CHALLENGE - DUST YOURSELF OFF

The Apollo missions showed us that lunar dust not only clung to everything and was impossible to fully remove, but it was also dangerous to humans and damaging to spacecraft systems. Your challenge is to develop a way to detect, map, and mitigate lunar dust to reduce the effects on astronauts or spacecraft interior systems.

PROBLEM FACTS

- NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE), launched in 2014 to study the moon from orbit discovered that the moon is surrounded by a permanent dust cloud lofted from the surface by the impacts of interplanetary dust particles at 34 km/s, vaporizing part of the soil and releasing heat.
- Object moving on the surface of the moon will charge due to contact with the surface as well as to the exposure to the surrounding plasma environment.

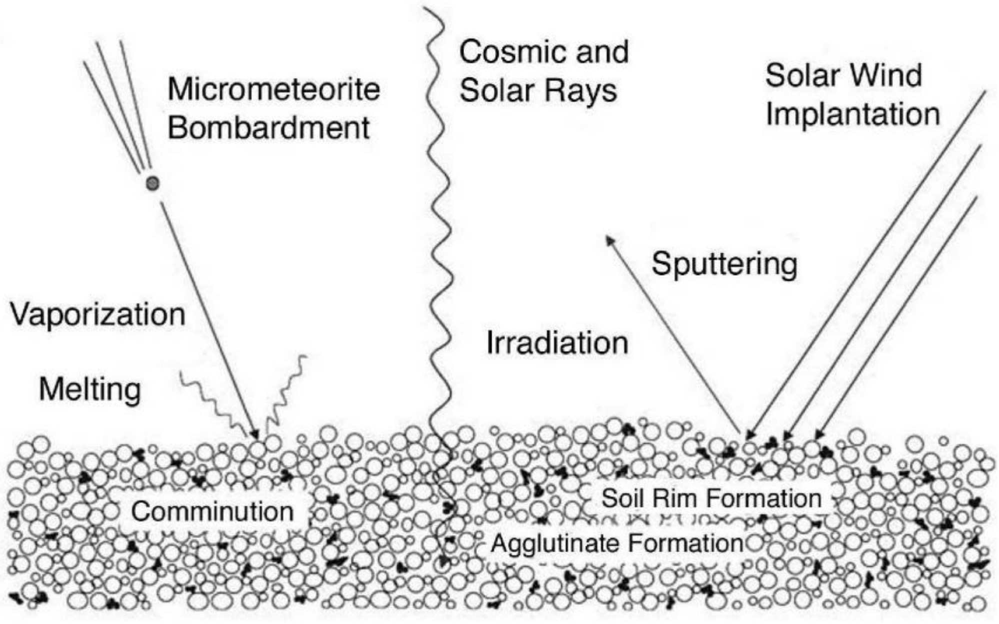

Figure 1. Cartoon showing the various components of space weathering. *NASA - Lunar Regolith - Sarah Noble*

1 - OUR PROYECT

We propose ByeDust! as an integral service of multiple stages designed to detect and mitigate the moon dust. This system is an inflatable structure thought to be annexed to the moon lander module.

The equipment consists of an easy-to-deploy inflatable module coupled to the gate that will be used as an airlock for Extravehicular Activities (EVAs). This is divided into two stages in which the lunar dust will be detected and optimally removed, as well as that which is attached to surfaces such as dispersed dust.

In our proyect, we centralize our efforts on the use and optimization of following items:

- Improved IN-OUT-PROTOCOL.
- External Suit build of special materials optimized for Extravehicular Activities.
- LUNAR PARTICLE MITIGATION (LPM):
    - Surface Decontamination with Ionized Air.
    - Dust Detection System using LASER.
    - Electrostatical Precipitator Equipment.
    - Robotic Arm.
- Electrodynamic Dust Shield.
- Particles Filters.

2 - A: SYSTEMS APPLIED

- **Improved IN-OUT-PROTOCOL.**

In order to improve the protocol of entry and exit to the lunar module to reduce to a minimum the presence of dust in it, we have developed a series of 3 stages where different mitigation techniques will be applied, especially in the reentry procedure.

