The Gandalf Staff: A Mobile Tool for Lunar Exploration

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PRESENTED AT:

AGU FALL MEETING
New Orleans, LA & Online Everywhere
13–17 December 2021
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INTRODUCTION

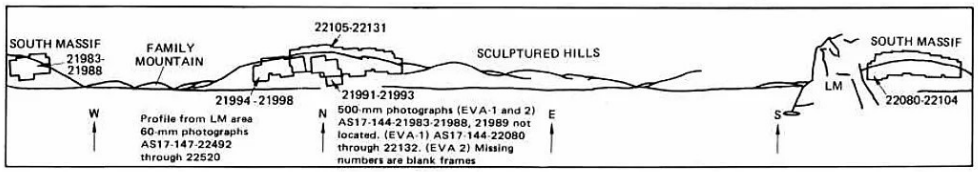
The Apollo program identified a need for a hand-held Extra-Vehicular Activity (EVA) tool to carry a camera, samples, and gnomon with camera calibration bars [1, 2]. Targeted for Apollo 18, the tool never flew; however, it provides the background for a new 21st century lunar surface tool.

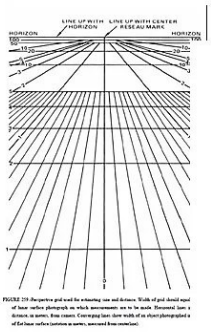
The Artemis program plans to deliver crew to the lunar south pole, which is different from the equatorial Apollo landing sites in many ways. From a lighting prespective, the pole provides no overhead sunlight as the sun skirts around the horizon at a very low angle (ranging from under the horizon to a maximum of 5◦) [3]. This low sun angle creates long shadows at the landing site, with much of the surface hidden in shadows (see video, credit NASA JSC ER7 simulation lab)

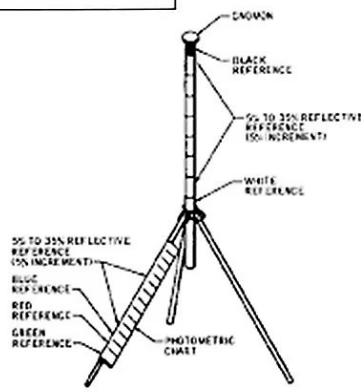
[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638831969/agu-fm2021/6C-1E-FA-84-6E-82-51-0F-F9-79-C7-C5-36-7C-07-0B/Video/Lunar_South_Pole_Lighting_rim_site_uhtogj.mp4

The original gnomon for Apollo provided a simple, gimbaled rod for determination of true vertical in calculating sun angle and direction. Combined with the fiducials on a square reseau plate of the Hasselblad 500/EL data camera, the location and orientation of collected surface samples could later be determined using perspective drawings. This 1960s version of photogrammetry is readily updated using new electronics for lunar sample curation. Gandalf Staff is a 21st tool for photogrammetry (and other users)!

Apollo Lunar Gnomon and Photogrammetry







Data Camera showing raised edges of the réseau plate Front view of the réseau plate with dimensions

Figure 14. Hasselblad 500EL Data Camera

DESIGN CONCEPTS

The conceptual “Gandalf’s Staff” is a rechargeable, battery operated utility platform that hosts multiple electronic components to aid science exploration of the Moon. The staff provides external lighting for illumination of the surface, which aids the crew in identifying, collecting, and documenting the sample curation process. The staff can also provide a LiDAR to create a 3D point cloud for precise distances to all features. When combined with imagery from 360◦ cameras and orientation data from an Inertial Measurement Unit (IMU) on the staff, detailed photogrammetry is created that can be rendered in Augmented Reality (AR) or Virtual Reality (VR). This enables the recreation of Extra Vehicular Activity (EVA) traverses by ground scientists and interested observers who can "walk alongside" the astronauts.

