Integration of the Electrodynamic Dust Shield on a Lunar Habitat Demonstration Unit

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Abstract— **NASA is developing a Habitat Demonstration Unit (HDU) to investigate the feasibility of lunar surface technologies and lunar ground operations. The HDU will define and validate lunar scenario architecture through field analog testing. It will contain a four-port vertical habitat module with docking demonstration capabilities. The Electrodynamic Dust Shield (EDS) is being incorporated into the HDU to demonstrate dust removal from a viewport and from a door prior to docking procedures. In this paper, we will describe our efforts to scale up the EDS to protect a viewport 20 cm in diameter. We will also describe the development of several 20 cm × 25 cm EDS patches to demonstrate dust removal from one of the HDU doors.**

I. Introduction

NASA has designed and built a Pressurized Excursion Module (PEM) for a Lunar Habitat Demonstration Unit (HDU), a full scale lunar habitat prototype, to perform analog testing of the lunar environment in desert locations. The Desert Research and Technology Study (RaTS), a series of analog tests that NASA has held at several different desert locations for several years, allows the Agency to run through potential "day in the life" scenarios at a lunar outpost with prototype equipment. These analog tests provide engineers and scientists with insights into the utilization of the different systems so that the exploration architecture and the operation concepts can be refined. The HDU will be operated during a 14- to 21-day mission at the 2010 Desert RaTS event planned for Black Point Lava Flow in Arizona.

The PEM has four doors with docking demonstration capabilities. Each door contains a 21-cm diameter viewport. During docking activities with the Lunar Electric Rover (LER), which contains a similar door, the two doors open inward. Any dust accumulating on the surface of these doors must be removed prior to docking. Figure 1 shows an example of a lunar architecture that is being evaluated at DesertRaTS.

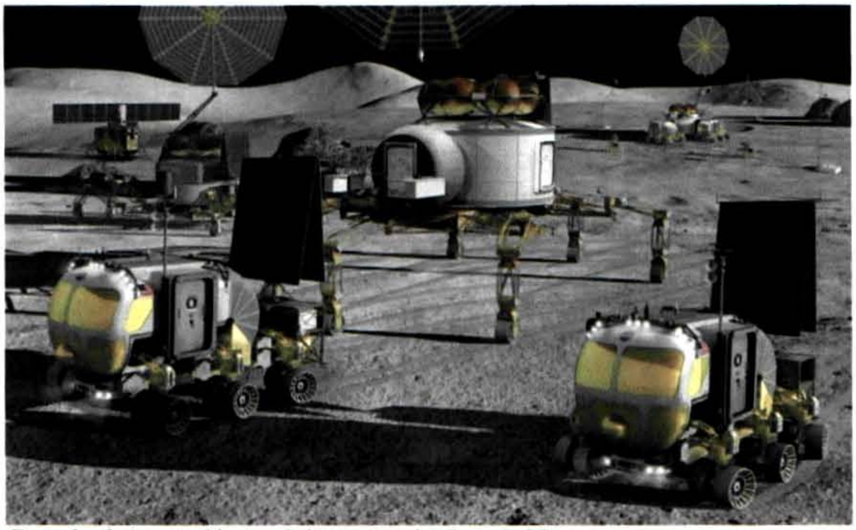

Fig. 1. Example of a lunar architecture being evaluated at DesertRaTS.

The Electrodynamic Dust Shield (EDS) technology that NASA has been developing as an active dust removal system during the past several years is being used to demonstrate dust removal from the PEM door. A transparent EDS system has also been installed on one of the viewports to maintain it dust-free during the Desert RaTS activities.

In this paper, we describe the development of the different EDS systems installed on the PEM and the demonstration tests planned for DesertRaTS. We also describe scale up plans for future HDU demonstrations.

II. Electrodynamic Dust Shields for the HDU

The EDS consists of a series of parallel electrodes connected to a multi-phase AC source that generates a traveling electrodynamic wave. This traveling wave allows controlled particle transport which can direct particles to a specific location. The EDS has been described in detail elsewhere [1-2]. The schematic diagram of Fig. 2 shows the three-phase electrode layout and the signal input of the EDS basic configuration. To illustrate the non uniformity of the electric field generated by this configuration, only one field line between consecutive electrodes is shown. The strength of the field varies proportionally to the potential difference between electrodes, which is dictated by the phase shift. Charged particles move in response to this non uniform field, as shown in Fig. 2.

