Martian Dust Impact on Human Exploration

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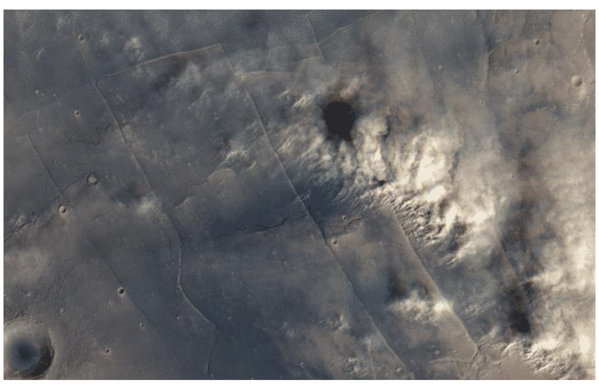
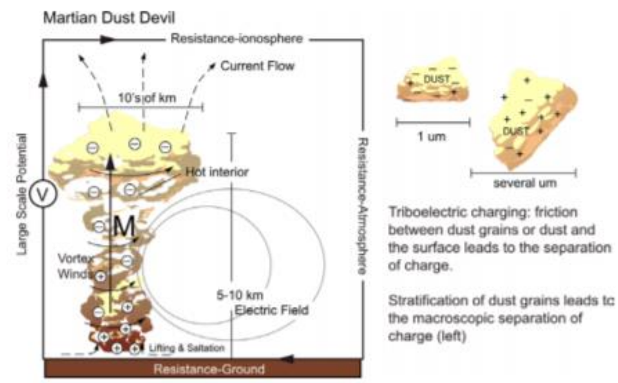
Introduction: Local, regional, and global dust storms have been blowing small, fine, and probably electrostatic grains in Martian atmosphere. Through the surface operations on the Moon of Apollo missions, it is expected that preventing Martian dust from penetrating into spacesuits, human habitats, and mobility systems will be challenging.[1] The thin Martian atmosphere warmed by sunlight as well as mobility system operation and astronaut walk will lift dust off the ground. Understanding Martian atmospheric electricity, and dust impact on human health, surface mechanical systems and surface operations are critical to reduce the risks of the human exploration on Mars.



Martian dust over Tempe Terra, seen by Mars Express on June 17, 2011 (Credit: ESA)

Electrical properties of Mars atmospheric dust: Significant data about dust properties have been obtained from Phoenix, MER (Opportunity and Spirit) and Curiosity. However, none of the instruments did soil conductivity test, which is critical to reduce the risks during Martian surface operations. Laboratory experiments and observations suggest that triboelectric effect causes dust electrification, and smaller particles tend to gain negative charge while larger particles tend to gain positive charge during collusion.[2][3][4]



A model of a Martian dust devil demonstrating how charged particles generate electric fields (Credit: Delory et al. 2011)

Direct measurement of Mars atmospheric electricity will be helpful to understand the charge transfer mechanism in details. The Schiaparelli Entry and Descent Module(EDM) of ExoMars 2016 crashed in October 19, 2016; consequently, its payload DREAMS(Dust Characterization, Risk Assessment, and environment Analyzer or the Martian Surface) is no longer available to measure the atmospheric electric fields close to the surface of Mars. ExoMars 2020, launched in July 2020, will directly measure Martian atmospheric electricity using its scientific instruments Dust Suite (Dust particle size, impact, and atmospheric charging instrument suite) and RDM (Radiation and dust sensors). Furthermore, the sample return of Mars dust collected by MARS 2020 is expected to answer many questions in regard to Martian atmospheric electricity.