The staff is 2m tall and can be carried by astronauts. It can also be mounted in a tripod base for hands-free operations. As a walking aid, the staff can be used as a crutch or stabilization pole for injured astronauts. Mechanical components include hooks for storing portable equipment, and a tag dispenser for labels on collected samples.

Other electronics on the staff provide communications and navigation relay functions. The astronauts can command features on the staff using a mounted tablet with a simple Graphical User Interface (GUI). The staff can also be commanded from a remote lunar surface workstation (e.g. lander or hab module) or from the Mission Control Center on Earth.

As a stand-alone device, the staff could be attached to external, surface solar array(s) and batteries for power generation and energy storage. This enables long-duration science instruments to measure lunar parameters without the need for astronaut attendance. Examples include geophysical, geochemistry, or observation sensors to measure the lunar environment, the celestial realm, or the Earth.

The novel contracting approach for this project is the use of Capstone senior engineering student teams from Texas A&M University (TAMU) developing "proof-of-concept" prototypes for key components. These teams spend one semester developing requirements and design, and one semester building and testing their product. Successful completion is required for their graduation. This provides NASA rapid development for low cost with high quality results.

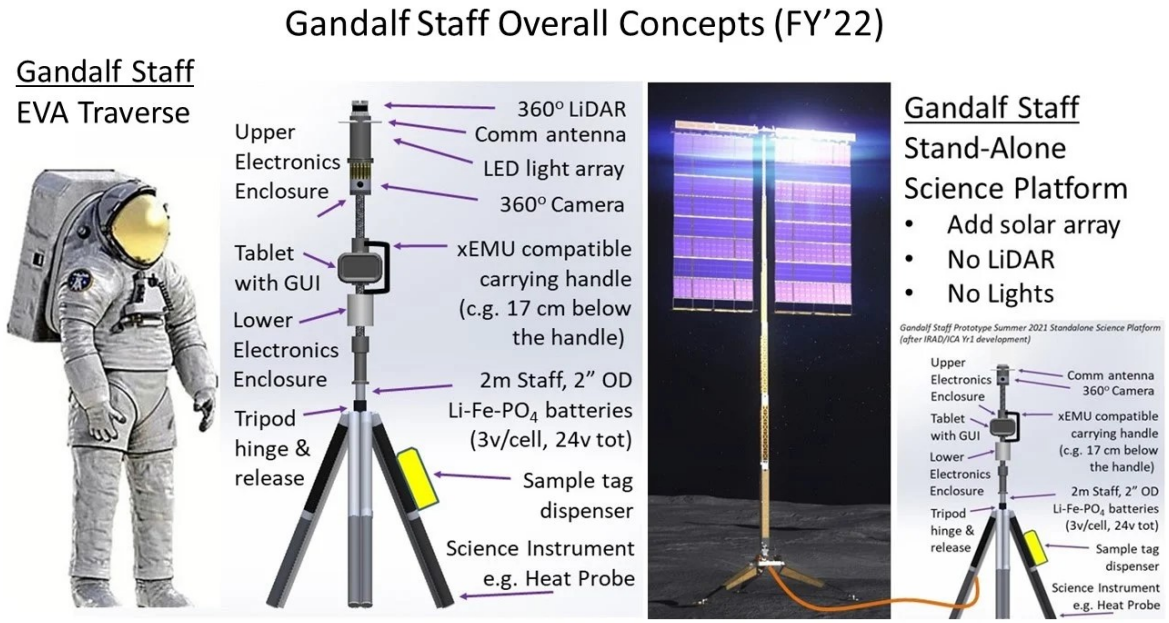
[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638836187/agu-fm2021/6C-1E-FA-84-6E-82-51-0F-F9-79-C7-C5-36-7C-07-0B/Video/Evans-Gandalf_Staff_lkpirx.mp4

The 1st generation lighting concept (video (https://youtu.be/7Rq_HR3gQfI)) is to develop computer boards mounted with rows of LED bulbs that can be controlled by the GUI. The boards are mounted on the top of the Gandalf Staff to provide illumination outwards and downwards. This concept was built and tested by the TAMU "Aether" team in Dec. 2021 (video (https://youtu.be/27iDU0xOtzA)).

