SCIENCE OPERATIONS FOR THE 2008 NASA LUNAR ANALOG FIELD TEST AT BLACK POINT LAVA FLOW, ARIZONA.

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Introduction: Surface science operations on the Moon will require merging lessons from Apollo with new operation concepts that exploit the Constellation Lunar Architecture [1, 2]. Prototypes of lunar vehicles and robots are already under development and will change the way we conduct science operations compared to Apollo. To prepare for future surface operations on the Moon, NASA, along with several supporting agencies and institutions, conducted a high-fidelity lunar mission simulation with prototypes of the small pressurized rover (SPR) and unpressurized rover (UPR) (Fig. 1) at Black Point lava flow (Fig. 2), 40 km north of Flagstaff, Arizona from Oct. 19-31, 2008. This field test was primarily intended to evaluate and compare the surface mobility afforded by unpressurized and pressurized rovers, the latter critically depending on the innovative suit-port concept for efficient egress and ingress. The UPR vehicle transports two astronauts who remain in their EVA suits at all times, whereas the SPR concept enables astronauts to remain in a pressurized shirt-sleeve environment during long translations and while making contextual observations and enables rapid (≤ 10 minutes) transfer to and from the surface via suit-ports.

Figure 1. Top: Unpressurized Rover (UPR). Bottom: Small Pressurized Rover (SPR). Photo Credit: NASA.

A team of field geologists provided realistic science scenarios for the simulations and served as crew members, field observers, and operators of a science backroom. Here, we present a description of the science team's operations and lessons learned.

Geologic Setting: Black Point lava flow (BPLF) is a 2.4 Ma, phenocryst-rich, massive, aphanitic, basaltic lava flow located along the southern end of the Colorado Plateau within the San Francisco Volcanic Field in northern Arizona (Fig. 2a) [3]. The BPLF is 20 km long, 5 km wide, with a variable thickness of 6 to 40 m, due to ponding within topographic lows of the underlying Moenkopi Formation, a 220-240 Ma series of Triassic sediments, representative of an estuarine environment, containing clay to sand-rich strata, fine (cm-scale) to massive (<5 m) bedding, with cross laminae, pebble horizons, mudcracks, and ripple marks [4].

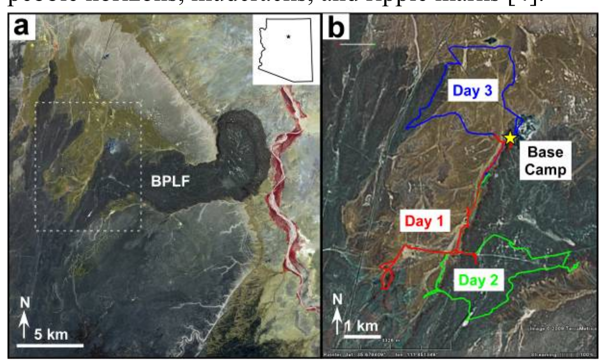

Figure 2. (a) Visible to Near IR ASTER image (15 m/pixel) of Black Point Lava Flow (BPLF), north of Flagstaff, AZ (inset). Dashed box marks Fig.2b. (b) Traverse paths for the SPR 3-Day mission (Google Earth).

Field Test Overview: The 2 week field test consisted of 4 EVA simulations: two 1-day UPR, a 1-day SPR, and a 3-day SPR (Fig. 2b). Two Crews (A & B), each with an astronaut-commander and a geologist, followed pre-planned geologic traverses in the UPR and the SPR. Crews were supported remotely by Mission Control and the Science Backroom stationed at the base camp, and in the field, by engineers and geologists. Crew members wore unpressurized mockup suits, Hard Upper Torso only, or shirt-sleeve backpacks during field operations. Samples were collected using Apollo-style tools, including a hammer, tongs, sample bags, drive tubes, and a gnomon. Field photographs were taken with digital cameras and suit- or rover-mounted, wireless video cameras, all displayed in the Science Backroom.

Science Operations: The Science Team drew on lessons and expertise from Apollo, but had to plan the traverses to utilize the respective capabilities of the two different rover prototypes.