On a Moon landing, this inflatable module will be attached to the lander, covered by a capsule designed specifically for the module in use. Once the dust generated during the descent process is dispersed, this capsule is opened. An aluminum platform, with honeycomb structure, from 90º to 180º will be deployed and fully extended, thus giving a step to a guide for the assembly of the inflatable module. This module will begin to spread thanks to the inflation of the space between its internal and external walls. These walls, in turn, are formed by a sequence of layers of resistant materials that offer protection of various kinds, both for radiation, thermal and against micrometeorites. Thus, as seen in Figure 3, we will have our system fully deployed.

The astronauts will be responsible for the final step of assembling different systems within the module. This will present all pre-assembled systems, such as gates, wiring and air ducts, but it will be necessary for more complex systems such as the robotic arm attached to the Lunar Particle Mitigator to be installed after inflation. Once these systems are installed, the module will be ready to develop its maximum dust mitigation capacity.

The actual exit process from the lunar module through the inflatable module does not require more preparations than:

- Preparation of the EVA suit.
- Placement of the TYVEK® type suit.
- Depressurization of the Module.

The entry process requires certain details to take into account so that the comprehensive lunar dust mitigation system meets its objectives:

External protective suit removal: remove the TYVEK® type suit on the outer metal platform, at the instant prior to entering Stage 1 of the inflatable module.

- Entry Stage 1: opening the hatch from the outside and entering the inflatable module. There, the system will begin to pressurize both stages. In this section the astronaut has at his disposal the LPM. Then and once turned on by the astronaut, the associated robotic arm will proceed to clean your suit.

The astronaut is located at the designated location and initiates the robotic arm decontamination protocol.

Upon listening to the cleaning completion signal, the user turns off the LPM.

- Entry Stage 2: at that time, the astronaut will proceed to the next and last stage. Finally, the robotic system, operated by the astronaut from Stage 2, performs an automated floor cleaning of Stage 1.
- After entering, the astronaut is in the stage where cleaning will be completed using air filters. Thus, the elimination of the greatest amount of suspended dust is sought, thus leaving a sufficiently clean environment before entering the Lunar Module.

