SITE PLANNING AND DESIGN TO ENABLE AND ADVANCE LUNAR SCIENCE EXPLORATION. R. Lewis[1], S. Hoffman[2], J. Gruener[3], A. Jagge[4], S. Deitrick[5], S. Lawrence[6], A. Britton[7], [8]R. Mueller, [9]L. Toups, [1] NASA Goddard Space Flight Center, Greenbelt, MD, 20771, ruthan.lewis@nasa.gov; [2,3,4,5,6,7] NASA Lyndon B. Johnson Space Center, Houston, TX, 77058, stephen.j.hoffman@nasa.gov, john.e.gruener@nasa.gov, amy.m.jagge@nasa.gov, sarah.r.deitrick@nasa.gov, samuel.j.lawrence@nasa.gov, andrew.w.britton@nasa.gov; NASA [8]Kennedy Space Center, FL 32899, rob.mueller@nasa.gov; [9]University of Houston, Houston, TX 77004, toupslarry@gmail.com.

Introduction: In concert with NASA's Artemis Program, current studies are taking a unique systems view and focusing on simultaneously fulfilling near-term and projected continuous lunar site-specific exploration needs as well as Mars readiness and extensibility to Mars surface operations. The studies are formulating needed capabilities and creating lunar field station plans that will facilitate survival in an extreme environment, habitation and long-term residence, exploration and learning, access to, collection, and communication of information and knowledge, historical and ethical preservation, and visitation for multiple arrivals and departures. They involve contrast and comparison of lunar and Mars environmental and operational characteristics to inform Moon-specific and testbed-specific aspects of site design; specific characterization of candidate reference sites; and an understanding of the ramifications and interplay of the surface elements and environment. In fact, further evidence of the need for appropriate site design planning and implementation, with data collected over the span of several years, has been demonstrated by Earth-bound exploration regions such as McMurdo Station, Antarctica. This evidence points to the impact of past science exploration on current and future science exploration and has strongly influenced and resulted in revamping infrastructure master planning and design to mitigate disruption of valuable scientific return and unnecessary resource consumption. Thus, there is a crucial need for utilizing site planning and design to enable and advance science on any planetary surface where robotic and human interaction is co-located and interactive.

Background: Site planning is an integrating process that helps allocate functions to derive efficient utilization of the land and resources at one's disposal, and where the character of the site(s) is emphasized to effect site selection and construction to support surface operations. A site plan expresses relationships between built elements (e.g. structures, transportation, etc.) and the environment, including orientation and potential temporal variations, and the degree of sustainability, over the lifecycle of the site or sites singly and as a system.

The intertwining composition of functional areas under consideration include:

- Human systems -- shelter, life support, etc.
- Support and utilities -- communications, power, logistics, etc.
- Mobility -- surface vehicles for construction, crew and materials transport, etc.
- In-situ resource utilization (ISRU) -- processing, storage, distribution, etc.
- Launch and landing elements -- ascent/descent, payload integration/deintegration, environmental protection, etc.
- Surface operations -- science, research, technology demonstration, etc.

Analytical parameters under study include physical characteristics and features such as terrain, topography, climate, seasonal patterns, albedo, and radiation. Additionally, operational characteristics including distance from landing and landing clearance, visual access, points of interest, robotic and crew activities, communication spectrum and access, safety, planetary protection, etc. are within the realm of variables that have been considered within preliminary exploration system design response options that identify functional adjacencies, buildup sequence, path and infrastructure directions, zoning, utility layout, circulation, etc.

Notionally, site development may be achieved in systematic phases such as emplacement (set-up and operation techniques), consolidation (developing technologies for in-situ resource utilization (ISRU), expanding the area of influence), and operations or demonstration (steady state operation with reliable ISRU). The reference architecture for lunar sites begins with the creation of a field station. Antarctica's McMurdo Station and Alaska's Toolik Field Station are precedents for sites and facilities that conduct science and engineering studies in remote areas. Much can be learned from their historical and ongoing experiences. Guiding principles such as simplicity and standardization, self-sufficiency, reliability, transversability, flexibility and adaptability, footprint reduction, strategic redundancy, knowledge of the existing environment, and conscious revisiting of site planning on a regular interval are applicable to effective and fruitful

lunar science return. Likewise, operational parameters including user demographics, phasing of improvements, resupply frequency, traverse frequency, consolidation of like functions, survivability elements, utilities, structures, and mobility paths are germane.

A variety of reference information, and planning and analysis techniques are being used for the current studies including imagery, mapping, remote sensing, GIS technologies, adjacency, zoning, and contamination analysis, and the like. These tools are used to probe and study the relationship of physical characteristics and features (e.g. terrain, topography, climate, seasonal patterns, albedo, and radiation), and operational characteristics (e.g. distance from landing and landing clearance, visual access, points of interest, robotic and crew activities, communication spectrum and access, safety, planetary protection, etc.).

Moving Forward: Site planning is an iterative and integrated process, requiring input from all parties that are involved with the exploration and usability of the environment, and serves best when applied prior to initial exploration operations. Site planning and design helps establish arrangement of surface facilities and transportation corridors to exploration regions, and methods for mitigating cross-contamination and site preservation. Additionally, the planning process facilitates transport and needed resources in vicinities that serve science, including sample processing, high-grading, and sample handling and return. Implementation of site analysis and design promotes efficiency of use of the lunar environment and will further ready us for Mars exploration. Its application and use will inevitably increase science exploration value and return.