

Permanent Protection System of the Astronaut Spacesuit, Optical Surfaces and all Other Equipment against Charged Particles of Lunar Dust



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Abstract

The illuminated surface areas of the Moon become positively charged as a result of photoionization under the influence of mainly the UV part of the solar radiation spectrum. And the shadowed areas of the surface acquire a negative charge due to the incision of the solar wind flow and the plasma layer of the Earth's magnetosphere tail. As a result, dust particles lying on these charged areas of the surface and having received the same electric charge are subject to the action of electric forces exceeding the sum forces of gravity and van der Waals adhesion. Which push them away from the surface and create a rarefied plasma shell near the lunar surface and conditions for their levitation and transportation along the surface due to the electric fields in the plasma shell. These levitating charged dust particles settle on the astronauts' spacesuit, optical surface and on surface all other equipment. They represent a serious danger to the successful work of astronauts and all optical-mechanical equipment on the lunar surface and seriously hindering further exploration of the Moon. The development of scientific research on the Moon requires the creation of a reliable permanently protection system for engineering systems and humans located on the its surface from the settling and adhesion of levitating above surface charged particles of lunar dust to them. The most effective way to permanently protect the optical surface, the astronaut's spacesuit and all other equipment from charged particles of lunar dust levitating above the surface both during the day and at night is to supply them with electrically conductive, electrically insulated outer shells (by flexible and stretchable material for the spacesuit), connected to a power supply unit, having the necessary electrical charge with a given frequency of polarity reversal, protected by two Russian invention patents. In vacuum and low gravity conditions, the excess of the electrical repulsion forces of their surface over the forces of gravity repels levitating rarefied charged particles with the same charge from settling on their surface both during the day and at night. And also, by installing the equipment in a special dust-protecting bowl with an electrically insulated outer shell at the maximum possible distance from the surface.

Keywords: Charged lunar dust particles; Electrically conductive shells equipment; Electrical repulsion forces; Dust-protecting bowl; Dust particle protection system; Lunar observatory; Special optical telescope

Introduction

The surface of the Moon was subjected to constant bombardment by micrometeorites and larger objects, as well as exposure to solar radiation, high-energy cosmic rays of solar and galactic origin, plasma from the Earth's magnetotail, and other factors of outer space. The dust on the surface of the Moon, formed as a result of the impact of high-speed meteorites, has an explosive nature of origin, has become sharp with an extremely diverse shape and abrasive – like tiny shards of glass. Because it has not been exposed to atmospheric influences and elements such as water and oxygen. Lunar dust, the finest submicron and micron fraction of lunar regolith. At a temperature of about 400 K on the illumi-

nated side of the Moon, as a result of photoionization under the action of mainly the UV part of the solar radiation spectrum, a certain number of negatively charged electrons are knocked out of the lunar surface, as a result of which the surface will have local areas charged positively [1-13]. Separate dust particles of submicron and micron sizes lying on these charged areas of the Moon's surface and having also received a positive electric charge q , are subject to the action of oppositely directed forces: electrostatic Coulomb force $F_e = qE$, repelling them from the surface, and gravitational force $F_g = mg_L$ (m is the mass of a particle several microns in size $\sim 10^{-15}$ kg, taking into account the density of the regolith material $\rho \approx 3000$ kg/m³, g_L is the acceleration of gravity on the Moon 1.6 m/s²) and the van der Waals adhesion force F_a , holding

these particles on the surface. The significant electrostatic fields that arise in these local areas during the daytime, as well as the fluctuations of positively charged individual micron-sized particles in this layer with a mass of $m \sim 10^{-15}$ kg as a result of photo-ionization, lead to the fact that the electrostatic force acting on them, repelling them from the surface, $F_e = qE$, will exceed the sum of the forces holding them on the surface: the gravitational force F_g and the adhesive van der Waals force F_c . As a result, individual charged particles of regolith of micron and submicron sizes are torn away from the surface with the same electrostatic charge and levitate above this near-surface electric field. The condition for the levitation of these rarefied charged particles above the surface is the approximate equality of the repulsive electrical forces and gravitational forces ($F_e \approx F_g$) with the absence of the intermolecular force of van der Waals interaction $F_c \approx 0$ [3-13].

