Lunar Rover Development

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NASA's planned return to the moon requires a crew mobility beyond the limits of footed extravehicular activity (EVA). Crew mobility systems, such as lunar vehicles, can improve human safety while expanding EVA duration, range, and payload capacity. These benefits impact both outpost construction efforts and scientific endeavors. NASA studies analyzed various crew mobility options, including unpressurized rovers that must be driven by crew wearing spacesuits (EVA) as well as pressurized rovers that surface crew can drive from inside their vehicle (intravehicular (IV)). The lunar studies have modeled various scales of rovers and many unique chassis kinematic options. The trade studies included analysis of rover mass and power, system interfaces with numerous lunar-lander/cargo manifest scenarios using crew safety, mission duration, and exploration range as figures of merit. These studies identified one rover configuration, the Lunar Electric Rover (LER), as having an ideal combination of performance, mass, and range specifications. Two key features envisioned in the LER are a suit-port interface that enables fast EVA egress, and a shielded cabin wall that can provide radiation protection from solar proton events. While this performance fits the architecture well, such a vehicle does not exist today; therefore the development and testing of several new technologies is required. The Exploration Systems Mission Directorate has funded the development of the LER chassis and cabin prototypes to study this configuration and buy down development risk. Early tests show promising results.

Description of the cabin design

The prototype of the LER cabin, shown in figures 1 through 4, was built during fiscal year (FY)08 for field tests in FY09. The LER cabin is designed to house two crew members for operations over 3 days, or up to 2 weeks, with logistical and power resupply. The cabin can house four crew members in a contingency mode, allowing excursions with two LERs to be redundant and extend beyond the EVA walkback distance now estimated to be on the order of 10 km. The cabin has two identical hatches for docking with other LERs or pressurized modules such as an outpost's habitat chambers. These hatches, on either side of the cabin, serve primarily as IV transfer corridors

Fig. 1. *Chariot during field testing at Moses Lake, Wash., June 2008.*

for the crew, but they can also be used as emergency EVA entrances or exits. Additionally, the cabin has two rear suit ports that can be used to provide fast EVA egress. The suit port design includes two hatches: an outer hatch on the rear entry spacesuit, and an inner hatch on the LER cabin. When both hatches are open, crew members can climb from the cabin into the suit. Closing the two hatches allows the suit to separate and provides a path to EVA in 10 to 15 minutes. EVA crew members can return to the LER cabin through the suit port by backing their suit into the port, then opening the two internal hatches in reverse order. The cabin interior features two captain's chairs in the front of the cabin, connected to a center aisle with sleeping bunks on either side in the cabin's rear. Storage under the bunks and in the floor holds food, equipment, and clothing. The cabin exterior includes windows, radiators, lights, cameras, and tool boxes.

Description of the chassis design

The prototype of the Chariot chassis was built in FY07 and field-tested in FY08 as an unpressurized rover. The LER cabin prototype was mounted on Chariot for field tests in FY09. NASA provided the Chariot design requirements for payload, range, speed, and interfaces. Design challenges included a reconfigurable payload deck, a high ground clearance, an adaptive suspension, crab-steering, redundant drive avionics, high-energy density batteries, and a steep-

slope climbing ability. The prototype can be configured either with crew accommodations (turrets) or rear-mounted decks (contingency crew accommodations). Other modular interfaces include the ability to receive a bulldozer blade called LANCE and various sensor modules for navigation. Future work packages now in development include logistics pallets, excavators, and manipulators. The vehicle's kinematics provide a zero turning radius, and enable the vehicle to drive sideways for docking cabin hatches or other payload interfaces. The chassis suspension allows Chariot to level its frame or align with a lander or another surface element that is at a general angle. The redundant drive trains have two-speed transmissions, providing up to 5 kilometers per hour (KPH) in low and 20 KPH in high. We have tested the Chariot prototype on slopes over 35 deg, on soft soils (<1 psi), and in rocky (>30-cm) terrain. Engineering tests at the Johnson Space Center Rockyard include studies of drive train motor power, steering power, and suspension dynamics. New technologies being tested on the vehicle include cryogenic tires, drive trains, active suspension, composite materials, batteries, crew interfaces, dark navigation, and intelligent control modes.

Fig. 2. *The LER during testing at the Black Point Lava Flow, Ariz., October 2008.*

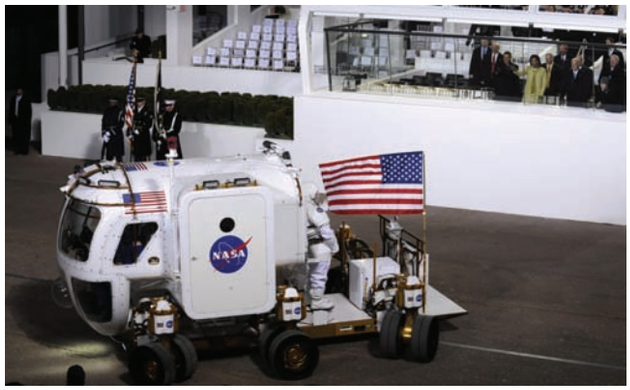

Fig. 3. *The LER during the Presidential Inaugural Parade, Washington, D.C., January 2009.*

Fig. 4. *The LER during the FIRST Robotics Competition, Houston, March 2009.*

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