Analytical Capabilities: In-situ vs Mass of Returned Lunar Samples
The Immense Science Value of Lunar Samples

- Terrestrial records of the first few billion years of Earth’s history are largely lost to time, due to the actions of plate tectonics, volcanism, and erosion by oceans, rain, and wind.
- The Moon is spared many of these processes, with lunar samples ranging in age from a few hundred million years to more than 4 billion years old.
- Lunar samples therefore represent immensely valuable scientific records for the Earth-Moon system, as well as for Mars and other planets.

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Apollo and Artemis

• The Apollo missions collected 382kg of lunar samples. However, samples were taken from similar areas of the Moon
• Many regions of the Moon, including diverse geologic terrains, and the lunar poles, remain unsampled
• Even within the Apollo landing sites, some collected rock types are represented by only a single sample. Other rock types even at these landing sites were likely not sampled.
• More samples, from more diverse sites, are needed to fully understand lunar history
What Can We Achieve In Situ?

- Miniaturization of scientific instruments enable significantly more science to be conducted by missions today than was possible during Apollo.
- A wide range of imaging, spectroscopy, and mass spectrometry can be conducted by mission instruments.
- Mission instruments are capable of characterizing mineralogy, identifying chemical compounds, and – for a subset of targets – provide useful information on the age of a sample.
- Many more opportunities are available for in situ analyses due to the number of smaller, lighter, and uncrewed missions.
What Can We Achieve with Sample Return?

- Sample return provides access to laboratories and instruments on Earth which have vastly superior accuracy and precision than is possible on small mission instruments.

- Complex sample preparation is required for many types of scientific analyses, e.g. separation of components, acid digestion, ion chromatography.

- A tailored analytical workflow can be followed for even tiny aliquots of individual samples, ranging from 3D analyses, to detailed mineralogy and chemistry, and age dating of a sample.

- Samples can be curated for years or even decades and be re-analyzed as scientific instruments and knowledge improve.

Mineralogy and chemistry of the Moon imaged at the nanometer scale (NASA JSC/Thomas-Keprta et al., 2014)
Looking to the Future

• Some science questions can currently be answered by in situ instruments, while many others require sample return.

• Continued development of mission instruments will enable more science questions to be addressed in situ, especially for small or uncrewed missions where sample return is not viable.

• However, many laboratory instruments, as well as the infrastructure required to prepare samples for analysis (e.g., separation of components, acid digestion, ion chromatography), are difficult to reconcile with miniaturization.

• The question of what can be achieved in situ versus returned samples should be addressed on a case-by-case basis; broad Artemis and Moon-to-Mars objectives are achievable only though an integrated strategy involving both in situ analysis and return of samples to Earth.