SUPERBOTS ON THE LUNAR SURFACE: A ROBOTIC MULTI-USE LUNAR EXPLORER (MULE).
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Introduction: SuperBots are modular, multifunctional, and reconfigurable robots [1]. They are an elegant example of "design for reuse" that can reduce cost and payload mass while enhancing mission performance, reliability, and safety through their ability to change shape and function as needed. Constructed of autonomous, intelligent, and self-reconfigurable modules, SuperBots can work independently or in concert to perform an enormous range of tasks [e.g. 2,3]. Our vision of a SuperBot autonomous explorer and astronaut assistant is called the Multi-Use Lunar Explorer (MULE). The fundamental idea is to set up 100+ SuperBot modules on a rover chassis and, with a few specialized tools, use and reuse these modules to accomplish a variety of geologic and resource exploration tasks on the lunar surface and subsurface, with or without the help of astronauts.

Reconfigurability of the SuperBot modules is the key to their success. MULE modules can combine in a variety of ways to perform multiple tasks during different mission stages. For example, one level of a toolbox (12 SuperBot modules) can reconfigure to make a trenching arm, which can later reconfigure to make an element of a seismic network. Only a few specialized components (e.g. scoop, geophone, cameras, etc.), built with common docking interfaces, can transform an arrangement of identical SuperBot modules into versatile tools. We highlight below some of the tasks planned for MULE as an astronaut assistant and as an autonomous explorer.

Astronaut Assistant: As a pack mule, we envision the MULE carrying the bulk of the SuperBot modules in two box configurations, one for rock sample storage and one to carry simple tools for the astronauts (rock hammer, shovels, rakes, scoops, etc.). As a deep drilling platform, we envision a specialized drill system, to help investigate the lunar subsurface, anchored to a platform of SuperBots and stabilized by SuperBot-constructed legs. To further assist in geologic and resource exploration, we envision the MULE with a scientific instrument package on board (e.g. multispectral cameras), programmable by the astronauts to carry out measurements that may need long integration times or that are in astronaut-inaccessible locations.

The MULE could also offer significant safety features for the astronauts by carrying extra air and consumables, rescuing fallen or injured astronauts, or even acting as an emergency shelter for radiation shielding.

Autonomous Explorer: The MULE would also act autonomously before astronauts arrive, after they leave, or during the mission while they are asleep. As part of exploring the lunar subsurface, we envision a shallow trenching device consisting of an arm made of SuperBot modules and a specialized terminal scoop or bucketwheel. The depth of the trench could be increased by simply adding more modules to the arm, while the trench width and length would be controlled by MULE movement. This arm could simultaneously dump scoops of regolith into an on-board ISRU experiment.

An additional scientific SuperBot project would be the deployment of a seismic geophone network. Several groups (~8) of SuperBot modules would reconfigure to form hexapods or wheels (~10 modules each), and with a specialized geophone module incorporated in each, these network elements could autonomously deploy themselves into multiple, reconfigurable lines or arrays to map the lunar subsurface [see 2 for more details].

Other MULE tasks: MULE could also perform other tasks, including: long-distance or rough-terrain mapping or reconnaissance, rock sample collection and return, E/PO teleoperation exercises for Earth-bound students, and photo-documentation (either autonomously or teleoperated) of mission events and astronaut activities for historical or artistic purposes.

Why SuperBot MULE? SuperBots reflect a revolutionary shift from the traditional approach of building separate robots for separate tasks. Flexible and durable, SuperBot technology and design can provide (1) near-term use as a MULE astronaut assistant and autonomous explorer and (2) long-term expandability in our exploration and development of the Moon and space.

References: [1] Shen et al., this volume [2] Taylor et al, this volume [3] Lawrence et al, this volume