The challenge is to focus the light to useful areas on on the surface for crew collecting lunar samples. The power budget is an iterative design process as the Gandalf Staff develops requirements within available battery constraints and bulb technology.

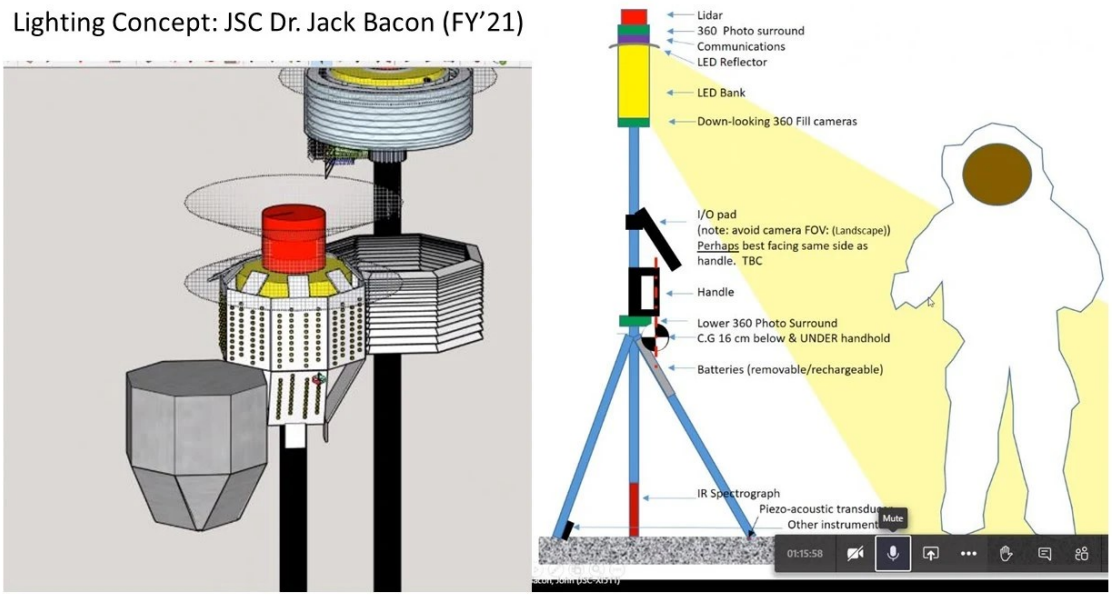
PICTURES OF GANDALF STAFF CONCEPTS

Key Components and Capabilities



CAD Overall Design

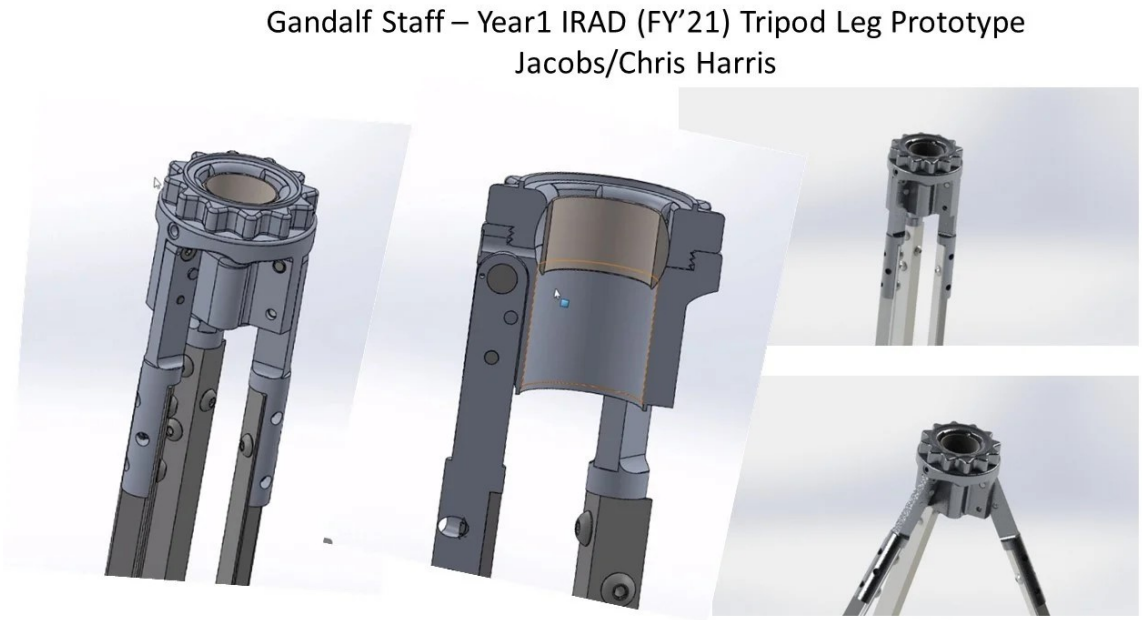
