THE LUNAR ELECTRIC ROVER (aka SPACE EXPLORATION VEHICLE) AS A GEOLOGICAL TOOL. David A. Kring[1,2], [1]Center for Lunar Science and Exploration, Lunar and Planetary Institute, Universities Space Research Association, 3600 Bay Area Blvd., Houston TX 77058 (kring@lpi.usra.edu), [2]NASA Solar System Exploration Research Virtual Institute.

Introduction: The Lunar Electric Rover (LER) was primarily designed to provide astronauts with mobility on the lunar surface. That design was improved in a series of trade studies involving field trials that mimicked 3-, 14-, and 28-day-long missions on the lunar surface. Those mission simulations were invaluable, in part because they taught us several unanticipated lessons. Here I focus on one of those lessons: that the LER is not just a mobility platform, but also a valuable geological tool for exploring a planetary surface. That is an important insight when discussing the implementation of a mission scenario that involves two LER at five human landing sites on the Moon, as recently proposed by the International Space Exploration Coordination Group (ISECG) [1] as part of the Global Exploration Roadmap (GER) [2].

Proof of concept and major trade studies: The initial concept for a new generation rover was Chariot [3]. This was an unpressurized rover (UPR) designed for a crew of two, but with a contingency capacity of four. The chassis had six wheel modules with independent suspension, drive, and steering systems. The vehicle was tested at the Moses Lake sand dune region (Washington) and Black Point Lava Flow (Arizona), showing the concept sound.

A cabin was then mounted on the chassis to simulate a small pressurized rover (SPR) and tested along with the UPR at Black Point in mission simulations that included realistic tasking, accurate traverse timelines, and an in-loop science CAPCOM. It was quickly realized that the SPR was a superior mission element. Traveling within the SPR was easier on crew than spending an entire day in a spacesuit. Crew had more energy at stations when traveling in the SPR and were, thus, more productive. The SPR, renamed LER (and, later, the Space Exploration Vehicle (SEV); Fig. 1), could also provide shelter during any suit malfunction, radiation event, or medical emergency [4]. To reduce time-line, mass, and volumetric overhead, rapid egress and ingress was envisioned, requiring lower cabin pressure (8 psi within the LER vs. 14.7 psi on the International Space Station) and suit ports on the aft cabin wall [4] rather than an airlock. A nominal speed of 10 km/hr is expected for lunar surface operations [5], although the Chariot had a 20 km/hr top speed as a design specification [3]. During mission simulations at Black Point, the LER had an average speed of ~5 km/hr.

Intravehicular activity (IVA) capabilities: Descriptions and photo-documentation of distant features are possible from within the LER during drives between stations. Likewise, descriptions and photo-documentation of features in the near-field, directly in front of the LER, are possible from within the vehicle. The vehicle can rotate 360º without any lateral movement, providing views in all directions.

Fig. 1. *A proto-type LER that has been tested extensively in simulations of 3-, 14-, and 28-day-long missions with (inset) a concept SEV.*

The LER can function like a geologist, approaching outcrops while photo-documenting them (Fig. 1). It has high-visibility windows, a ForeCam, AftCam, port and starboard cameras, docking cameras, and a GigaPan camera (Fig. 2).

The view from within the SPR is very good. To evaluate the quality of that view, I conducted a test at Black Point: After examining the geologic details of a shale and siltstone region like that in Fig. 1 on foot, I re-examined it from within the LER and was able to conduct 90% of the geology from within the vehicle. While that value will vary depending on geological and topographical complexity, the test demonstrated the value of IVA from within the LER.

Extravehicular activity (EVA) capabilities: When needed for closer inspection and sample collecting, crew can quickly egress in about 10 minutes through suit ports. Crew use SuitCams for additional photo-documentation, transmit mobile observations verbally, and sample surface materials. We learned that a structural element, like the aft deck, which is akin to a table, is also a useful external surface on the LER, because it allows crew to re-describe samples if needed prior to storage on the vehicle. Typical simulations involved 3 to 4 EVA stations/day and 2 to 3 hrs/day of boots on the ground. This allowed crew to explore a far larger territory, with more complex geological and ISRU features, than would a single, longer-duration EVA at one location, while also minimizing crew time in a spacesuit. During EVA, crew utilized hammers, scoops, tongs, and sample bags available on an aft tool rack adjacent to a sample storage compartment. Voice and video from crew were streamed through the LER to mission control.

