Electrodynamic Dust Shield on the surface of the Moon

Dr. Charles Buhler, Dr. Joseph R. Toth, Dr. Krystal Acosta, James Phillips, Dr. Aaron Olson, Jerry Wang
NASA Electrostatics and Surface Physics Laboratory
Kennedy Space Center, FL 32899

NASA's leading active dust mitigation technology called the Electrodynamic Dust Shield or EDS, has been in development by the Electrostatics and Surface Physics Laboratory (ESPL) at the Kennedy Space Center for almost 25 years. The technology is based on the work of Masuda and his students at the University of Tokyo in the 1970s and was passed onto Dr. Sid Clements at the Florida State University. At an Electrostatics Society of America (ESA) Conference in 2002, the work was shared with the researchers at NASA and the University of Arkansas at Little Rock. As a result of those early ESA meetings, we can proudly say that the EDS, an active dust mitigation technology for lunar exploration systems, has been successfully demonstrated on the surface of the moon in March 2025!

As NASA aims to develop a continuous presence on the moon, dust will pose a major threat to numerous systems, including solar panels, heat rejection systems, cameras, sensors, and seals. The EDS offers a solution to this problem as an active dust mitigation technology that can be built into various surfaces. An EDS works by applying a high-voltage square wave across a set of two or more electrodes to generate an electric field that varies in time and in space. This electric field is designed to have sufficient strength at the surface of a material such that it will move and repel dust off the surface. While this has been demonstrated repeatedly on Earth, to prove this technology works, the ESPL team built a payload to test it on the moon.

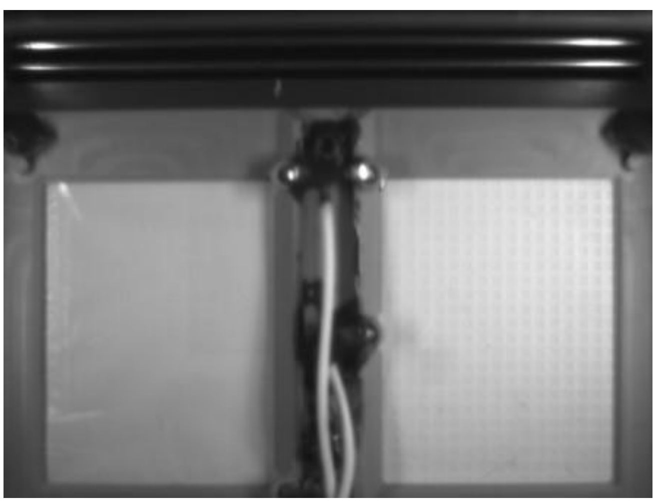

Figure 1. A glass in-plane interdigitated-electrode EDS (left), a thermal-radiator out-of-plane grid-electrode EDS (right), and one set of reduster EDS bars (top). This image was taken with the payload camera as the lander travelled to the moon.

The EDS Payload was designed to test coupons of a transparent glass EDS and a thermal-radiator EDS on the lunar surface, shown in Figure 1. The glass EDS had in-plane interdigitated electrodes that were operated in a two-phase mode. The thermal-radiator EDS had out-of-plane grid electrodes that were operated in a one-phase mode. Figure 2 shows the EDS payload attached to Firefly Aerospace's Blue Ghost lunar lander. The payload also consisted of numerous sub-systems including heaters, a thermal radiator, a camera, a motorized dust cover, high-voltage power supplies, and LEDs. These subsystems were necessary to ensure payload survival, operate each EDS, and characterize the ability of the EDS to remove dust. Further, a 'reduster' EDS assembly was incorporated that could lift dust from the lunar surface directly onto the two test EDSs. This is useful if there was no dust on the EDSs from landing and deployment. The aim was to have a camera take videos of before, during, and after EDS operation to show the device moving dust.

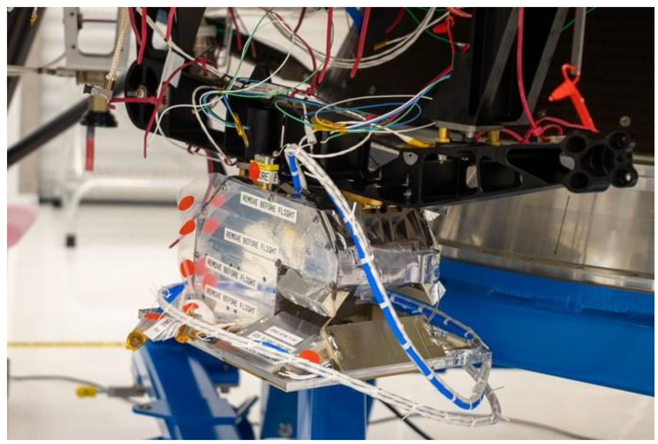

Figure 2. The EDS Payload mounted onto the Blue Ghost lunar lander. The payload is connected to an arm that deploys the payload directly onto the lunar surface.

