Short Communication

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Hybrid Material for Radiation Protection in Lunar Environment

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ABSTRACT

In the context of an overview of radiation as the prime showstopper of human deep space exploration and a regolith-based material as a candidate for protection, this synthetic paper presents an original possible technology for hybrid hybrid protection-wall. This concept takes advantage of different elements available on site in a planetary base, in particular in the lunar regolith.

Abbreviations: ALARA: As Low as Reasonably Achievable; ISRU: *In-Situ* Resource Utilization; GCR: Galactic Cosmic Rays; SPEs: Solar Particle Events

Short Communication

Future space exploration plans of all major national agencies include missions and settlements on the Moon and even missions to Mars. Such ambitions require astronaut life support both in transit vehicles and on planetary surfaces. One of the potential show stoppers for deep space human exploration is radiation because of the health risks from radiation exposure. The associated engineering challenge is to develop radiation protection systems that respect all aspects of mission design and minimise doses as well as mass and complexity of the solution. As Low as Reasonably Achievable (ALARA) [1] is a principle which has been adopted by the space radiation protection community in order to search for optimal solutions which lead to minimal dose exposure as long as they remain feasible and affordable. Maximization of *in-situ* resource utilisation (ISRU) is the number one priority in this regard as the mission cost may be significantly decreased and the safety and maintenance of equipment may be enhanced and facilitated. The prime candidate for ISRU on the Moon is regolith, or the lunar soil. It is abundant and relatively easily accessible on the surface, thus becoming the perfect source of raw materials. This paper presents the idea of using regolith-based materials as passive radiation shielding on the Moon.

Space Radiation

There are two main primary sources of radiation that astronauts need protection from: Galactic Cosmic Rays (GCR) and Solar Particle Events (SPEs). When primary radiation hits target material, for instance a passive shielding of a habitat, it creates a chain a secondary emission. The type and energy of secondary particles depend on the nature and properties of the primary particle-matter pair. CGR are cosmic particles that originate from supernova remnants [2]. They are 83% protons and alpha particles, 14% helium nuclei, about 1% heavier ions, and electrons. Through shock explosions, GCR are accelerated up to very high energies which makes them difficult to be stopped in shielding [3]. Galactic rays are omnipresent in space; however, the probability of encountering an ion decreases drastically with the increase in the atomic number. SPEs are mostly protons and electrons of the solar wind that are accelerated through coronal mass ejections. Their flux can increase up to 10^{10} cm^{-2} and extend over several hours or days which makes SPEs dangerous in terms of radiation exposure [4]. In a short period of time, an unprotected astronaut would be exposed to extremely high doses [5]. Despite this, a major difficulty regarding protection from SPEs is their unpredictability. Generally, the chances of encountering an SPE are higher during the solar maximum a period of high solar activity during the 11-year solar cycle. However, the exact timing and nature of SPEs remains highly unpredictable. SPEs are different in their proton spectra. Some historically recorded SPEs dominate the spectrum in the range of 10-30 MeV – for instance the SPE of August 1972 [6]. Others stretch more evenly over the energy spectrum of 10-1000 MeV protons, as for example the October 1989 event series [7]. Any primary radiation reacts with target material and produces new particles or fragments thereof through nuclear and electromagnetic reactions. Often, secondary emissions are more dangerous to the human body when they deposit more energy than the primary particles, which are often too energetic and thus mainly pass through the body or create secondary radiation. Due to the mixed nature of the primary radiation environment in space, secondary emissions also range from protons, to heavy nuclei, X, and γ rays. It has been repeatedly shown that neutrons present the biggest hazard in space [4,8,9]. In deep space, it has been predicted that neutrons can account up to half the radiation doses [10].

Radiation Shielding with Planetary Materials

The original and new solution that is presented here consists in using materials sourced on the Moon, by combining materials of different natures. Indeed, the Hybrid Shield solution integrates a plastic-polymer matrix in which regolith grains are embedded. The advantages are multiple. This solution embeds a fractal or powdery material in a relatively soft paste, to make the most of this combination. First, the processes exist to extract the constituents on site, and in particular the regolith is immediately available in powder form. Then the integration of the lunar powder in a plastic binder avoids or minimizes the problem of abrasion due to the fractal and powdery character of the lunar powder, which poses a real problem of handling and use. The “concrete” thus obtained becomes a relatively neutral material, made by projection of powder in the matrix, and usable in coating directly applicable on inflatable structures for example. Finally, we hope to combine the protective advantages for radiation of a light amorphous material (plastic) and a heavy mineral material (regolith). Indeed, ions and harmful particles are more easily stopped by hybrid materials that create particular paths, combining mass and volume effects.

Technological Stakes

The combination of amorphous and powdery materials is likely to protect not only against solar bursts (which traditionally constituted the major risk of distant stays) but also against the long-term effects of galactic background radiation (which we know today to be just as damaging). To take a comparison with aerospace structures (airplanes) we can say that the biological structure in the cockpit will be protected from both transient damage such as a major gust, and from the effects of cyclic fatigue due to dynamic turbulence.

Outlook

Future work with regolith is based on the principle of using several promising materials to capitalize on their combined beneficial properties for radiation protection and structural integrity. Such solutions can be used primarily for habitat construction on planetary surfaces. Radiation protection efforts are put towards minimizing the doses exposed onto astronauts inside a habitat. The evaluation of proposed methods will be done through a combination of numerical simulations and experimental validations with radioactive sources available on Earth.

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