

A Notional Artemis Lunar Surface Exploration Package (ArLSEP) based on the Gandalf Staff Platform. M. E. Evans¹, M. D. Leonard², and J. A. Morgan³, ¹NASA Johnson Space Center ARES (2101 NASA Parkway, Houston, Tx. 77059 Mail Code XI4, michael.e.evans@nasa.gov), ²Texas Space Technology Applications, and Research (T STAR), ³Texas A&M University Department of Engineering Technology and Industrial Distribution

Introduction: The Artemis program is planning to deliver crew and cargo to the lunar surface, but there is no current package for supporting lunar instruments and experiments similar to the Apollo Lunar Surface Exploration Package (ALSEP). This abstract provides a possible concept for such a package using the Gandalf Staff Platform as a common core.

Gandalf Staff: The Gandalf Staff is an early prototype system developed over FY'21/FY'22 using NASA Science Technology Mission Directorate (STMD) Center Information Fund (CIF) grants to design, build and test “proof-of-concept” components. These components include a 24v battery powered monopole that powers a suite of subsystems, including a Graphical User Interface (GUI) for crew, surface voice and data communications, Lunar Search and Rescue (LunaSAR) navigation and communications, LiDAR, field site external lighting, 360-degree camera, and a geothermal instrument for measuring subsurface temperature gradient. The staff can be carried independently by an Extra-Vehicular Activity (EVA) astronaut, or can be mounted into a tripod for “hands free” support at a surface site being investigated. The staff can be attached to an external solar array and power storage system for long-duration operations. [1,2]

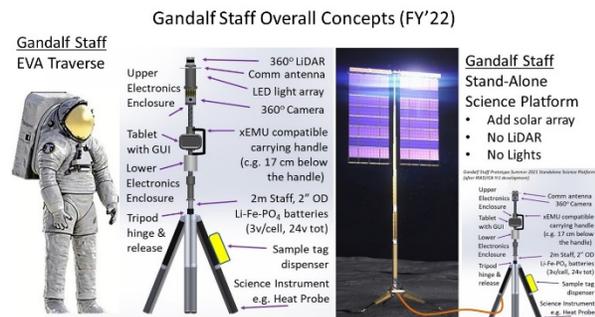


Figure 1 : Gandalf Staff Prototype (FY'21, Year 1)

ALSEP: An ASLEP flew on each mission Apollo 12 to Apollo 17. For Apollo 11, a simplified packaged called the Early Apollo Scientific Experiments Package (EASEP) was flown. Each package included a “Central Station” that provided the power and communications connected to a variety of instruments and sensors. The power was provided by a Radioisotope Thermoelectric Generator (RTG) fueled by Plutonium-238 generating 70 watts of power (initially, decayed over time) [3].

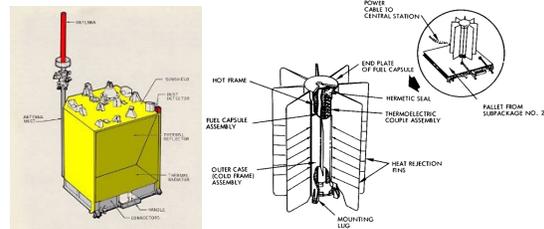


Figure 2: ALSEP Central Station (left) and schematic for RTG (right)

The communications system provide for direct to Earth data transfer from the lunar surface. Each package was stowed externally in the Lunar Module (LM) Scientific Equipment (SEQ) bay with a mass up to 163 kg (Apollo 17).

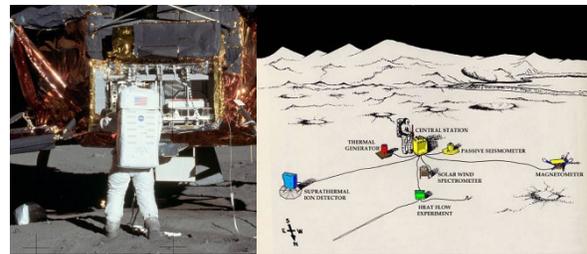


Figure 3: ALSEP stowed in LM (left) and deployed on lunar surface (right)

The crew unloaded the ALSEP from the LM and deployed the instruments on the lunar surface. Although designed to operate for only 1 year, many sites operated for up to 8 years successfully [4]. The Active Seismic Experiment (ASE) included 3 geophones for detecting seismic waves created by mortars and thumpers deployed by the crew. Other active experiments measured the lunar atmosphere, the heat flow in the subsurface, the lunar gravity and potential gravity waves, the lunar magnetic field, the solar wind and plasma interactions in cislunar space. Passive experiments included collectors for dust and cosmic rays, and retroreflectors for precise measurements of distance using a laser from Earth. The ALSEP program continues to generate insights into lunar formation and evolution.

