Developing Science Objectives in the Context of an Operational Concept for Lunar Surface Exploration. J. E. Gruener[1], [1]National Aeronautics and Space Administration, Johnson Space Center, Constellation Program Office, 2101 NASA Parkway, Houston, Texas, 77058, john.e.gruener@nasa.gov.

Introduction: Developing science objectives for human and robotic activities on the Moon is only one of the first steps in defining the scope of a lunar exploration architecture. While defining 'what' needs to be done on the lunar surface, it is important to put the objectives in the context of 'how' they will done, describing the needed capabilities for both surface operations and system hardware. An operational concept provides this context, specifying locations of interest; the use of human and/or robotic explorers and amount of their time needed; surface mobility needs; access to the subsurface; payload mass and dimensions; analytical equipment and laboratory needs; sample return capability; supporting infrastructure such as power and communications; and maintenance, resupply, and logistics needs. Once operational concepts have been developed for each science objective, time phasing of the objectives can be matched with the early, intermediate, and mature capabilities of a growing and an evolving lunar exploration architecture. Developing science objectives within this context will better focus the technical requirements for the eventual operations and systems hardware that will be used on the Moon to meet those objectives.

Operational Concept: Operational concepts are simply 'stories' or 'scripts' describing how something is done, and bridge the gap between defining the scope of a lunar exploration architecture and writing the technical requirements for the systems needed within that architecture. However, even in the scope definition phase, a high level operational concept is needed to more fully describe the objectives and their associated needs. This high level description only involves 'order of magnitude' estimates that can be used to shape the contents of an architecture. These estimates can be made through answering a series of questions, most of them listed below.

Locations of interest. Is the objective associated with a very specific region or location on the Moon (e.g., equatorial, polar, mid-latitude, near side, far side, mare, highlands, pyroclastics), or can it be met at any location? Does the objective require repeat visits to the same site, or visits to multiple sites? Can the objective be met by orbital assets alone?

Human/robotic explorers and time on-site. Does the objective need the use of human crews, and if so is this intervehicular or extravehicular activity? Does the objective require special expertise or a routinely trained astronaut? Will the crew members be involved with this objective for a short period of time (e.g., ≤ 10 days) or an extended period of time (e.g., > 10 days)?

Can the objective be met with the use of robotic explorers, and if so would the robots be autonomous or teleoperated? Will the robot be involved with this objective for a short period of time (e.g., ≤ 14 days, sunlight) or an extended period (e.g., > 14 days)?

Surface mobility needs. Does the objective need the capability to travel short distances (e.g., ≤ 10 km) from the landing site or outpost facility, intermediate distances (10-50 km), or long distances (>50 km)?

Access to the subsurface. Does the objective need access to the subsurface, and if so how deep would this access need to be (e.g., < 1 m, several meters, tens of meters, hundreds of meters, ≥ 1 km)?

Payload mass and dimensions. What is the mass of payloads associated with the objective (e.g., kilograms, tens of kg, hundreds of kg, ≥ 1 mt)? What are the dimensions of payloads associated with the objective (e.g., measured in cm, m, tens of m), and do the payloads come complete and ready to use or do they need to be constructed?

Analytical equipment and laboratory needs. Does the objective need analytical equipment and laboratory facilities at a lunar outpost, and if so does this equipment need to be inside a pressurized volume or can it be operated out on the lunar surface?

Sample return capability. Does the objective need samples returned to earth, and if so how big of a sample (e.g., kilograms, tens of kg, hundreds of kg) and in what condition (e.g., vacuum, ambient, cold, frozen)?

Power and communications. What are the power needs associated with the objective (e.g., ≤ 100 w, kilowatts, tens of kw, hundreds of kw, ≥ 1 Mw)? Will this power be needed for a short period of time (e.g., ≤ 14 days, sunlight), extended periods (e.g., > 14 days), or continuously? What are the communication needs associated with the objective (e.g., continuous communication with a lunar outpost or Earth, intermittent)?

Maintenance, resupply, and logistics. Will the objective need equipment or facilities maintained and resupplied at regular intervals, and if so can this be done out on the lunar surface or will this need to be done inside a pressurized volume?

Time Phasing: Once the operational aspects of science objectives have been described, it is possible to categorize the objectives according to the capabilities available on the lunar surface. Though there is no

definitive development plan for lunar outpost facilities, an evolving outpost with increasingly expanded capabilities is likely. The development phases can be roughly be described as:

Early Capability. The early capability on the Moon will likely involve human sortie operations lasting 4-7 days, with minimal facilities and utilities. Surface traverses will likely be restricted to distances no greater than approximately 10-20 km.

Intermediate Capability. The intermediate capability on the Moon will likely involve intermittent visits of human crews lasting up to several months in duration, with modest facilities and utilities at an established outpost facility. Surface traverses may extend out to distances approximately 50 km from the outpost.

Mature Capability. A mature capability on the Moon will likely involve permanent human presence at an established outpost. Multi-day surface traverses could likely travel hundreds of kilometers away from the outpost. There is also the possibility of human sortie missions to other locations on the Moon using spacecraft on ballistic trajectories from the outpost, fueled with lunar derived propellants.