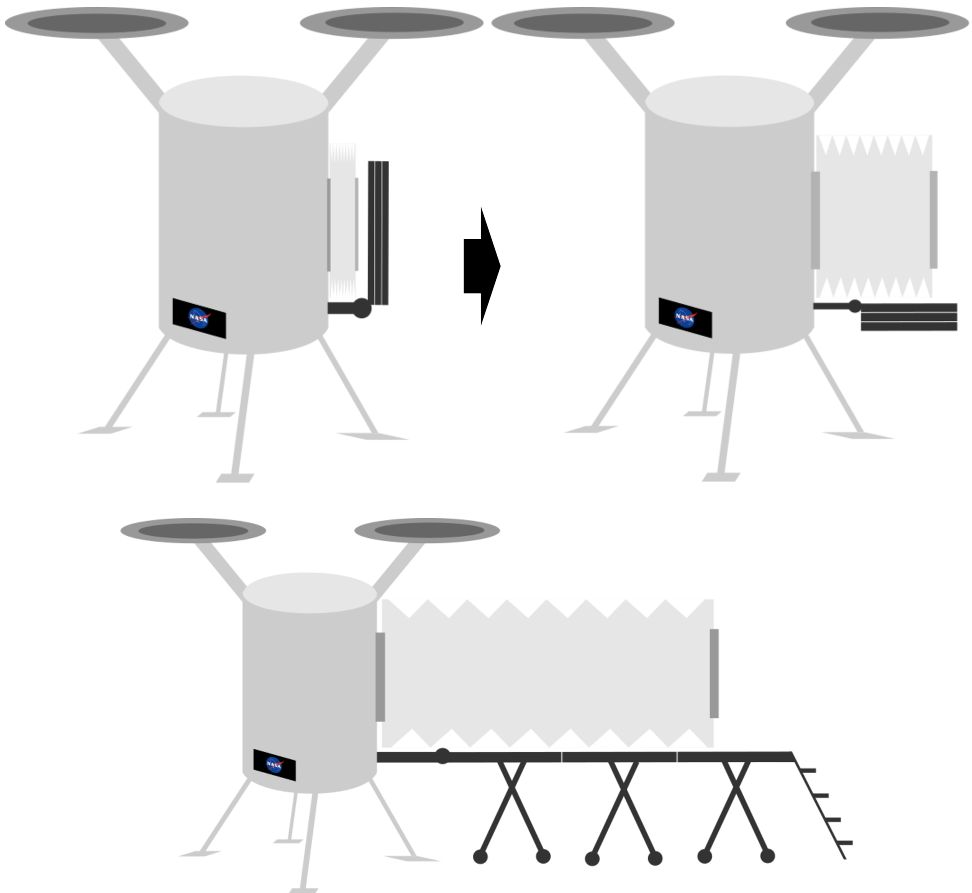

Figure 2: Lunar Module with Inflatable Module and attached Platform. Later extension of both.

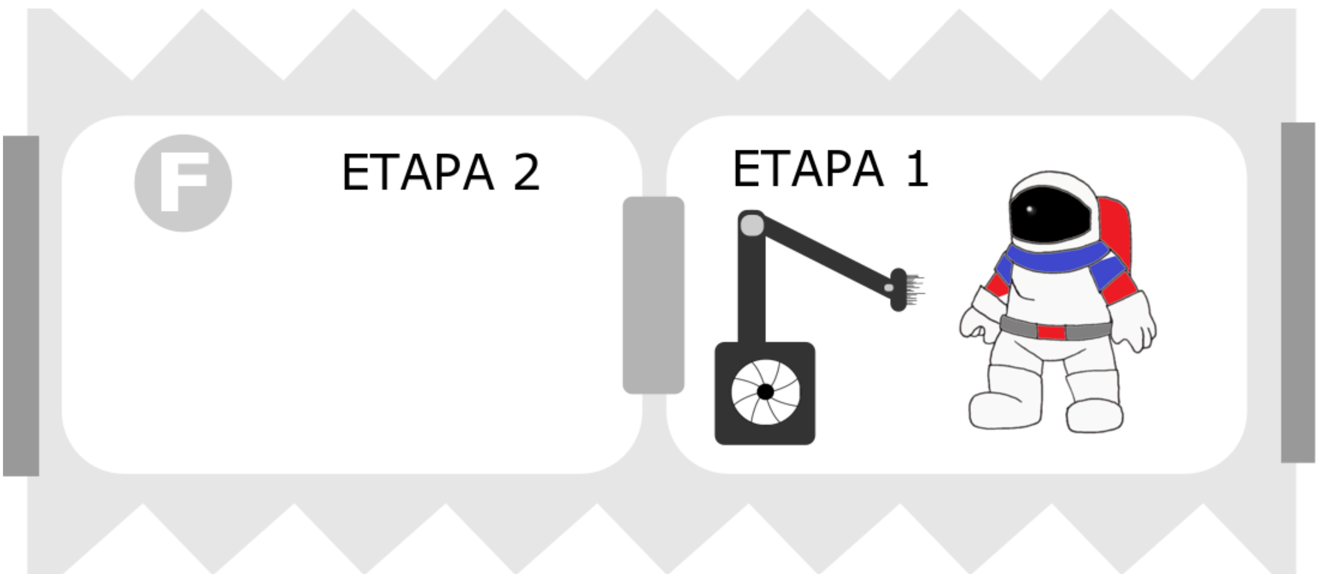

Figure 3. *Stage 1: Astronaut and LPM. Stage 2: Ambient particle filter.*

- **External Suit build of special materials optimized for Extravehicular Activities:**

The use of a properly modified TYVEK®-type suit provides the astronaut with the main active and passive preventive barrier when dust enters the extravehicular activity system.

TYVEK® suits and their technological derivatives are well known for their abrasion resistance and particle impermeability capabilities. We propose the optimization of the suit using flexible systems in key points such as shoulders and elbows to improve the adaptation to the new space suit, accompanying its better mobility compared to previously used models.

In addition, the various configurations of Life Support Systems (LSS) offer a problem at the time of the placement procedure given its size and location. Faced with this problem, we propose assistance among astronauts. The opposite procedure, upon returning from an extravehicular activity, would be facilitated by the implementation of a rupture cord that would allow the opening of the posterior sector of the suit and its extraction from the front.