Martian dust impact on human health: None of the instruments sent to Mars could measure how toxic Mars dust and regolith are to humans. On Mars, silicate minerals, perchlorates and gypsum exist in regolith or atmospheric dust. It is known that silicate dust causes respiratory disease silicosis, perchlorates damage thyroid gland, and substantial amount of inhaled gypsum damages lungs.[5] Especially, it is critical to understand the presence and distribution of Hexavalent Cromium (CrVI), which is known as a carcinogen.[6]

Dust covered Apollo 17 astronaut Gene Cernan, seen on the lunar surface (above) and aboard the lunar module (below) on the Moon in December 1972 (*Credit: NASA)*

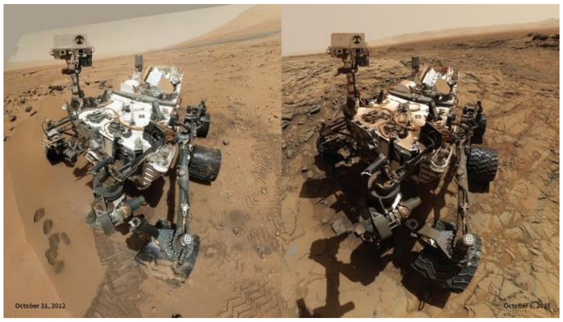
While astronauts of the six missions (Apollos 11, 12, 14, 15, 16, and 17) were exposed to lunar dust less than 10 days, astronauts on Mars will be exposed to Martian dust at least one year if dust enters and remains in their habitats and spacecraft for their return trip to Earth, which may be long enough to develop serious illness.

Martian dust impact on human health can be better understood through data collected to study the association between human health and dusts such as Dust Bowl in 1935, and seasonal African and Asia dusts. In all three cases, a higher rate of respiratory problems is reported when dust density increases in the air.[7] Many findings and health prevention practices to avoid dust impact on Earth are worthwhile in the effort to protect astronauts on Mars.

In order to protect astronauts from inhaling Martian dust, all possible preventive measures need to be developed and available onsite. Astronauts should be aware of the strength of electric fields before EVA. Electrometer [8] to detect static levels on Mars and charge-dissipation technology such as anti-dust agent need to be developed. Astronauts need to carry portable electrometers during EVA to avoid highly charged area, and permanent electrometers need to be installed in Service Field Station, Science and Resource Regions of Interest (ROIs) in Exploration Zone (EZ). Disposable Martian airtight dusters need to be developed. By wearing a disposable airtight duster on a spacesuit, an astronaut can prevent dust from sticking on the spacesuit. Furthermore, an effective airlock system as well as filtering technology to remove imported dust in living quarters need to be developed. The human landing site on the surface of Mars should be chosen among sites with a history of minimal local and regional dust storm occurrence and weak electric fields close to the surface.

Martian dust impact on surface mechanical systems and surface operations: Significant data about dust effects on mechanical surface systems on Mars have been obtained from Phoenix, MER (Opportunity and Spirit) and Curiosity. MEPAG Goal IV Science Analysis Group (2010) highlights the importance to understand the effect of dust on seals and electrical properties of mechanical surface systems, and the corrosive chemical effects of dust on different materials.[9] The effort to understand Martian dust properties using current assets on Mars should be continued until a sample of Martian dust returns to Earth.

Spirit and Opportunity, designed for a minimum 90 days operation, far exceeded their lifespans and survived during the global dust storm in 2007. Curiosity has exceeded its target lifespan also. The performances of the three rovers are promising in terms of supporting human exploration on Mars.



Dust accumulated on Curiosity in October 31, 2012(left) and October 6, 2015(right) (Credit: NASA/JPL-Caltech)

Human presence on Mars will significantly reduce the adverse effects of dust on surface systems. Trained astronauts will be able to maintain the surface systems in a properly working condition by removing dust on surfaces, fixing or replacing malfunctioning components, and minimizing or preventing corrosion with anti-corrosion agent treatment. Technology to manufacture mechanical parts using 3D printers need to be developed for the use in Exploration Zone (EZ).

Sunlight is expected to be a significant energy source to surface mechanical systems and surface operations on Mars. During the global dust storm in 2007, Spirit and Opportunity experienced a dramatic decrease of solar power supply. All possible ways to harvest energy should be considered. A solar panel system with maximum performance in dust storms, equipped with panel cleaning capability such as dust wipers, is needed to be developed. Due the low atmospheric density on Mars, which is about one percent of Earth's, harvesting energy using wind force is expected to be minimal. Nevertheless, the wind power system, which is relatively easy to install, can supply an additional energy when a dust storm passes through Exploration Zone (EZ). A radioisotope power system (RPS), which can complement the solar panel system and the wind power system, and an efficient energy storage system need to be developed.

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