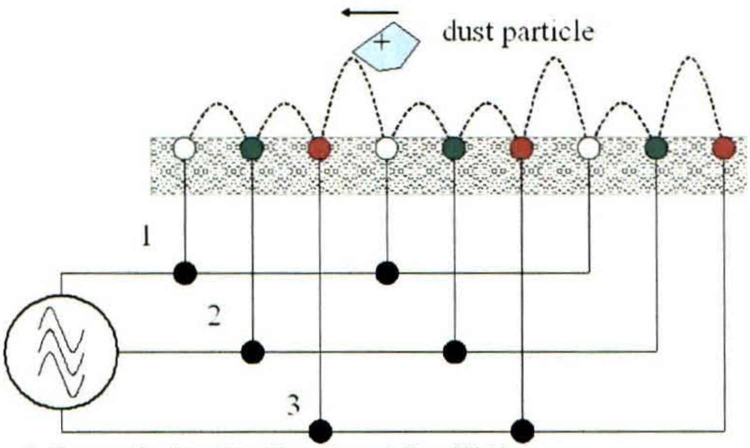

Fig. 2. Schematic diagram of a three-phase Electrodynamic Dust Shield.

EDS systems have been developed in our NASA laboratory for dust mitigation of solar panels, optical systems, viewports, thermal radiators, and spacesuits for lunar and Martian exploration missions [3-6]. The EDS systems developed for these demonstrations have ranged in size from 2.5-cm diameter discs for thermal radiators to 10 cm^2 for spacesuit fabrics.

For the PEM demonstration, the EDS had to be scaled up to larger sizes. A transparent 20 cm diameter EDS with indium-tin oxide (ITO) electrodes on a polyethylene terephthalate (PET) film was developed and tested to protect the PEM viewport. Three 20 cm × 25 cm EDS with copper electrodes on Kapton™ film 0.1 mm thick were also manufactured and tested. Two of these dust shields were coated with a Lotus coating currently being developed at NASA Goddard Space Flight Center. This coating simulates the nano-structures of the lotus leaf and reduces the surface area that comes in contact with dust particles in the micrometer range, thus decreasing their adhesion. One of the two Lotus-EDS panels was painted with A276 white thermal paint. This thermal paint has been used in space and is a useful coating for short term missions [7]. A fourth Kapton ™ panel was installed as a control. This panel was divided into four sections: plain Kapton™, Lotus coating, Lotus coating on A276 paint, and A276 paint. Figure 3 (a) shows four panels installed on one of the PEM doors and the transparent EDS covering the viewport. Figure 3 (b) shows the finished PEM with the Lunar Electric Rover mated.

III. EDS DESIGNS

The EDS systems developed for the PEM demonstration use a two-phase electrode design, as shown in Fig 4. The figure depicts the electrode layout for one of the EDS systems after installation on the PEM door. The two-phase electrode configuration consists of two sets of parallel copper electrodes interlaced in a comb configuration. Each set is connected to one of the signal inputs which have a 180° phase shift.

Fig. 3 (a). One of the PEM doors with the EDS systems installed. (b) The Lunar Electric Rover mated to the PEM.

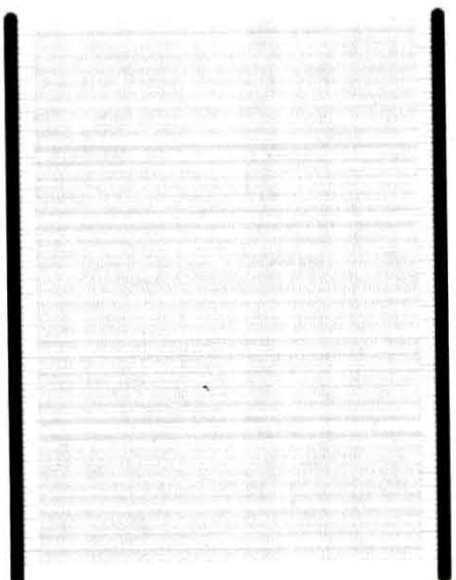

Fig. 4. EDS installed on the PEM door. Two sets of parallel copper electrodes in an interlaced comb configuration are embedded between two sheets of Kapton™ film.

The four EDS systems were connected in parallel. A power supply, installed under the PEM floor, provided power to the EDS systems (Fig. 5). The operation of the EDS systems was controlled with a LabView program running on a small computer attached to the power supply.