Following this system, each suit proceeds to be discarded after each use. This is possible given its moderate cost and the little space they occupy.

- **LUNAR PARTICLE MITIGATION (LPM):**

    - ***Surface Decontamination with Ionized Air:***

The surface decontamination is done with a nozzle (Figure 3) consisting of a main flexible tube of 4 centimeters in diameter, the end of which is placed on the contaminated surface. This tube consists of 16 0.5 cm semi-flexible tubes, of which 7 tubes expel ionized air and 9 tubes suck air with dust. The main benefit of having several tubes of a smaller size is that it can be adapted to the shape of the contaminated surface, reaching contaminating particles on non-flat or narrow surfaces (Figure 4). In addition, the asymmetry between air inlet and outlet tubes generates a pressure gradient that increases suction efficiency.

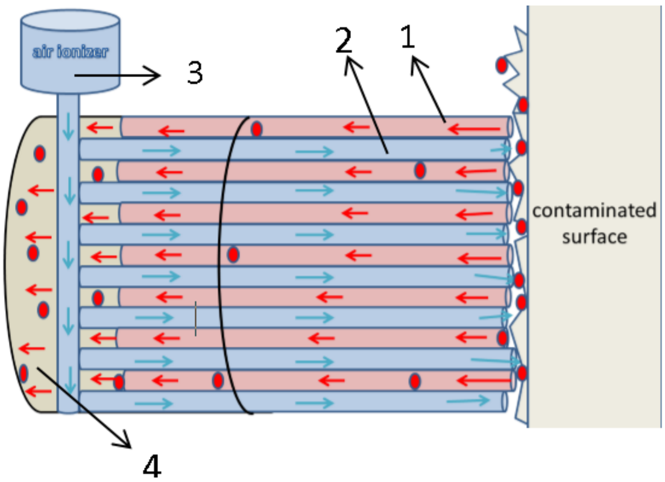

Figure 4: Internal lateral representation of the nozzle. **1**- Red: flexible tubes that produce air aspiration with the contaminating dust. **2** - Blue: flexible tubes that expel ionized air. **3**- Ionized air inlet that is distributed in 7 outlet tubes. **4** - Main tube that connects the nozzle to the second stage.

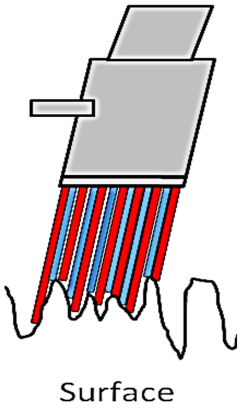

Figure 5: *External lateral representation of the nozzle on an irregular surface.*

We use adjacent and simultaneous ionized air injection with aspiration of particulate material to minimize particle-surface interaction by decreasing electrostatic adhesion, which is the main cause that prevents effective and cost-effective decontamination of different surfaces.

- ***Dust Detection System using LASER:***

We will use an in situ detection system consisting of a LASER system, which is between the nozzle and the electrostatic precipitator. During the aspiration process, this system detects the existence or absence of dust continuously. This is of great relevance because the particles have tiny sizes of up to less than 10 micrometers.

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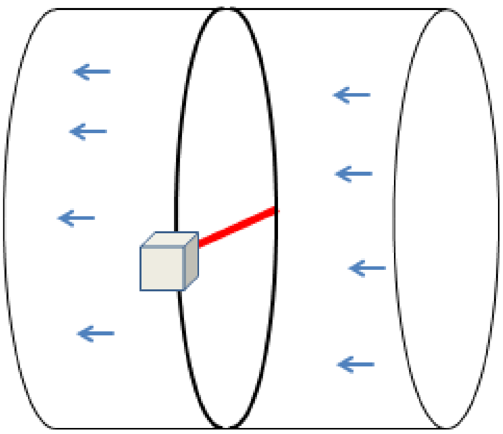

Figure 6: Laser without interruption.

