The Gandalf Staff: A Mobile, Self-Powered Platform for Lunar Surface Exploration

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TEXAS SPACE, TECHNOLOGY, APPLICATIONS & RESEARCH

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Gandalf Staff Project

The Gandalf Staff is an early prototype system developed to support requirements development for Artemis lunar surface exploration. The project has been funded in FY'21/FY'22 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 a external solar arrays and a power storage system for long-duration operations. [1,2]

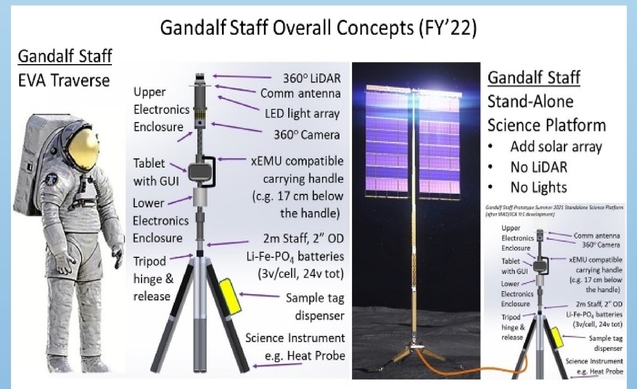


Figure 1: Gandalf Staff Design Concepts

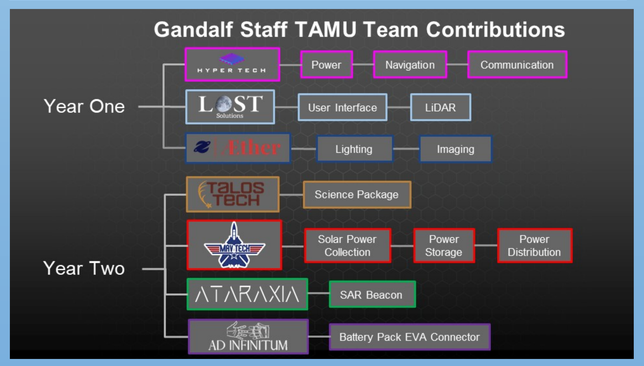
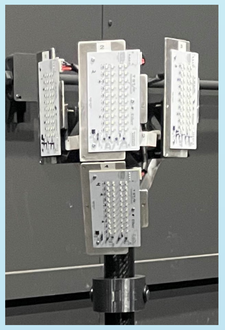


Figure 2: TAMU Capstone Student Teams developing prototypes

Prototype Development

The project uses an innovative collaboration for rapid prototyping with senior Capstone students in the Texas A&M University (TAMU) Engineering College. NASA provides funds, project management, requirements, & Subject Matter Experts (SMEs). T STAR and TAMU faculty mentor each student team for design, build and test over a 1-year period.



Insert: 4-card external illumination system (actual)

Figure 3: FY'22 CAD Design of Gandalf Staff – Elements from top downward: LiDAR, Lights, 360-degree Cameras, Router inside Electronics enclosure, Tablet with GUI, Grab Handle, Support Tripods, Rechargeable $LiFePO_4$ batteries (internal to central pole)

External Lighting Systems Tests (Sept. & Dec. 2021)

The first-generation lighting system (FY'21) includes 4 cards (each containing 40 LED bulbs) capable of generating 1460 Lux at 2m range (near field) or 2 Lux at 50m (far field). The 2nd generation design (FY'22) incorporates technology similar to the xEMU helmet lights with lens for beam focusing and holographic diffusers for enhanced site illumination.

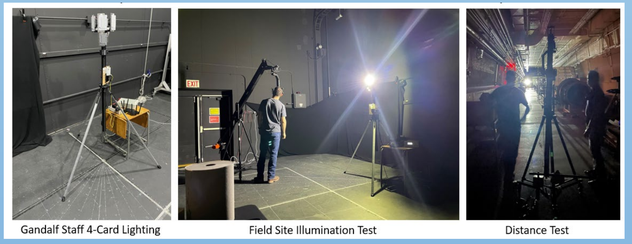


Figure 4: Testing Gandalf Staff at NASA/JSC/B14 lighting lab.

Figure 5: Live demonstration at AGU 2021 NASA booth

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 Experiment Package (ALSEP), from https://www.hq.nasa.gov/alsj/HamishALSEP.html.

ALSEP

An Apollo Lunar Surface Experiment Package (ALSEP) 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].

