such an approach could be coupled with commercial interest in lunar cargo services and international interest in robotic lunar missions to further leverage a cycler concept.

Returning samples to the DSG as a stepping stone for returning samples to Earth would allow for sample high-grading as well as, in a multiple lander scenario, allow for designing future traverses. Complementary DSG analysis also allows more sample weight, which translates to more and larger samples that can be studied in context and by consortium. Risk and cost of sample return (SR) missions are perceived as having a higher risk and cost than other planetary exploration missions.

Not having to launch separate lunar surface missions, but rather using a reusable lander refitted with descent and ascent solid rocket motors at the DSG, would uniquely enable samples from multiple locations to be returned. This would represent an incredible bounty of lunar science at a drastically reduced cost, pushing the "science per dollar" through the roof.

A campaign of multiple landers could also update and test technologies at system and subsystem levels – for example, new algorithms for precision landing and hazard avoidance, and different modes and controls for coring and sample manipulation. International cooperation on SR missions could be enabled by specific reusable hardware contributions, or by revising the science team for each mission based on science and technology interests across international programs.

Onboard sample processing: Returning samples to the DSG also opens up the possibility of human-tended onboard sample processing. The main value of sample return lies in the ability of terrestrial laboratories to collaborate using sophisticated analysis techniques enabling high spatial resolution and high analytical precision. Despite advances in in situ instrumentation, it is unlikely that onboard examination will be sufficient to answer the questions motivating scientific sample return. However, there is an important role for onboard processing, which is using lunar samples as an *in situ* life-detection blank.

Life detection techniques are being developed for in situ analyses of extant and extinct lifeforms at destinations like Mars, Europa, and Enceladus. However, two fundamental issue with these techniques are how to sufficiently decontaminate instruments (removal of biomolecules and other interferences) as to maintain science integrity, and how to disentangle abiotic organic signals from biotic ones. Analytical approaches to life detection involve molecular detection, often at trace levels. Thus, removal of biological materials and other organic molecules from devices used for sampling and analysis is essential for ascertaining meaningful results.

The Moon is known to be lifeless, but its regolith has a non-trivial organic component contributed over aeons by comets and asteroids. These samples could be analyzed by instruments in a BioLab/GeoLab-like configuration [5] that has been sterilized using best practices and segregated from the crew cabin or otherwise attached to the external surface of the DSG. If a sample return capsule is configured with dual chambers, astronauts aboard the DSG would be able to ingest and manipulate a subsplit of samples without opening the main lunar sample container. BioLab/GeoLab instruments would include those for the detection of biotic and abiotic molecular signatures (e.g. chromatography combined with mass spectrometry or capillary electrophoresis, tests for polyelectrolytes and related biopolymers), contextual measurement devices (e.g. spectral mapping, x-ray diffraction, gas analysis instruments), and instruments for investigating morphological features or activities (various forms of microscopy from fluorescence to scanning electron).

Such activities would buy down significant risk in future life-detection activities by demonstrating required blank levels, testing sterilization techniques, and developing confidence in the community in how to robustly interpret life-detection results.

In a mission architecture with multiple landers that will potentially include teleoperating robotic assets on the surface, having a GeoLab capable of providing a quick look at the chemistry and mineralogy of samples prior to SR to Earth would provide the robotic operators (whether they be Earth or DSG-based) with more information about how to plan and execute traverses as well as how to select landing sites. Though the most valuable scientific work will occur in laboratories on Earth, this near in situ processing gives the distinct advantage of providing the crew and supporting science teams with a higher resolution look at the samples without undergoing the risk of returning samples all the way to the Earth's surface.

Conclusions: Sample analysis is an extremely critical step in the process of unraveling the history and evolution of our nearest neighbor. Though DSG-based analyses will never replace the need for more thorough laboratory work, these analyses do have the ability to maximize the science return of a sustained human presence in lunar orbit. Including sample analysis capabilities on the DSG could provide scientists with an efficient and valuable way to interrogate samples prior to return to Earth, while preserving and even enhancing the ability of scientists in Earth-based laboratories to access and analyze the most valuable sampling targets.

References:

[1] Shearer, C. and L. Borg (2006) *Chemie der Erde* **66**, 163-185.
[2] Neal, C.R. and S.J. Lawrence (2017) *Planetary Science Vision 2050 Workshop*,
[3] Neal, C.R. and S.J. Lawrence (2017) *LPI Contributions* **2041**.
[4] Ryder, G., et al. (1989) *EOS* **70**, 1495.
[5] Evans, C.A., et al. (2013) *Acta Astronautica* **90**, 289-300.