Electron Beam Regolith Separation (EBRS) System for Lunar In-Situ Resource Utilization. A. Cabra[1,2], X. Wang[1,2], and M. Horanyi[1,2]. [1] NASA SSERVI's Institute for Modeling Plasma, Atmospheres, and Cosmic Dust (IMPACT), University of Colorado, Boulder, CO 80303; [2]Laboratory for Atmospheric and Space Physics (LASP), University of Colorado, Boulder, CO 80303 (Email: anna.cabra@colorado.edu)

Introduction: In-Situ Resource Utilization (ISRU) is essential for long-term, sustainable exploration on the lunar surface. Regolith separation by size is important for sintering and element extraction which concentration offen depends on dust size, for example. Current technologies include electrostatic (e.g. triboelectric charging), magnetic based on material's magnetic suscepbility, and mechanical sieves [1]. However, these technologies have their limitations. Here we present a new Electron-Beam Regolith Separation (EBRS) technology. EBRS utilizes an electron beam to charge dust particles in a well-controlled manner to separate them by size through electrostatic deflection. EBRS is aimed to separate fine grains with high throughput.

Technology: The EBRS device consists of a dust cup that holds a quantity of dust and a hopper through which the dust is fed, forming a uniform, thin sheet. It also contains an electron beam charging unit, high-voltage (HV) deflection electrodes, and collecting bins for sorted particles (Fig. 1a) [2]. These units are aligned vertically from the top to the bottom. The electron beam with an optimized energy and flux will charge the fall-through particles to a desired potential. The deflection depends on particles' charge-to-mass ratio. Smaller particles experience greater deflection than larger particles, allowing them to be separated into different bins based on size.

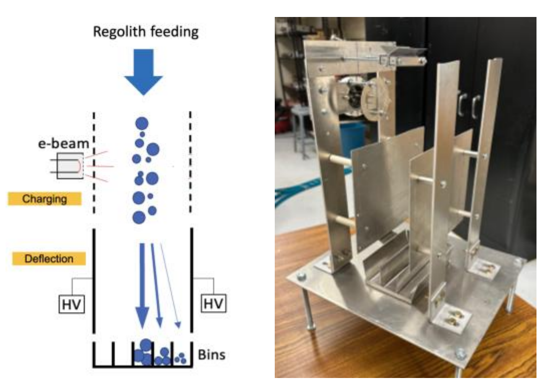

Fig 1. a) Schematic of an e-beam dust size separation device - EBRS. b) Physical model of the EBRS laboratory prototype.

Development and Testing: A laboratory prototype of EBRS is built and currently undergoing tests within a vacuum chamber. A physical model is shown in Fig. 1b. Experimental validation included Langmuir probe and Faraday cup diagnostics. As a key component, the eletron beam charging unit was characterized using a Langmuir probe. With measurements of the electron-beam flux with and without electrodes turned on allowed us to pinpoint electron beam interference from the HV electrodes. A shield was implemented and successfully prevented this interference, ensuring the beam can reach and charge the fall-through dust. Langmuir probe measurements of electron beam flux with varying energy indicated that the amount of flux reaching the location of the falling dust is siginifcantly influenced by the beam energy, likely due to the space charge limit when the beam energy is relatively low. To address this issue, a two-stage grid for the electron beam source will be implemented. This configuration will create an electric field that continuously accelerates beam electrons from the source throughout the falling dust region, ensuring they effectively impact and charge the dust particles. Dust drop tests will be undertaken to ultimately demonstrate size separation efficacy.

Summary: A novel regolith size separation technology utilizing an electron beam - EBRS is under development. Dust particles are charged in an efficient and well-controlled manner to be separated by size through electrostatic deflection. EBRS is expected to greatly improve the throughput of the process compared to current methods. A laboratory prototype of EBRS is developed and undergoing tests in a vacuum chamber.

References: [1] Rasera et al. (2020), PSS, 186, 104879; [2] Wang et al. (2024), pending patent PCT/US25/19999.