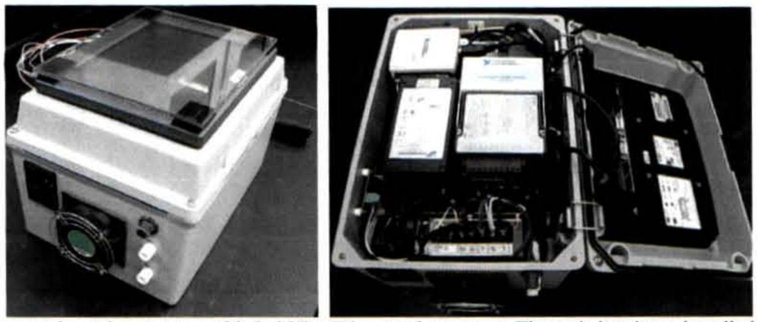

Fig. 5. Power supply and computer with LabView™ control program. The unit has been installed under the floor of the PEM.

IV. TESTS

Extensive testing of the two prototypes was performed in the laboratory. Tests were done with a 10 Hz two-phase square wave input signal in a glove box at room temperature and standard pressure. We used JSC-1A lunar simulant grains in the size range of 50 to 100 micrometers. This simulant, produced from a volcanic tuff near Flagstaff, Arizona, has a mineral composition similar to certain soils found at the Apollo 14 landing site [8-9]. The size range was selected because it lies outside the respirable range and was therefore considered safe to use in repeated testing.

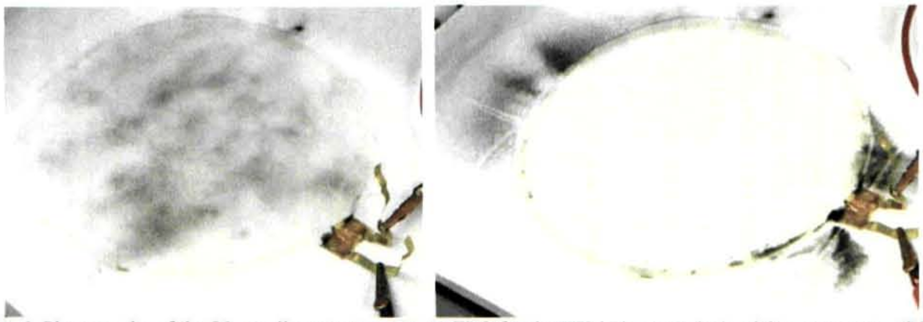

Fig. 6. Photographs of the 20-cm diameter transparent EDS for the PEM viewport during laboratory tests. JSC-1A stimulant dust was deposited in a relatively uniform fashion, as shown on the left. The photograph on the right shows the EDS after activation. Dust has been removed to the region outside the electrode grid. These tests were performed with the EDS sitting horizontally in a glove box.

The simulant dust was sprinkled over the EDS units by hand using a 1-cm wide nylon brush inside a portable vent hood. The EDS units were first placed horizontally, as shown in Fig. 6. The two-phase signal was activated, supplying about 100 mW of power to the EDS for 60 seconds. Fig. 6 shows the 20-cm diameter transparent EDS with JSC-1A dust sprinkled on it (left side of the figure). The photograph on the right of Fig. 6 shows the EDS after activation, with dust swept outside the perimeter of the electrode layout. Additional tests were also performed with the EDS units in a vertical position.

Fig. 7. Post installation tests of the 20 cm × 25 cm EDS. JSC-1A simulant dust was thrown at

Tests were performed on the final EDS units after installation on the PEM at the Johnson Space Center. Fig.7 shows the result of these tests. JSC-1A simulant dust in the 50 to 100 micrometer range was slung at the EDS units with a nylon brush. Triboelectric charging of the dust in contact with the brush bristles allowed a fraction of the dust to adhere to the EDS units, as shown on the photograph on the left of Fig. 7. The photograph on the right shows the EDS after activation.

Performance of the EDS systems installed on the PEM will be measured during the 2010 DesertRATS event using a spectrometer, a digital camera, and a portable microscope. Images and data from these instruments will provide dust removal efficiency information. We will report on those measurements in the future.

V. CONCLUSION

Electrodynamic Dust Shield units were successfully developed and installed one door of the Pressurized Excursion Module of the Habitat Demonstration Unit developed by NASA. Laboratory tests showed that these systems are able to remove dust that can accumulate on the door and on the viewport. Measurements of the EDS performance will be done during the 2010 DesertRATS demonstration. These results will be reported in the future. We will also report on the performance of the EDS integrated with the Lotus coating developed at Goddard Space Flight Center. We are planning on developing EDS units that will cover the entire PEM door for a second demonstration event next year. Lessons learned from the initial project reported here will be applied to the scaled up version planned.

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