ArLSEP Concepts: The lunar surface science package for the Artemis program will hopefully exceed the capability of the ALSEP. There are multiple issues for

discussion leading to the design of a new ArLSEP, needing requirements definition from the science community, NASA mission architecture, and NASA budget planners.

1. Delivery Mechanism

Two possible projects currently provide capability to deliver scientific cargo to the lunar surface: 1) the Commercial Lunar Payload Services (CLPS) [5] and the Human Landing System (HLS) [6, 7]. Each project is controlled by a different organization within NASA and budgeted with different criteria although both support lunar exploration. The HLS system delivers crew (and potentially cargo) to human landing sites. If an ArLSEP is “predeployed” to such a site, the design must include power (either from the vehicle or independently) to keep the electronics functioning until deployed by the crew. If an ArLSEP is delivered on a vehicle after the crew is present on the lunar surface, safety protocols require adequate distance from the humans for impact from descent propelled surface regolith ejecta. This distance can not exceed the capability of the crew to walk (if no rover) to the vehicle for ArLSEP deployment.

2. Overall Guidelines

The general design of ArLSEP will likely follow the ALSEP with a common system for communications and power; however, significant architecture differences between Apollo and Artemis exist.

Power: The RTG will not be available for early Artemis missions nor likely follow-on Lunar Exploration Transportation Services (LETS) missions [8]. Thus, ArLSEP power must be supplied by solar arrays with sufficient battery capability to “keep alive” necessary electronics during any lunar surface eclipse period.

Communication: The Artemis program is developing a series of communications satellites for lunar orbit to provide surface transmission of data and voice to Earth. Called “LunaNET”, this network is component useful for ArLSEP since south polar locations may not always have direct “line-of-sight” to Earth [9].

3. Concept of Operations (ConOps)

The general ConOps for ArLSEP is to deliver the package to lunar surface before the crew arrives, and then have the crew deploy the package after some period of time. This requires coordinated design (for power systems) and launch window (for schedule) on both the cargo and crew missions. Once the ArLSEP is deployed, it will operate autonomously for a number of years. It should be designed to be EVA compatible for crew maintenance and upgrade.

4. Notional Design (for discussion purpose only)

The landing site near the South Pole is expected to have no eclipse cycle exceeding 5 days, so the “keep alive” power is 144 hours (6 days to include margin). A 12v ArLSEP will use rechargeable LiFePO₄ cells, which are common in Electric Vehicle (EV) industry. With a current of 5 amps and a 125 watt system, the mass is about 90kg. The comm. system and structure adds another 10kg, thus the “Central Station” is approximately 100kg. The solar power is collected on four arrays (each 2m above the surface), and the entire ArLSEP is designed to stow in a 2m x 1m x 1m volume. The experiment and instrument design will vary for each installation and add mass to the total (although they are expected to fit within the 2m³ volume). Seismic wave generation will likely not be provided with mortars, thus an electric “thumper” will be required. Active instruments such as imaging systems and sensing instruments will benefit from the additional power and communication capability provided by ArLSEP. Passive systems such as retroreflectors, witness plates, and cosmic dust collectors can be added to either the landing vehicle and/or the ArLSEP. With repeated HLS missions to the same human site, the ArLSEP can be expanded and easily maintained for long duration science collection on the lunar surface.

References: [1] Evans, M. E., et al. (2020), The Artemis “Gandalf’s Staff” Science Suite for Crew EVA Lunar Field Geology, LPSC. [2] Evans, M., et al. (2021). Initial Prototype Work on Artemis “Gandalf’s Staff”- Science Suite on a Lunar EVA Walking Stick, LPSC. [3] NASA (2008), “Apollo Lunar Surface Experiments Package (ALSEP), from <https://www.hq.nasa.gov/alsj/HamishALSEP.html>. [4] Bates, J. R., et al. (1979), ALSEP termination report, NASA. [5] Bussey, B., et al. (2019). NASA’s Lunar Discovery And Exploration Program, AGU Fall Meeting Abstracts. [6] NASA (2020a), “NASA Selects Blue Origin, Dynetics, SpaceX for Artemis Human Landers” from <https://www.nasa.gov/feature/nasa-selects-blue-origin-dynetics-spacex-for-artemis-human-landers>. [7] NASA (2020b), “NextSTEP H: Human Landing System” from <https://www.nasa.gov/nextstep/humanlander2>. [8] Spaceflight.Com (2021). “NASA Lunar Exploration Transportation Services (LETS) RFI and Appendix N BAA” <https://forum.nasaspaceflight.com/index.php?topic=53708.0>. [9] Israel, D. J., et al. (2020), Lunanet: a flexible and extensible lunar exploration communications and navigation infrastructure, IEEE.