Asteroid Initiative Request for Information
Solicitation Number: NNNH13ZCQ001L

Organization information:
NASA Kennedy Space Center
Surface Systems Office, NE-S
Engineering and Technology Directorate

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Abstract:
The NASA Kennedy Space Center, Surface Systems Office, NE-S is responding to the Asteroid Initiative RFI under the areas of:

(2) Asteroid Redirection Systems,
(3) Asteroid Deflection Demonstration**,**
(5) Crew Systems for Asteroid Exploration,

System Concept:

Each identified area will have a system concept described below. Technology Readiness Levels and timelines for developing and testing the proposed system concepts are identified.

5. Crew Systems for Asteroid Exploration: NASA is interested in concepts for lightweight and low volume robotic and extra-vehicular activity (EVA) systems, such as space suits, tools, translation aids, stowage containers, and other equipment, that will allow astronauts to explore the surface of a captured asteroid, prospect for resources, and collect samples.

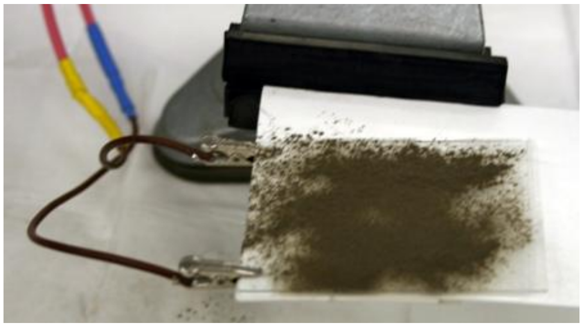
Abstract:

This RFI response is targeting ***Area 5****. Crew Systems for Asteroid Exploration: concepts for lightweight and low volume robotic and extra-vehicular activity (EVA) systems, such as space suits, tools, translation aids, stowage containers, and other equipment.*

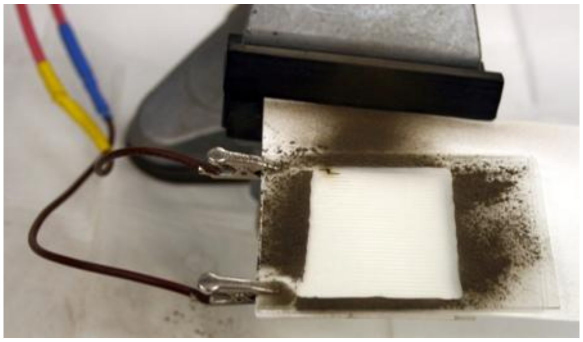
The NASA KSC Surface Systems Office, Granular Mechanics and Regolith Operations (GMRO) Lab and the Electrostatics & Surface Physics Lab (ESPL) are dedicated to developing technologies for operating in regolith environments on target body surfaces. We have identified two technologies in our current portfolio that are highly relevant and useful for crews that will visit a re-directed asteroid in Cis-Lunar Space. Both technologies are at a high TRL of 5/6 and could be rapidly implemented in time for an ARM mission in this decade.

Introduction

Dust is a major concern for crew while operating on a surface covered with regolith. The Apollo experience has shown us without a doubt that dust mitigation is challenging and must be addressed for crew safety and for mission operations efficiency reasons. The ESPL at KSC has developed the Electrodynamic Dust Shield, which can be embedded in tools, helmet visors, space suits, spacecraft walls and interiors, airlocks and instruments to repel dust and channel it into a desired location.



Dust Covered Witness Plate



Dust Removed with the Electrodynamic Dust Shield

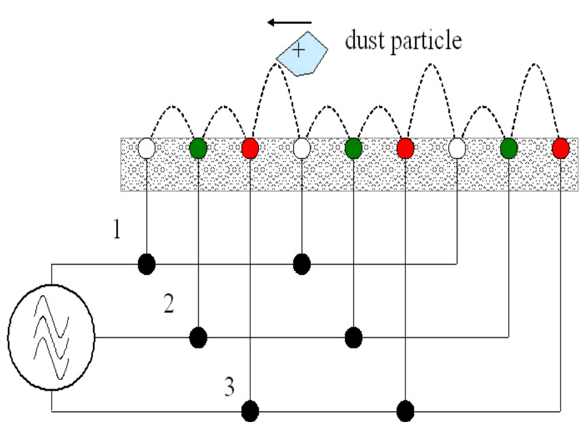
A video of this demonstration is available at:

http://empl.ksc.nasa.gov/CurrentResearch/ElectrodynamicScreen/Electrodynamic.htm

NASA developed 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 contains a four-port vertical habitat module with docking demonstration capabilities. The Electrodynamic Dust Shield (EDS) was incorporated into the HDU to demonstrate dust removal from a view-port and from a door prior to docking procedures. Development of several 20 cm × 25 cm EDS patches to demonstrate dust removal from one of the HDU doors has been completed.