Traverse Planning. Initial planning occurred in two phases. The first phase was a 3-day Traverse Planning Workshop held at NASA JSC in July 2008. A GIS data base of ASTER, topographic and slope maps were used to discuss the regional and local geology, identify major photo-geologic units, and determine the science goals. In the second phase, a sub group of the team prepared detailed traverse plans combining the above objectives with the operational constraints, such as EVA duration, range of communication, rover speed, time-lines for egress and ingress, the daily suit time limit of 8 hours, location of fences, and excessively steep slopes. Detailed EVA timelines were then developed based upon the science team's objectives.

EVA Traverses. Four traverses were planned: a) 1-day-long UPR (6:30 hour duration), b) 1 day SPR (9:30 hour duration), c) 3 day SPR with 2 new traverses for days 2 and 3 of the long duration field test (Fig. 2b). The 1-day UPR and 1-day SPR had identical stops with one extra station added to the SPR utilizing the additional time enabled by the SPR vehicle. UPR 1 day was 12 km long, SPR 1 day was 18 km, and the 3 day SPR was 56 km total. Traverses included detailed way points, sample stations, science objectives, and timelines discussed in pre-EVA crew briefings. The duration of 1-day SPR traverses was greater than 1-day UPR traverses because the crews were not constrained by (simulated) EVA consumables.

Field Science Operations. During the field test, the division of the science team was patterned after Apollo training exercises with 1) field observers and 2) science backroom. Two field observers followed the suited subjects in the field to make notes on quality of observations, sample selection, and sample documentation procedures. The Science Backroom was headed by a Field Geology PI, supported by 1 or 2 Co-I's, a Science CapCom, a Navigator, and a Note Taker (Fig. 3). The science team had access to 5 video cameras on the SPR/UPR and the suited subjects (Suit-Cams). Single frames could be manually captured from the Suit-Cams by the backroom (Fig. 3). The simultaneous use of multiple video cameras mandated very different backroom operations than occurred during Apollo (still video camera, Lunar Rover camera). After each traverse, a science debrief was held between the backroom and field observers, with a final field briefing held with the Crews on the last day.

Lessons Learned: As we prepare to return to the Moon, the science community will need to build on Apollo surface operation protocols and develop new surface science operation concepts that support more crew members, longer stays, new vehicles and technology, and a larger amount of data return. Specific observations are as follows:

1) Real time imaging by multiple rover and suit-mounted cameras are highly amenable to document the sampling process and are critical to the success of the science backroom and its capability to advise the crew. The large amount of data transmitted to Earth will mandate ground support operations and science backroom(s) that differ substantially from Apollo.

2) Both UPR and SPR seem exceptionally capable vehicles to support lunar science operations. They will support longer duration EVAs and increased mobility compared to Apollo.

3) The innovative suit-port concept on SPR allows for relatively rapid egress from and ingress into the shirtsleeve environment provided by the pressurized cabin, resulting in less crew fatigue and thus relatively long EVA times and increased travel distances. The times needed for suit-pressurization may be utilized profitably to make science observations of the local scene.

4) Total sample mass collected during long duration EVAs can be substantial and may require deselection and culling of specific samples via hand held or rover-mounted instruments to comply with the sample mass acceptable for Earth return.

5) Highly trained crews/skilled geologic observers will be as critical to lunar surface operations as they were during Apollo.

Figure 3. (Left) Science Backroom operations at the base camp. (Right) Image from the suit camera during training.

References: [1] NASA (2005) *Exploration Systems Architecture Study*, NASA-TM-2005-214062. [2] Cooke D. (2007) *AIAA Space Conference and Expo*., Session 90-STSA-20. [3] G.H. Billingsley et al. (2007) *Geologic Map of the Cameron 30' x 60' Quadrangle, Coconino County, Northern Arizona*, USGS SI-Map 2977. [4] E.D. McKee (1954) *GSA Memoir* 61, 133p.

Acknowledgements: Our deep appreciation to Robert Ambrose, Lucien Junkin, Bill Bluethmann and their Rover Team, Joe Kosmo, Barbara Romig, Charlie Allton and the Suits/Suit Port Team, Bill Dearing, Marc Seibert, and Mike Downs for the suit cameras and communications, Andrew Abercromby, Zane Ney, Chris Looper for Mission Operations, Spider Web Ranch, the Babbitt Family and ADOT for land access, Lela Prashad and Phil Christensen (ASU) for providing the ASTER image, and everyone who participated in the field test.