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# LUNAR-MULE: A CONCEPTUAL MOBILE UNMANNED LOADING ELEVATOR SWARM FOR LUNAR PAYLOAD HANDLING

**Abstract**

Future lunar development and settlement will require the management and execution of complex cargo loading and unloading operations. However, these activities, usually performed by humans, face an obstacle in the lunar environment. Therefore, the circumstances call for an intelligent and autonomous artificial entity to manage daily lunar operations and logistics to provide flexibility and adaptive decision making to manage uncertainties in situ, rather than instructions from ground control on Earth. To address the challenges and complexities of unmanned lunar cargo operations, an innovative solution proposes the use of an autonomous robotic swarm system to plan, communicate, and coordinate tasks during lunar lander loading and unloading operations. In this context, a conceptual robotic agent called Lunar-MULE (Mobile Unmanned Lunar Elevator) consists of an intelligent scissor lift system that is self-folding, self-deploying, and self-driving. It is designed to lift, handle and transfer a wide variety of lander cargo from 0.5 m to 10 m in height and up to 12 tons in weight, completely autonomously and unmanned. In addition, Lunar-MULE is a hybrid cargo loader and transporter designed to be reliable, robust and simple, capable of working alone or in a swarm configuration depending on the difficulty of the task. Lunar-MULE features a design with two electrically powered tracked vehicles, two scissor lift platforms, and a 7DOF robotic assist arm. The distributed computing capabilities of the agents collectively determine the best solution to complex operational problems (e.g., accidents or basic repairs) that are critical in a sustainable lunar operations scenario. The Lunar-MULE philosophy is to be a zero maintenance, fully unmanned system.