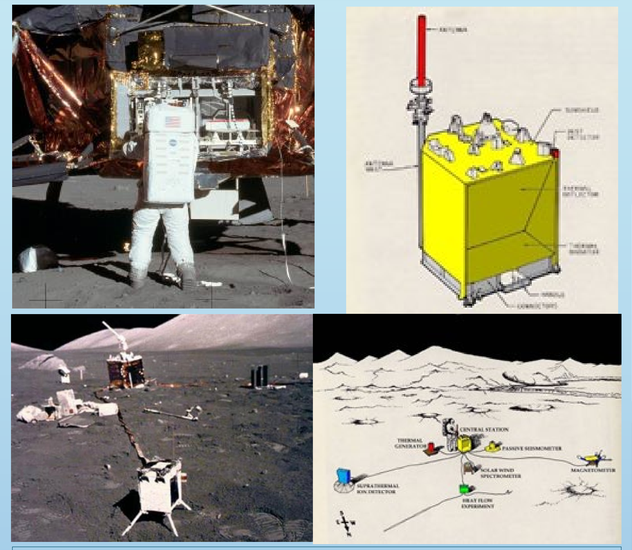


Figure 6: Top: Apollo 11 ALSEP stowed in Lunar Module (LM), schematic of ALSEP Central Station. Bottom: Apollo 17 ALSEP deployed (photo and map)

Gandalf Staff for ArLSEP

The power for an ArLSEP will be provided by solar arrays, not an RTG. 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 could use rechargeable $LiFePO_4$ cells, which are common in the 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 (based upon the Gandalf Staff components), thus the "Central Station" is approximately 100kg. The solar power is collected on four arrays (each 2m above the surface), and the entire ArLSEP will 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 $2m^3$ volume. Passive systems such as retroreflectors, witness plates, and cosmic dust collectors can be added to either the landing vehicle or the ArLSEP.

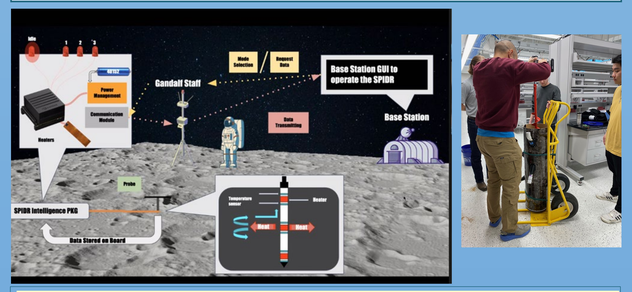


Figure 7: Left: Gandalf Staff concept for ArSLEP on the lunar surface (providing power, comm, and science instruments). Right: Testing prototype of the subsurface thermal probe in simulated regolith

Gandalf Staff Internal Power

The 24v internal power for the Gandalf Staff is from $LiFePO_4$ battery cells located in the lower portion of the staff. The connection between the electronics in the upper staff and the batteries in the lower staff is designed as a simple spring release mechanism compatible with EVA gloves and a dusty environment. When the battery pack is depleted during an EVA, the astronaut can rapidly disconnect the lower staff and replace it with a fully charged set of batteries.

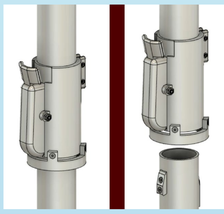


Figure 8: Spring assisted connection lever includes keys on each side to ensure proper orientation, and bristle crusted ring to remove regolith before attachment

Gandalf Staff External Power

The Gandalf Staff can be attached to an external power system for long duration operations as a self-powered platform. Solar arrays provide a 36v charge to the external battery system, which is used in three modes: 1) directly power the Gandalf Staff, 2) recharge the internal batteries on Gandalf Staff, or 3) power an external science platform.

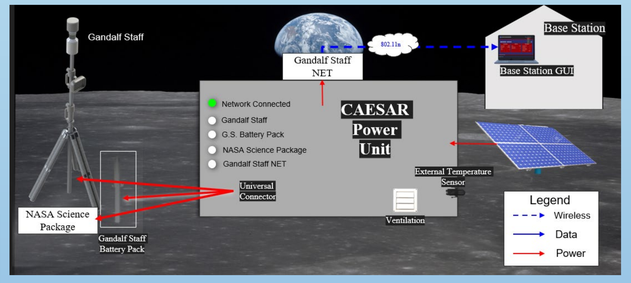


Figure 9: Top: Concept for Gandalf Staff connections to external power system, Middle: Prototype 4 solar panel collection system with three 12v battery storage system, Bottom: Prototype metal enclosure for battery storage system and electronics, next to solar arrays