A South Pole-Aitken Basin Sample Return Mission Using Commercial Rovers and Landers

Response to Call for Mission Concept and Technology Needs Abstracts for NASA SMD's Technology Showcase for Planetary Science

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INTRODUCTION: The 2022 Planetary Science and Astrobiology Decadal Survey declares that a robust lunar exploration program necessitates a working synergy between the Human Exploration and Science Mission Directorates at NASA [1]. The report specifically recognizes JPL's Endurance-A sample return campaign from the South Pole-Aitken (SPA) impact basin as exemplifying human-enabled decadal science at the Moon.

The SPA is the largest and oldest of its kind on the Moon and, perhaps, the entire solar system. The SPA essentially functions as a time machine from which critical data about the formation and early history of the solar system can be acquired via in-situ measurements and sample return to Earth. Additionally, the impact that created the SPA basin may have uncovered material from the mantle, which can provide insight into the thermochemical processes in the formation of rocky bodies.

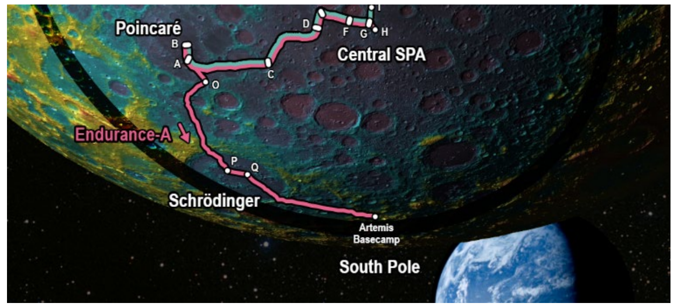

Figure 1: The Endurance-A traverse across the South Pole-Aitken Impact Basin to the Artemis Basecamp [2]

According to the Decadal Survey, the JPL Endurance-A rover has the potential to revolutionize our understanding of the Moon and the early history of the solar system by traversing 2000km over diverse terrains and collecting a suite of 12 samples (~100kg in total) across a number of sites in the SPA [2] (Figure 1). The rover will then deliver the curated samples to an Artemis program human landing site, where astronauts will subsequently retrieve them and return them to Earth.

Despite SPA sample return mission concepts being proposed in the three most recent Decadal Surveys and Endurance-A being identified as the highest priority of the NASA Lunar Discovery and Exploration Program in the current Decadal Survey, the mission will not land on the Moon until 2030 and the samples will not return to Earth before 2034. JPL has also estimated that the Endurance-A mission will cost more than $1.5 billion to execute. In an era of increasingly strained budgets, it is important for NASA to take advantage of its existing investments in lunar landing and to also lean on industry for new approaches that allow maximum science return across the broad spectrum of competing objectives and priorities.

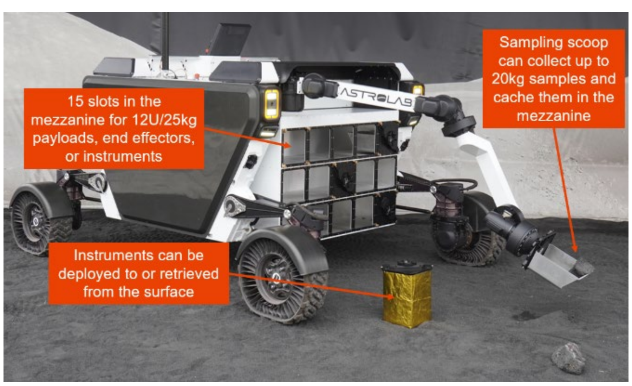

Figure 2: A terrestrial prototype of the FLEX rover, which can collect 100s of kg of samples with its 6-DoF robotic arm

A NEW APPROACH: Astrolab was founded by veterans of SpaceX, NASA, and JPL to bring commercial innovation and cost efficiency to planetary surface mobility and robotics. To that end, Astrolab is developing the multi-functional Flexible Logistics & Exploration (FLEX) (Figure 2) rover from ground up to be the most versatile, capable, and cost-effective rover ever made. FLEX can be launched as early as 2026 as a rideshare payload on SpaceX's Starship Human Landing System (HLS) or other HLS/Commercial Lunar Payload Services (CLPS) landers under development. The rover can drive more than 1000 km/year and is equipped with a 2m-long, six degree-of-freedom (DoF) robotic arm with swappable end effector. FLEX can collect and cache sample batches of up to 20 kg at a time (and 100s of kg in aggregate) and deploy a multitude of scientific instruments/experiments. In addition to conducting robotic science, FLEX can also be configured to provide unpressurized mobility for a crew of two astronauts and their equipment - consistent with the requirements of the Lunar Terrain Vehicle (LTV) program.