Lighting Concept



PROOF-OF-CONCEPT TEAMS

Jacobs Engineering:

- 1st generation mechanical prototype
- Tripod Stand

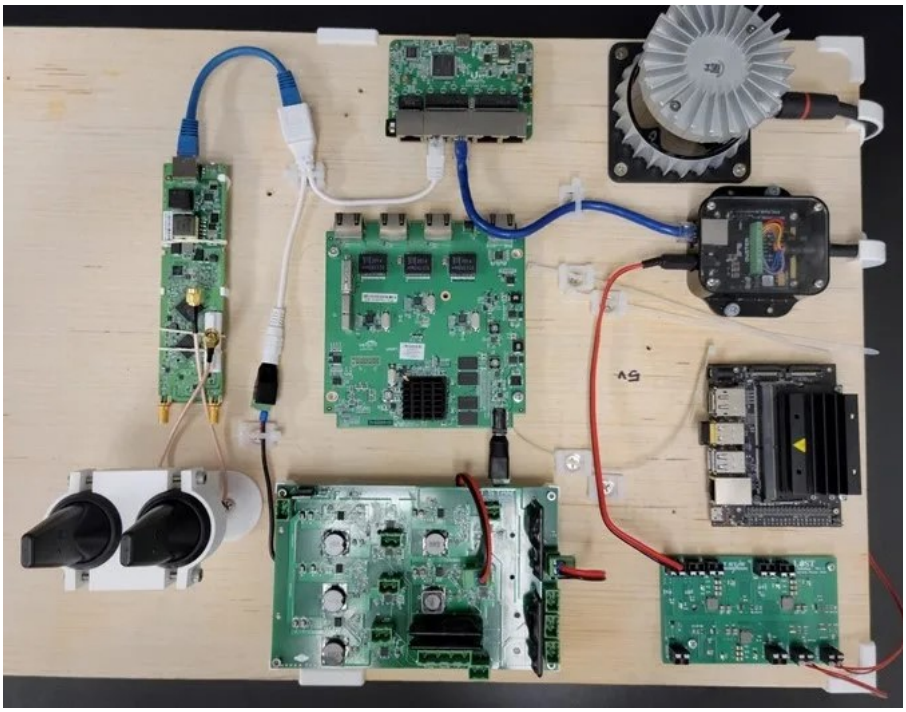


T STAR

2nd generation mechancal prototype for field testing

Table Top version for rapid testing and system evolution

Testbed for geothermal science team ("Talos")



Texas A&M University (TAMU) Engineering Capstone Teams:

- Internal Battery Power ("HyperTech")
- Communications Relay ("HyperTech")
- LiDAR ("LOST")
- Graphical User Interface (GUI) ("LOST")
- External Lighting and 360˚ Cameras ("Aether")
- Lunar Search and Rescue (LunaSAR) ("Ataraxia")
- External Solar Array Power and Energy Storage ("Maverick")
- Swappable Battery Packs ("Ad Infinitum")
- Science geothermal heatprobe instrument ("Talos")

HyperTech Summary

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638835993/agu-fm2021/6C-1E-FA-84-6E-82-51-0F-F9-79-C7-C5-36-7C-07-0B/Video/HT_Showcase_Vid_x2bu9n.mp4

LOST Summary (click on picture for video)

(https://youtu.be/O-Hmr5qvZaM)

Aether Summary

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638835709/agu-fm2021/6C-1E-FA-84-6E-82-51-0F-F9-79-C7-C5-36-7C-07-0B/Video/Aether_-_Poster_Presentation_yissgm.mp4

Ataraxia Summary

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638836058/agu-fm2021/6C-1E-FA-84-6E-82-51-0F-F9-79-C7-C5-36-7C-07-0B/Video/Ataraxia_ye4ywk.mp4

Maverick Summary

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638835903/agu-fm2021/6C-1E-FA-84-6E-82-51-0F-F9-79-C7-C5-36-7C-07-0B/Video/Maverick_Technologies_zgv6mb.mp4

Ad Infinitum Summary

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638835524/agu-fm2021/6C-1E-FA-84-6E-82-51-0F-F9-79-C7-C5-36-7C-07-0B/Video/Ad_Inf_Showcase_Vid_eicy8y.mp4

Talos Summary

[VIDEO] https://res.cloudinary.com/amuze-interactive/video/upload/vc_auto/v1638920905/agu-fm2021/6C-1E-FA-84-6E-82-51-0F-F9-79-C7-C5-36-7C-07-0B/Video/Talos_Tech_NASA_Update_11_12_2021_hbq0p1.mp4

FUTURE WORK

Gandalf Staff is funded by a NASA JSC internal grant for innovative projects working with low TRL techology. Since FY'20, the team has advanced the concept of a self-powered science platform to the component prototype level, but there is much work left to develop an integrated system that is capable of space flight. Many of the concepts may become parts of other projects, but the goal is to develop an integrated system for requirements generation supporting Artemis lunar surface science.

New **component**s are yet to be completed for this goal, including:

1. Photogrammetry using a 3D point cloud from LiDAR integrated with images from an onboard camera system. Rendering in VR and AR

2. Surface navigation using either orbiting satellites or other surface assets to provide detailed location determination. This may augment continued work on LunaSAR for astronaut tracking and rescue

3. Science instrument - contact spectrometer for determination of regolith composition and mineralogy

4. Science instrument - geophysical seismic instrument to support a Lunar Geophysical Network (LGN)

Enhanced **testing** of the Gandalf Staff in relevant environments:

1. LunaSAR component testing (handheld unit with properly formatted message) to terrestrial network of Earth orbiting satellites

1. 2. Lighting lab test to characterize illumination parameters and develop lunar surface requirements. Pics below are from the test in December 2021.

Video from the single LED board testing at JSC lighting lab Sept. 2021: video (https://youtu.be/oeJGKiBXeoM)

3. Field testing of mechanical prototype and/or electronic components to assess ergonomics and EVA viability (click on picture for video of 2021 portable LiDAR field test led by Dr. Michael Zanetti)

(https://youtu.be/_VeQvgsJefc)

