**Effective Approaches and Tools to support ARTEMIS surface activities based Apollo Lessons Learned and Successful Recent Surface Exploration.** P.E. Clark[1], F.J. Calef III[1], and L. Dahl[1], California Institute of Technology Jet Propulsion Laboratory, 4800 Oak Grove Drive, Pasadena, CA 91109 Email: Pamela.E.Clark@JPL.NASA.GOV

**Purpose:** We incorporate lessons learned from the Apollo Program [1] and NASA Mars surface missions with human interactive components to propose approaches and tools to structure a science backroom to work closely with flight personnel including astronauts for the Artemis program during active operations.

**Apollo Context**: The Apollo program presented an extraordinary challenge to mission designers, scientists, and engineers, faced with planning the first robotic and human expeditions to the surface of another solar system body and led to the development of a distinctive and highly successful strategy for humans in the loop, on the ground and at the remote location, exploration. These included:

- limitation of resources on the Moon, including EVA time, mass, and bandwidth,
- the limited availability and ability to utilize conventional geology tools. Science activities were and will be extensive to include deployment of instrument packages as well as sampling and documenting field sites.

An extensive archive of the Apollo era science activity related documentation, provides evidence for keys to the success of the field work, which can be utilized in planning the ARTEMIS astronaut activities on the lunar surface. These included:

- highly integrated, intensive, science planning, simulation (e.g., time-limited, regional contextual sampling emphasizing down select), and astronaut and flight crew training;
- development of a systematic scheme for description and documentation of geological sites and samples (e.g., oral documentation training in lieu of geologist's notebook)
- a flexible yet disciplined methodology for site documentation and sample collection (e.g., 'lower' resolution maps carried);
- capability for astronaut communication with a 'backroom' of geological experts who made comments and recommendations, refereed by the capcom, an innovative and very useful in encouraging rapid dissemination of information to the greater community in general.

The Apollo Lunar Surface Journal allows analysis of the astronaut's performance in vehicles and on foot, documentation and sampling of field stations, and operation of tools and instruments, all as a function of time.

**Current Surface Exploration Context:** In addition, JPL has, in the ensuing decades, honed a range of widely used, high heritage mission operations tools that have been used to support science teams, instrument operations and mission operations (MER, MSL, InSight, M2020 and others) [2]. These tools have evolved to meet more refined needs with shortened science planning times to support more challenging tactical ('today') and strategic ('tomorrow, next week, next month') mission objectives, that are well suited to support the key features for success as described above. Key features which could be provided as hands free display to the astronauts as well as to the 'backroom', would provide for:

- Data access at appropriate resolution for task, from low resolution data, most useful in providing strategic context for a field area, to high resolution data, to support tactical activities, such as sampling, within a given area.
- Enhanced geographic contextual awareness of the geographic area of interest, leveraging datasets from PDS and other archives that may be toggled on/off as necessary, coupled with high-performance processing to make near real-time updates to archived or displayed features.
- Geographically distributed flight planning and science teams equipped with real-time editing/updating site and target review tools using high-resolution terrain mesh and quick-look products to enable new insights and inform subsequent lunar activities
- updated terrain maps using near real-time surface localization and mapping capabilities
- Data aggregation from multiple Lunar orbital and surface missions in Operations concurrently
- Support placement of sensors and deployment of autonomous mobile platforms (e.g. MER or MSL rovers)

**Application of Tools**: We plan to leverage current Advanced Multi-Mission Operations (AMMOS) products, already proven and easily adapted for ARTEMIS surface activities:

- Multi-Mission Geographic Information System (MMGIS) [3], a distributed GIS suite and processing capability with data standards, tools, and interfaces for accessing science instrument and engineering data on a map in near-real time achieved by automating the localization/ georeferencing of science data results and providing a unified mapping interface for spatial situation awareness.

- AMMOS Science Targeting Toolkit for Robotic Operations (ASTTRO) for selecting science targets using in situ datasets allowing multiple team members to communicate and plan instrument observations [4].
- AMMOS Planetary Image Viewer for viewing and annotation of in-situ imagery and other science data products [4].
- Simultaneous Localization And Mapping (SLAM) using LIDAR and vision sensors to support rover navigation [5].
- JavaScript 3D tile renderer for streaming content rich base maps to low bandwidth handheld or mounted display devices [6].

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**References:** [1] Clark, EMP, 106, 133-157, 2010; [2] Volpe, IEEEAC, #1641, 2005; [3] Calef et al., Planetary Data Workshop IV, 2019, abs. #7071; [4] https://ammos.nasa.gov/pdf/AMMOS_Catalog-V5_2_Public_Release.pdf;
[6] https://github.com/NASA-AMMOS/VICAR;
[7] https://github.com/NASA-AMMOS/3DTilesRendererJS