Indeed, data obtained from the Surveyor spacecraft indicate the presence of a glow the lunar horizon at altitudes of about 100-300 mm above the surface at sunset due to the presence of levitating rarefied charged dust particles of micron and submicron sizes at these altitudes [13-15]. The Blue Ghost M1 spacecraft of the American company Firefly Aerospace on March 16, 2025 the first captured sunset on the Moon, also directly recorded a "stream of light" over the lunar surface, caused by the glow of tiny dust particles charged exposed mainly to UV solar radiation, raised by electrostatic forces from the illuminated surface [16]. A rarefied charged lunar dust will distribute above a surface due to electrostatic lifting and dynamic processes, which pose a threat on the lunar surface exploration activities. On the dark side of the Moon, electrons that are part of the solar wind stream, the plasma layer of the Earth's magnetotail, crash into the surface and are captured by it, giving local areas of the surface a negative charge. As a result, a separate negatively charged micron and submicron-sized regolith particles, due to the mechanism of electrostatic repulsion of like charges, become capable of breaking away from the surface (with the same electrostatic charge) and levitating above it. At the same time, the intensity and height of levitation of negatively charged dust particles at night decreases. As a result, local areas of the Moon's surface illuminated by the Sun tend to be positively charged, while shaded areas acquire a negative charge. These dynamic processes cause the transfer of dust particles over the lunar surface and the scattering of sunlight on these particles directly above the surface to the observed glow of the lunar horizon at sunset, as observed by Norton et al. [14] & [15], the Blue Ghost M1 spacecraft [16]. Such charged particles of lunar dust of regolith of submicron and micron sizes, levitating above the surface at altitudes of about 100-300 mm, settle on optical surfaces, the astronauts' spacesuit and the surface of equipment, and also penetrate into cracks and moving parts of the spacesuit, into rotating parts and mechanisms of equipment. They pose a serious danger to the successful work of astronauts and all optical-mechanical equipment on the lunar surface and are a serious obstacle to further exploration of the Moon.

Universal Effective System of Permanent Protection against Charged particles of Lunar Dust of the Astronaut Spacesuit and all Equipment both during the Day and at Night

Intricate dynamics of lunar dust near-surface plasma, are primarily driven by electrostatic forces generated by the continual bombardment of highly energetic UV photons and solar wind on the lunar surface, and dust particles. Lunar dust, a significant hazard for lunar missions, exhibits unique properties that pose challenges for lunar exploration. Because the fine component of the lunar regolith contributes to the operational and health hazards posed to planned lunar expeditions. Therefore, with the rapid development of lunar exploration, it is necessary to ensure that all equipment and also an astronaut's spacesuit is protected from charged lunar dust on the lunar surface for meet the need of future lunar exploration missions. Reliable protection of astronaut's spacesuit, optical surface and all other equipment from adhesion of particles of charged lunar dust will be of decisive importance for the success of all future active research on the surface of the Moon. Therefore, reliable permanent protects urgently require to advance lunar science and successful implementation lunar exploration projects scientific equipment, engineering systems, landing vehicles and the health of the astronauts themselves, located on the surface of the Moon, from the settling and adhesion of particles of charged lunar dust levitating above the surface. The most effective system for permanent protection of the astronaut's spacesuit as well as the optical surface and all other equipment from charged particles of lunar dust levitating above the surface of the Moon both during the day and at night are:

a) For the first time, optical instruments and all other equipment are installing in a special dust-proof bowl more than 700 mm high, shaped like an inverted truncated cone (Figure 1). A durable bowl with a rigid and solid bottom is raised by support posts to a height of about 300 mm above the surface of the Moon, protected by two Russian patents [1,2]. The location of the upper level of the bowl at a height of more than 1,000 mm above the surface will practically ensure the protection of the scientific and technical equipment located inside the bowl from possible penetration and settling on their surface of charged particles of lunar dust levitating on the underlying (~ 100 -300 mm) layers [13-15]. A longitudinal section of the special optical robotic telescope with the primary mirror of the diameter 300 mm and with sliding visor (SOTR-300V) in a special protective (from charged near-surface particles of lunar dust) bowl (with the ground glass removed) for studying the climate from the lunar surface and the energy imbalance between the Earth and space is shown in Figure 1 [17,18]. The active operation of the unprotected from lunar dust Chinese Lunar-based Ultraviolet Telescope (LUT), launched on December 2, 2013, during the daytime on the lunar surface shows a fairly high stability of its photometric