AUTHOR INFORMATION

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REFERENCES

[1] NASA (1965) Summer Conference on Lunar Exporation and Science

[2] NASA (1967) Summer Study of Lunar Science and Exploration

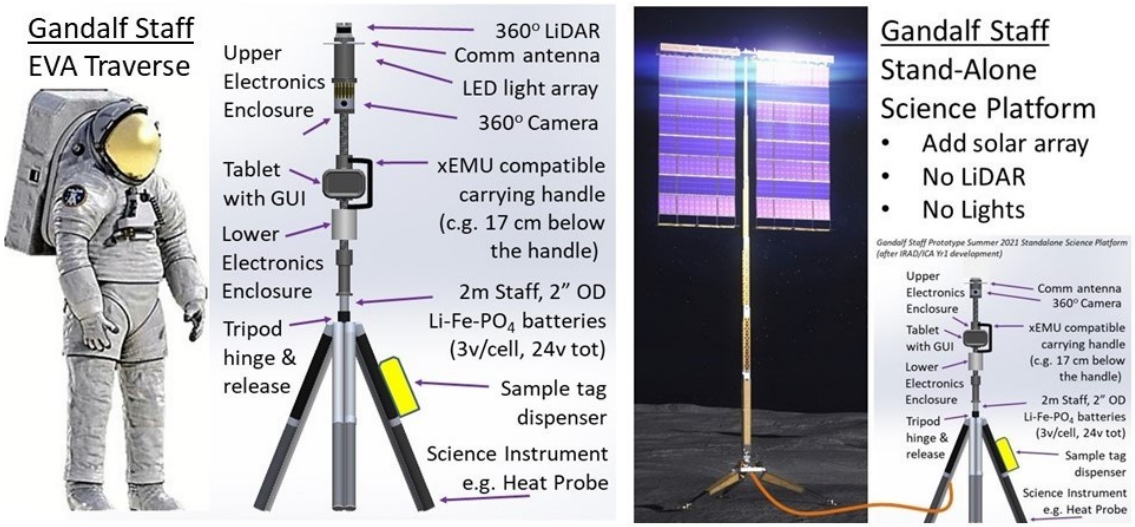
[3] Glaser, P. et al (2014) Illumination conditions at the lunar south pole using high resolution digital terrain models from LOLA, Icarus #243, p78-90

ABSTRACT

The Gandalf Staff is a mobile tool designed to be a flexible device supporting crewed and uncrewed operations on the lunar surface. The core of the device is a 24v battery with communications and data storage systems. Initial optional components supporting crewed Extra-Vehicular Activity (EVA) include a LiDAR and 360˚ camera. These provide 3D mapping of the traverse for documentation, and to aid future planning. The mapping also creates outreach opportunities for the public to "stand beside" the astronaut in Virtual Reality (VR). The staff provides external lighting for field site illumination in the south polar region low sun angle environment. Navigation instruments for crew position determination with Lunar Search and Rescue (LunaSAR) are also included. The staff itself can be used as a walking aid or as a splint for Incapacitated Crew Rescue (ICR). As a stand-alone device, the staff operates as a long duration untended science platform collecting environmental data and sending it to a lunar base station. The stand-alone mode requires connection to an auxiliary power source (e.g. solar array) and energy storage system (e.g. battery), so it could become an electrical recharging station.

To make rapid progress in the 1st year, and also to demonstrate innovative project management techniques, NASA guided a private industry partner, T STAR, in leading Capstone Engineering student teams at Texas A&M University (TAMU) for proof-of-concept development and testing. These teams developed the power system and demonstrated successful integration of LiDAR, WiFi communications, and external lighting subsystems. Another industry team at Jacobs Technology prototyped a tripod to hold the staff upright. For the 2nd year (FY'22), NASA will again collaborate with partners to prototype enhanced power and lighting concepts. Year 2 will also add new capability for LunaSAR and geophysical science instrumentation using a heat probe. The heat probe is based upon Apollo heritage but modified to measure subsurface volatile ice regimes at the Artemis landing site.

Components of the Gandalf Staff can be developed, tested, and deployed independently, or on the integrated staff, rovers, or utility trailers. The project supports crew safety, lunar sample curation, mission science, and public outreach goals of NASA.



(https://agu.confex.com/data/abstract/agu/fm21/4/8/Paper_947284_abstract_879497_0.jpg)