The EDS was one of ten payloads on board the Blue Ghost lander built by Firefly Aerospace. In January of 2025, the lander was launched out of Kennedy Space Center, and in early March 2025, Blue Ghost became one of the first commercial landers to land on the moon. A few hours after landing, the EDS payload was powered on, and its operations began.

Initially, operational constraints required operating the reduster prior to imaging the EDSs to check if they were already covered in dust, and its results are shown in Figure 3. Post data review showed that the reduster was not necessary, as the EDSs had dust on them. LEDs were positioned to the left and right of the EDSs to give full illumination and reduce shadows. Unfortunately, the left

LEDs failed during lunar descent and/or landing causing shadows and loss of light.

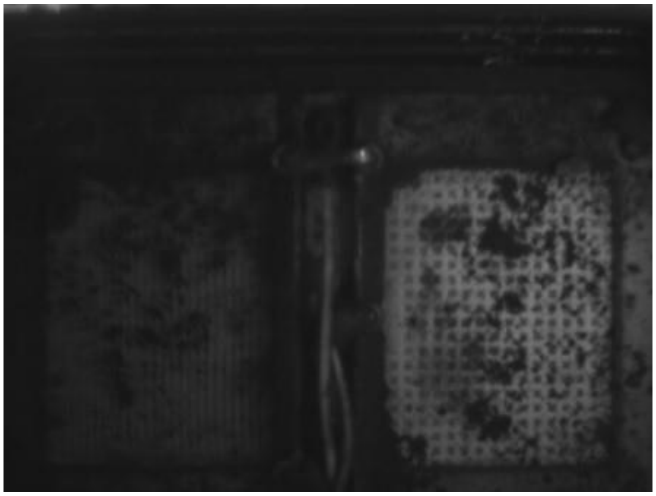

Figure 3. The EDSs shown in Figure 1, covered in dust after landing and reduster operation. Loss of a set of LEDs resulted in darker images and non-uniform lighting conditions. The lunar surface is visible underneath the reduster bars at the top of the image.

After dust was confirmed on the EDSs from images received on Earth from the lander, the EDS operators sent the command to operate the EDSs. Figure 4 shows the EDSs after a few dust-clearing cycles, showing that it has successfully removed dust from the surface. We report that our demonstration of the EDS payload on the lunar surface was successful in removing 82% of the dust off a thermal-radiator surface, 97% of dust removal off a glass surface, and showed a successful demonstration of the reduster technology.

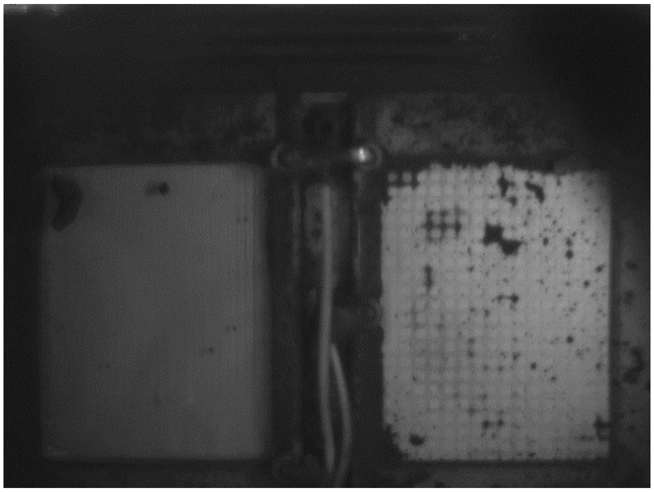

Figure 4. The EDSs shown in Figure 3, after operation to remove the dust. The glass EDS (left) removed 97% of the dust while the thermal-radiator EDS removed 82%.

Most of the remaining dust on the glass EDS (top left and top middle) are considerably large ‘boulders’ that the EDS is not capable of removing. For practical applications, these large particles would slide off surfaces that are not mounted perfectly horizontal as is typical for systems. The thermal-radiator EDS had worse performance, likely due to its operation in a one-phase mode vs a two-phase mode that the glass EDS was operated in. In the one-phase mode, the field was between a single high-voltage electrode and a ground electrode. The two-phase mode had one electrode biased at one polarity and the other electrode biased at the opposite polarity, allowing twice the electric field at the same magnitude of voltage.

This technology demonstration of the EDS proves that the EDS can remove most dust from critical surfaces and gives further insight into the optimal operational requirements. The next steps for this technology are to infuse it into future lunar missions such as rovers, habitats, landers, etc., where dust can cause serious problems or even mission failure. Electrostatics is successfully solving one of NASA’s greatest challenges for lunar exploration.