Other scientific instrumentation: Ground-penetrating radar (GPR) was installed on the UPR Chariot during the Moses Lake test and successfully detected subsurface water. A more advanced unit was installed beneath the aft deck of the LER (Fig. 2) for an extended 14-day mission simulation at Black Point, demonstrating its application in rugged field conditions. A neutron spectrometer is another ISRU-related survey tool for volatiles that could be installed on future LER.

Exploration potential: The LER was designed to carry 14 days of consumable supplies, so crew do not need to return to the lander each day, providing a capability for extended traverses. A single 14-day-long LER traverse was simulated with a crew of two at Black Point. In addition, a 28-day-long, dual rover mission was tested with two crews of two. A dual LER operational mode may extend the ~6 mile Apollo-era walk-back limit on distance from a lander to 150 mi (~240 km) [5], which would exceed that needed to traverse the 100 km-radius exploration zones being examined [6] for the ISECG five-mission scenario.

Crew landing sites: Potential capabilities of the LER were previously evaluated for missions to the Schrödinger basin [7] and Kepler crater [8]. Based on a global landing site survey for locations that address the largest number of lunar science and exploration objectives [9], the Schrödinger basin was found to be the highest-priority target [10]. As part of the ISECG study of human missions to the lunar surface [1], a sequential series of five landing sites that included the Schrödinger basin was identified for crew: Malapert massif, South Pole, Schrödinger basin, Antoniadi crater, and the center of the South Pole-Aitken basin. At each of those sites, four crew would use dual LER to explore regions up to 100 km radius with two 14-day-long loops during 28- or 42-day-long missions. An initial assessment of those landings sites has been completed [6] and demonstrates that a large fraction of the science objectives for the Moon [9] can be addressed at those sites.

Tele-robotic capabilities: In the ISECG five-mission scenario [1], the LER are tele-robotically driven from one landing site to another during year-long intervals between crew landings. A recent study of those traverses [11] revealed that a tremendous amount of science and exploration can be conducted along those traverses. For example, with on-board GPR and a neutron spectrometer, the LER can survey the floors of Cabeus and Amundsen craters for subsurface volatile deposits that could be mined for important ISRU constituents needed for a sustainable exploration program. Thus, while crew can provide detailed studies of the 100-km-radius regions around landing sites, the rovers can extend that exploration potential to the entire 2,570 km length between the five landing sites along a 3,718 km-long route optimized for science and exploration purposes [11].

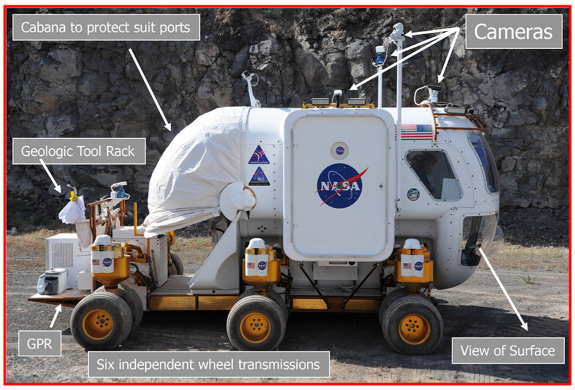

Fig. 2. *The LER as a geologic tool, providing IVA and EVA capabilities. This version provides close-up views of the surface, contains a suite of cameras, ground penetrating radar (GPR), and a geologic tool rack.*

Conclusions: The LER provides mobility, visibility, accessibility, surface documentation, and surface sampling, making it a valuable geologic tool. It potentially extends the distance travelled from the lander by a factor of 25 compared to the limit of the Apollo Lunar Roving Vehicle (LRV) and, thus, an area 625 times larger. It also greatly reduces daily spacesuit time for crew, while extending their exploration potential.

Acknowledgements: The lessons captured here are a product of NASA Desert Research and Technology Studies in 2008 through 2011 and would not have been possible without the input of vehicle crews and the science, mobility, communication, health and safety, human factors, and mission operational teams that supported them. The JSC mobility team built an incredibly capable vehicle.

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