Electrodynamic Dust Shields For the HDU

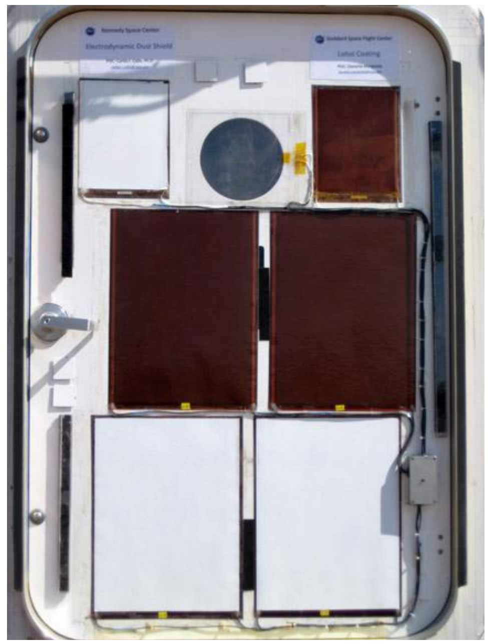
The EDS consists of a series of parallel electrodes connected to a multi-phase AC source that generates a traveling electrodynamic wave. This traveling wave allows controlled particle transport which can direct particles to a specific location. The schematic diagram shows the three-phase electrode layout 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 be-tween 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 the figure below.



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. The EDS systems developed for these demonstrations have ranged in size from 2.5-cm diameter discs for thermal radiators to 10 cm2 for space-suit fabrics.

For the Pressurized Excursion Module (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 36 cm × 46 cm EDS with copper electrodes on Kapton™ film 0.1 mm thick were also manufactured and tested.



(a) One of the PEM doors with the EDS systems installed

(b) The Lunar Electric Rover mated to the PEM.

Electrodynamic Dust Shield Test on the International Space Station

Electrodynamic Dust Shield panels for solar panels, optical systems, thermal radiators, and spacesuit fabric are currently being developed for long duration exposure to the space environment on the International Space Station as part of the DoD Space Test Program STP-H5 mission. The EDS experiment will be placed in the wake orientation of the STP-H5 payload. This location will experience an environment similar to that of the moon. Performance of the EDS panels will be monitored throughout the mission. The panels will be returned to our laboratory for post-flight inspection and testing.

Pneumatic Regolith Rake for Astronauts

As a result of recent research and technology development in the GMRO, various pneumatic regolith transportation methods have been investigated. One of the most promising methods is pneumatic regolith transfer where a dusty gas is created and the regolith dust is transported in the gas flow. To separate the dust from the gas, staged cyclone separators are used which are also effective in zero gravity. This technology can be used to filter breathing in crew cabin areas and air locks.

A dusty Gene Cernan in the LM at the end of an Apollo 17 EVA. Credit: NASA/JSC

"The dust was so abrasive that it actually wore through three layers of Kevlar-like material on Jack [Schmitt's] boot." – Professor Larry Taylor, Director of the Planetary Geosciences Institute, University of Tennessee (2008).

The dust-covered spacesuit of Apollo astronaut Harrison Schmitt (lower half). The favorite method of picking up a dropped item on the Moon was to do a "face-plant," followed by a one-arm pushup. (Note that this is a color photograph).

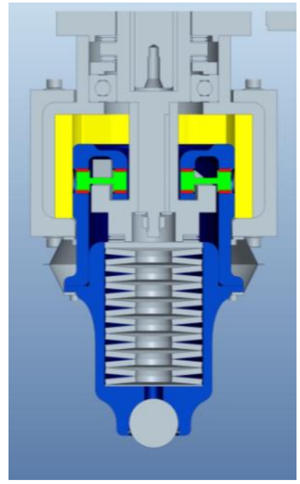
The KSC GMRO Lab has developed a Pneumatic Regolith Rake that is ideal for use by an astronaut on an asteroid EVA. By simply raking the surface of the regolith, the crew member can acquire large quantities of dusty regolith samples while being far enough away to prevent dust lofting onto the astronaut's suit. The physical and ergonomic effort is also minimized so that the astronaut will be safe and not exert excess energy.

Hand-held Pneumatic Regolith Rake to excavate fluidized regolith. System can also be housed inside a can to contain any dust.

Percussive Excavation Shovel for Astronauts

The NASA Kennedy Space Center has developed a percussive excavation device that reduces the forces of excavation. It is lightweight and compact and could be integrated into a shovel for astronauts. Since the digging forces are reduced then the crew will be able to capture samples more efficiently and from deeper locations. In addition, icy volatiles are brittle so that a percussive digging operation is very effective in these conditions.

Badger Percussive Excavation Mechanism



Cross Section CAD model of the Badger Percussive Mechanism

The Badger technology is at TRL 4 and could be developed to TRL 6 within 1-2 years for use in an EVA on an ARM. This task is currently funded by the STMD Game Changing Division.

Currently the Badge implement will be mounted on the Centaur 2 robotic mobility platform at JSC and is intended to be robotically operated, but an Astronaut operated version or a co-robotic operation is equally valid for limited excavation or sample acquisition. Longer term mining operations would require an astronaut operated robotic platform.

Conclusion

Three viable technologies for EVA tools have been described. These technologies have been tested and proven to work. The issues of dust mitigation, sample collection and regolith excavation are both highly relevant to the ARM mission when the crew visits the retrieved asteroid.