characteristics and the absence of any change in their readings during the 18-month lunar experiment, i.e., the absence of any adhesion of lunar dust to the telescope mirrors [20]. The preservation of highly stable photometric characteristics of the LUT during its 18-month successful operation directly on the lunar surface during the daytime allows us to state that its mirrors were not damaged due to the location of the LUT mirrors above the surface at a height of more than 700 mm, i.e., charged micron and submicron near-surface lunar dust particles, practical will not be able to rise above the surface to such a height. The absence of any dust particles deposited on the telescope mirrors and the maintenance

of high photometric efficiency of the reflectivity of the LUT mirrors during 1.5 years of active operation during the lunar daytime indicate the practical absence of any charged dust particles at the altitude of the LUT installation (significantly more than 300 mm) above the lunar surface and confirm the conclusions of Norton et al. [14], Popel' [13] and Zakharov et al. [11]. However, only such protection of equipment from charged lunar dust is necessary, but not sufficient for its complete protection over a long period of time, as well as for the protection of the astronaut's spacesuit. This requires the introduction of additional reliable protection, introduced below.

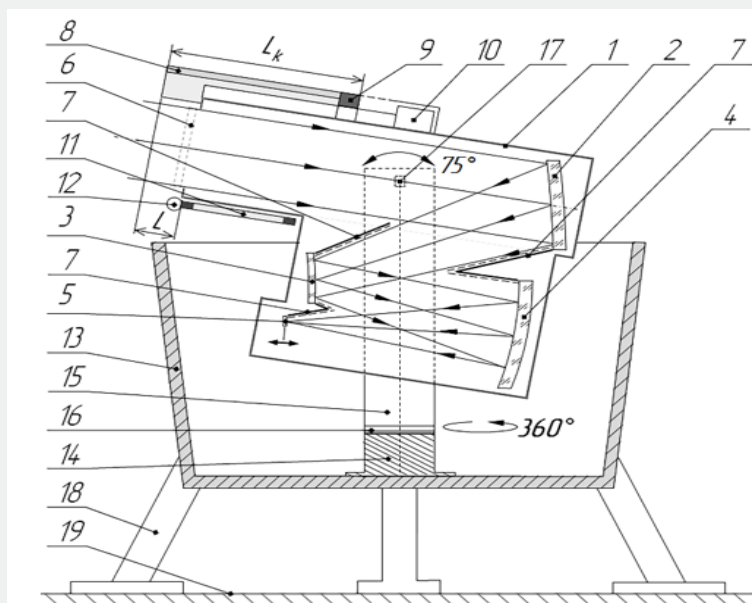


Figure 1: The general view of SOTR-300V of the Lunar Observatory (with the ground glass removed) in the dust-protecting bowl in the longitudinal section for studying the climate and the energy imbalance between the Earth and space [17,18], where 1 – is the reliable hermetic enclosure of a telescope tube, 2 – the concave mirror, 3 – the convex mirror, 4 – the concave mirror, 5 – the CMOS image sensor; 6 – the entrance pupil, 7 – the antflash lens hood, 8 – the sliding visor, 9,10 – the mechanisms of the displacement of the sliding visor, 1) – the diffusing glass, 12 – the joint, 13 – dust-protecting bowl, 14 – basement of the mount, 15 – upper part of the mount, azimuth-rotating, 16 – means of azimuth rotation of the upper part of the mount, 17 – means of altitude rotation of the tube, 18 – support feet of the bowl, 19 – the lunar surface.

b) For the first time, the outer surface of the equipment, the astronaut's spacesuit, optical surfaces and dust-proof cup are covered with electrically conductive electrically insulated shells (by flexible and stretchable material for the spacesuit), connected to a power supply unit having the necessary electric charge with a given frequency of continuous polarity reversal, protected by two Russian patents [1,2]. In vacuum and low gravity conditions, the excess of the electrical repulsion forces of their surface over the forces of gravity repels and throws back levitating charged particles with the same charge from settling on their surface, since intermolecular van der Waals forces are absent. To ensure reliable repulsion from the surface of the optics, the astronaut's spacesuit, the dust bowl and all other equipment of individual charged particles

of lunar dust of submicron and micron sizes, levitating above the surface at heights of 100-300 mm, it is necessary that the repulsive electrostatic force of their shells be comparable to the force of detachment of such particles from the lunar surface under the influence of electrostatic forces of the regolith charge.