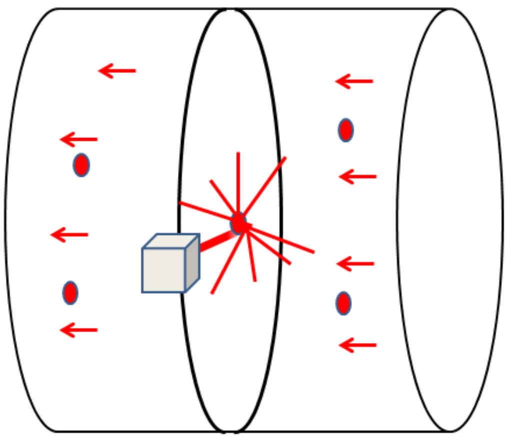

Figure 7: Laser being interrupted by particles

- ***Electrostatical Precipitator Equipment.***

The function of the Electrostatic Precipitation Equipment is to purify the air that contains the contaminant. The particle that comes from the detection stage decreases its speed when entering the region of the electrostatic precipitator, which by means of the electric field that is generated between the negative plate and the positive plate, divert the particle towards one of the plates. Once there, by successive and continuous shaking the particle is moved to a container, where it will be confined.

In search of solutions to emerging problems, avoiding the movement of confined moon dust and ensuring complete retention is a possibility to consider, so the magnetic properties are of great help. This is why a neodymium magnet will be placed outside the final container, taking advantage of the magnetic qualities of ferrous microparticles and the paramagnetic ones of ferrous oxide, both constituents of the lunar dust to retain.

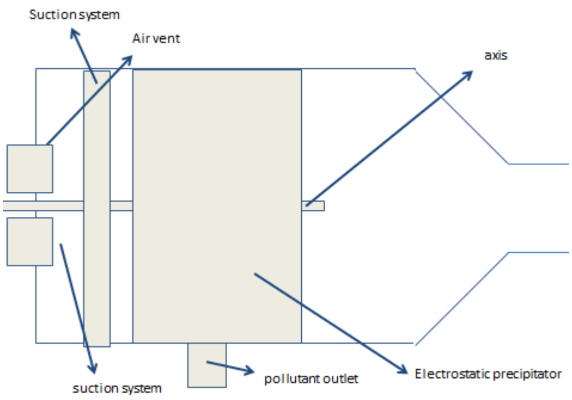

Figure 8. *Side view of Electrostatical Precipitator Equipment*

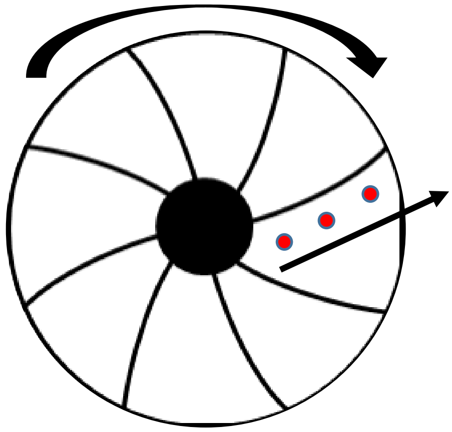

Figure 9. *Front view of Electrostatical Precipitator Equipment. Plates are alternated between positive and negatives.*

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Sample	SiO_2	Al_2O_3	TiO_2	FeO	MgO	CaO	Na_2O	K_2O	MnO
Lunar: 10019	41.1	13.7	8.25	15.7	7.86	11.9	0.93	0.14	0.22
Lunar: 10022	43	13	7	16	8	12	0.54	0.12	0.23
Lunar: 70161	40.34	11.6	8.99	17.01	9.79	10.98	0.32	0.08	0.23
Lunar: 64501	53.63	12.77	3.47	13.37	3.57	9.2	0.73	1	0.2
Lunar: 14053	48	12	1.5	16	8.4	12	0.38	0.14	0.29

Table 1. Main chemistry components of Moon Dust.

In summary, this system offers us a very high efficiency of particle collection. For particles of similar characteristics to the lunar dust, the removal efficiency was 97% by means of the electrostatic precipitator (up to less than 10 microns) and in the case of equal particles and greater than 10 microns, 99% was reached. It causes only a very slight pressure drop and a constant operation can be maintained with a low cost of resources. Based on industrial electrostatic precipitators that are used for particles with physical and chemical characteristics similar to lunar dust. It is possible to determine the most favorable measures in relation to size and performance so that it can be placed in the first stage by an astronaut.