With FLEX, the Endurance-A science goals can be achieved at a fraction of the cost (less than $300M - including instrument development and launch/landing) while returning samples as soon as the very first human landing (Artemis III). Essentially, FLEX can do the science of a New Frontiers class mission at less than the cost of a Discovery class mission and return the samples nearly a decade sooner than currently planned.

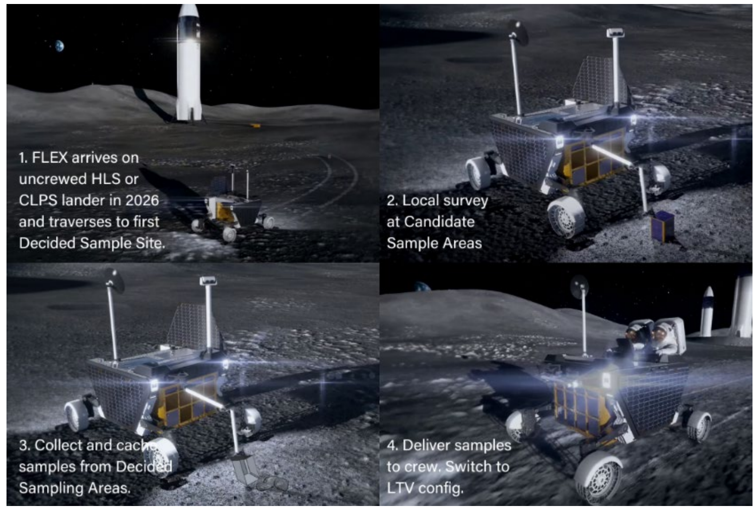

Figure 3: Concept of operations for a FLEX rover SPA sample return mission

FLEX's robotic arm mezzanine module shown in Figure 2 can host all of the moving and static instruments from Endurance-A, including the Magnetometer (Mag), Point Spectrometer (PS), Gamma Ray Neutron Spectrometer (GRNS), Alpha Particle X-ray Spectrometer (APXS), and Hands Lens Imagers (HLI). The instruments can be easily accommodated in three or fewer of the fifteen total 12U (22cm X 22cm X 36cm) mezzanine slots. The remaining twelve mezzanine slots can contain sample caching scoops (20 kg max. capacity each). The robotic arm will be used to deploy and point the instruments and then subsequently fill the sampling scoop containers and cache them back in the mezzanine for transport to the Artemis crewed mission landing area.

CONCEPT OF OPERATIONS: The overall Concept of Operations (ConOps) of the Commercial South Pole-Aitken Sample Return Mission is shown in Figure 3. After FLEX is off-loaded from a Starship HLS (or other HLS/CLPS lander) and performs essential deployment and setup activities, it would be ready to start its traverse as envisioned in the Endurance-A concept. Note that the following steps are directly taken from the referenced mission: Upon arriving at the first of twelve sample sites, it would perform a local survey to study mineralogy, elemental composition, and sample potential of five Candidate Sample Areas (CSA) distributed at ~30 m from each other. Up to three areas would be selected for in-depth elemental composition analysis - called Candidate Sample Area Survey. When traversing to and from each CSA, FLEX would stop every ~10 m to take additional images and spectra and help the science team decide if the original path is to be followed or if there are new findings that merit changes to the plan. Once each CSA has been investigated, the science team would determine to which area FLEX would need to return to collect and cache the sample. This area is called Decided Sample Area. With the sample stored inside the mezzanine, FLEX would continue its journey to the following sample sites. It will repeat the same process until all twelve pre-selected sites have been visited and samples have been acquired. Then, the rover would continue supporting science and mission support activities before it arrives at the Artemis human landing site, where the crew will retrieve the samples. At this point, FLEX will finish its robotic sample return campaign and can change into the Lunar Terrain Vehicle configuration for augmented crew surface mobility and science return.

References:
[1] National Academies of Science. (2022). Origins, Worlds, and Life: A Decadal Strategy for Planetary Science and Astrobiology 2023-2032. Washington, DC: The National Academies Press. https://doi.org/10.17226/26522.
[2] James Tuttle Keane, Sonia M. Tikoo, & John Elliot. (2022). Endurance: South Pole-Aitken Traverse and Sample Return Rover. NASA.