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Title

Regolith-based Lunar Habitats - an Engineering Approach to Radiation Shielding

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Abstract

All major agencies are invested to support humanity's return to the surface of the Moon. For instance, the European Space Agency is developing their Moon Village concept where sustainable exploration is largely based on in-situ resource utilisation (ISRU). 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. One key utilisation of regolith is habitat construction. Regolith can make up the bulk of a habitat structure, ultimately becoming the main load-carrier material as well as the radiation, thermal and micrometeoritic shield. This work aims to study the radiation shielding properties of lunar regolith, and assess it from the engineering perspective - considering the feasibility and technological readiness of proposed solutions. Radiation-matter interactions are simulated with RayXpert® software developed at TRAD Tests & Radiations. The software is a Monte Carlo based user-friendly tool. It allows for selective generation of primary radiation sources, detailed 3D visualisations and energy deposition calculations based on GEANT4 physics. The radiation protection potential is evaluated from the analysis of the secondary emissions produced in a regolith wall and their relative significance both in terms of energy deposition and quality factors. In this paper, we investigate the relative effectiveness of polymer-enriched regolith. A significant amount of literature proposes sintering techniques using polymer binders to make regolith bricks that can be arranged to make habitats. Same literature often highlights the added radiation protection because polymers are hydrogen-rich. However, to the authors' knowledge, no comprehensive study using Monte Carlo tools and calculating the dose equivalent in the body has been performed (that would conclude if indeed the technique has added value for protection from radiation. This paper presents the results of such study. We calculate the dose equivalent in the ICRU-sphere behind a representative regolith slab, successively enriched with a polymer binder. The primary radiation sources are Galactic Cosmic Ray spectra for protons, helium, and carbon ions. Secondary emissions are studied, with main focus on neutron and proton production. The results are cross-compared to hydrogen-rich materials and their alternative utilisation in habitats on the Moon. From the engineering point of view, simple yet effective solutions can be achieved with more cost-effective and radioprotective characteristics. While polymer binders are a competitive option in terms of time effectiveness, the energy and infrastructure required remain a major concern for construction on the Moon. This work provides quantitative insight into how much polymer is required to claim a significant improvement in terms of radiation protection when compared to a bare regolith wall.