Earlier, when developing the concept of the Lunar Observatory (LO) for studying the climate and the energy imbalance between the Earth and space [17-19] in 2016 and 2017, we were the first to patent our inventions for effective protecting only the mirrors of the special optical telescope SOTR-300V from levitating charged particles of lunar dust using a similar effective system [1,2]. In this case, later

modernized SOTR-300VM LO for continuous simultaneous monitoring of the asteroid-comet hazard across the entire celestial sphere and the Earth's climate [21-23] is installing in the central zone of the dust-protective bowl (Figure 1), and its entrance pupil is located at a height of more than 1,000 mm above the surface of the Moon to reliably protect its mirrors from the settling and adhesion of charged particles of lunar dust, levitating above the surface at heights of about 100-300 mm, raised from the surface by electrostatic forces. Additional safety protection of mirrors against the possible impact of charged particles of lunar dust is provided by continuous inversion of the polarity of the charge of the electrically insulated, electrically conductive shells of the mirrors, the entrance pupil of the telescope and the dust-proof cup with a given frequency, which repels and throws levitating charged particles away from the mirrors [1,2].

Conclusion

a) The surface layer of the Moon is covered with charged dust particles, since on the sunlit side of the Moon it is mostly the ultraviolet part of the solar radiation spectrum that interacts with the upper layer of regolith, charging its surface. The electric field generated in this layer and fluctuations of the like charge of separate particles on the surface create conditions under which the electrical repulsive forces can exceed the sum of the forces of gravity and the van der Waals adhesion force. As a result, individual like-charged regolith particles of submicron and micron sizes break away from the surface and levitate above it [1,2]. "Streams of light" just above the lunar surface, caused by the scattering of sunlight by these rarefied charged dust particles, were directly recorded during sunset by the Surveyor spacecraft in 1967 [14,15] and Blue Ghost M1 on March 16, 2025 [16]. These charged dust particles levitating above the surface represent a serious obstacle to the successful work of astronauts, all scientific and technical equipment on the lunar surface and for the further exploration of the Moon.

b) Protection of all scientific and technical equipment on the surface of the Moon from the settling and adhesion of charged particles of lunar dust levitating above the surface is primarily carried out by installing (placing) them in a special dust-proof bowl with an upper level at a height of more than 1,000 mm above the surface [1,2]. Direct experimental data from the Chinese Lunar Ultraviolet Telescope (LUT) during the daytime on the lunar surface indicate that there was no influence of near-surface charged particles of lunar dust on the optical elements of the telescope during its 18-month operation on the lunar surface during the daytime at an altitude significantly exceeding 300 mm [20]. The mirrors of the LUT telescope were not damaged due to their location above the surface at a height of more than 700 mm. The absence of dust particles deposited on the mirrors of the LUT telescope and the preservation of their high photometric efficiency of reflectivity during 1.5 years of active operation during lunar daytime hours indicate the practical absence of charged dust particles at the height of the LUT installation (significantly more than 300

mm) above the surface of the Moon.

c) The astronaut's spacesuit, optical surfaces and other equipment, as well as the dust-proof bowl, are covered with electrically conductive, electrically insulated outer shells (by flexible and stretchable material for the spacesuit), connected to a power supply unit. The power supply unit produces the necessary electric charge with a given frequency of continuous polarity inversion, which repels and throws away from their outer shells like-charged particles of lunar dust in conditions of reduced gravity and vacuum of the Moon both during the day and at night.

d) As a result, the specified frequency of polarity inversion of the required electric charge of the electrically insulated outer shells of the equipment, the astronaut's spacesuit, optical surfaces and dust-proof bowl will ensure their permanent reliable protection from the settling and adhesion of levitating particles of charged lunar dust.

Thus, the proposed universal system of continuous and reliable protection of equipments both during the day and at night from charged particles of lunar dust levitating above the surface consists in: (1) placing scientific and technical equipment in a special dust-proof bowl at the maximum possible distance from the surface; and (2) covering the astronaut's spacesuit, optical surfaces and other equipment, as well as the dust-proof cup with electrically conductive electrically insulated outer shells (by flexible and stretchable material for the spacesuit), connected to a power supply unit with the necessary electric charge with a given frequency of continuous polarity inversion [1,2]. Such a round-the-clock effective system of protection of the astronaut's spacesuit and all other equipment on the surface of the Moon from levitating charged particles of lunar dust opens up a broad reliable prospect for the creation of scientific, industrial, habitable infrastructure and permanent scientific bases using the latest technologies. And, finally, a global scientific task for all countries of the world will be successfully solved – the organization on the surface of the Moon of the Lunar Observatory with a system of round-the-clock simultaneous monitoring of asteroid danger throughout the celestial sphere and the Earth's climate [17,18,21-23].

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