- ***Robotic Arm:***
    - It has a series of pre-set movements to cover the surface of the EVA suit, using the LPM together and sensors placed at specific points of the suit. All these tools together allow an integral control of the cleaning, even reaching difficult to reach sections individually.
    - Due to the delicate movement, the robot will consist of 4 servomotors that allow absolute control of the tasks. The movements will be preset and the astronaut must be placed in the position designated for decontamination. To increase the sensitivity and natural adjustment to the body, the movement will be assisted by real-time adjustments thanks to information from the EVA suit sensors.

- For a more enjoyable experience with the astronaut, a WiFi® system (ESP8266) will be used that will receive information from the robot and make sound announcements to the astronaut, informing him of the cleaning procedure and its completion.

- **Electrodynamic Dust Shield:**

Electrodynamic Dust Shields (EDS) have been in development at NASA as a dust mitigation method for Lunar and Martian missions. The development of a dynamic and instantaneous dust removal system is essential for the development of future travel and space bases.

This technology is being tested in different NASA-funded laboratories, and is widely proposed as a surface dust mitigation technique, being studying its application on spacesuits, thermal radiators, solar panels, optical instruments, and viewports for future lunar and Mars exploration activities.

This shield works on the basis that when an electric field is generated and a dielectric particulate is present in it, it is electrically polarized, thus giving rise to a dipole moment. The application of a non-uniform field results in a phenomenon called dielectrophoretic force that transports the particles in a preferential direction.

Our objective when using this technology is its installation in the internal walls of the inflatable module with the intention of reducing the adhesion of the lunar dust in them. Thus, we achieve that the particles decant to the bottom of the module and thus be aspirated by the LPM. Having this additional barrier enables us to deep clean the modular space.

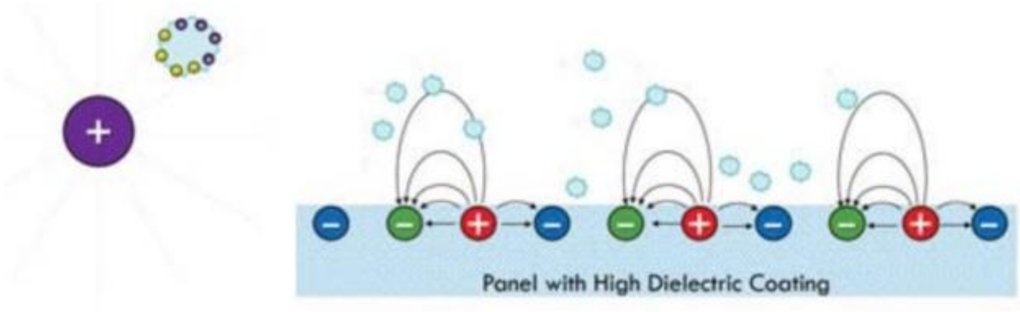

Figure 10. *EDS operation.*

Particle Filters:

Particle filtering with filters is carried out in Stage 2, thus achieving, after reducing the concentration in the air and surfaces to the maximum possible with the electrostatic precipitation method in Stage 1, filtering the finest particles that have have been suspended

This final filtration is an additional precaution to take care of the astronaut's health and the integrity of the systems. The filters used at this stage would be Spun bond prefilters and HEPA or HUPA filters, commonly used by NASA.

Prices:

Estimation of a price of US $ 5,000 per kg of cargo on a space mission, can be done quickly. The price of sending the cleaning platform proposed by ByeDust! It costs US $ 650,000, specifically contacting the weight of all equipment and structure.

In a no so far Future:

The proposed System proposes the abandonment of the inflatable platform and module on the lunar surface. This is based on previous missions and the different methods of return orbit, which require little weight to reduce the consumption of propellant.

We propose the use of our system in a sustainable way, being able to be reused, and even applicable to long-term missions, such as lunar bases, and even, with few modifications, Martian. In addition, with certain less complex adaptations, this integral inflatable system can be used on Earth, whether in industries or laboratories.

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EDS:

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Filters:

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Price:

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