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Simulations Of Solar Particle Events Using OLTARIS

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Abstract
Due to high energetic radiation coming from SPE particles on Mars, it is required to find the best shielding for astronauts. In this work, various shielding materials, namely Kelvar, Polystyrene, and LiH, are simulated in spherical geometry around the martial regolith for various events of SPE namely August 1989 and October 1972 using OLTARIS software. The effective dose equivalent is simulated and studied by varying the material thickness for different SPE particles and ions. In addition, LET spectra are also systematically investigated.

Key Words: Solar Particle Events, OLTARIS, Polystyrene, LiH, Kevlar

1. Introduction
The energetically charged particles released from energetic processes in the solar corona are known as Solar Energetic Particles (SEP) [1]. They are mainly associated with coronal mass ejections as well as solar flares. The SEPs consist of 90 % proton and 5% helium nuclei, along with 1% of heavy ions. The SPE energy spectra cover the range of a few KeV to hundreds of MeV. In extreme cases, SPE can reach up to 10 GeV. The SPE are rare events, mostly occurring during the solar cycle when the sun plays maximum solar activity. However, some of them occur at any time during solar activity. Further, they are also produced during solar eruptions, where the particles are accelerated at a relativistic speed via plasma. Historically recorded events of exceptionally intense solar activity include the Carrington event on September 1859, February 1956, August 1972, and September 1989. The August 1972 event had the largest proton flux.
To protect from such higher radiations from SPE on Mars's surface, proper shielding materials are required for space suits and for other electronic equipment. This work uses various shielding materials such as Kevlar, Polystyrene, and LiH, where thickness is optimized for these materials. The effective dose is equivalent for different shielding materials as well as for various organs of the body, LET spectra are studied for SPE environment, which is discussed in the following sections.

2. Simulation Set-up
In this work, two spheres are simulated in OLTARIS [2]. The first outer sphere is made up of martial regolith, and the second inner sphere is made up of shielding material of various thicknesses (1-5gm/cm^2), namely Kevlar, polystyrene, and LiH. At the center of the setup, the portion represents the female adult voxel (FAX) in Oltaris framework.

Sr. No	Material	Chemical Formula	Density
1.	Martian regolith	H_2O(7.4%). $Al_2CaK_2MgNa_2O_7$ (32.1%). Fe_2O_3 (9.3%). O_2Si (51.2%)	1.70
2.	Kevlar (polypara-phenylene terephthalamide)	C14H14N2O4	1.44
3.	Polystyrene	C8H8	1.06
4.	Lithium hydride	LiH	0.82

Table 1: different materials used for shielding purposes on Mar's surface.

For the simulation, the Solar Particle Event (SPE) environment is set on the Mars Surface with the event in October 1989 with Mars parameters of MarsGram (MGRAM) and elevation 0.0 km. In the simulation, the Dose Equivalent is calculated with quality factor = ICRP60 [3].

3. Results
3.1 Effective Dose Equivalent
The effective dose equivalent [4] for different shielding materials such as Kevlar, Polystyrene, and Lithium Hydride are shown in Figure 1. In this study, we have varied thicknesses of shielding materials from 1, 3 and 5g/cm^2 for Kevlar, Polystyrene, and Lithium Hydride, respectively.

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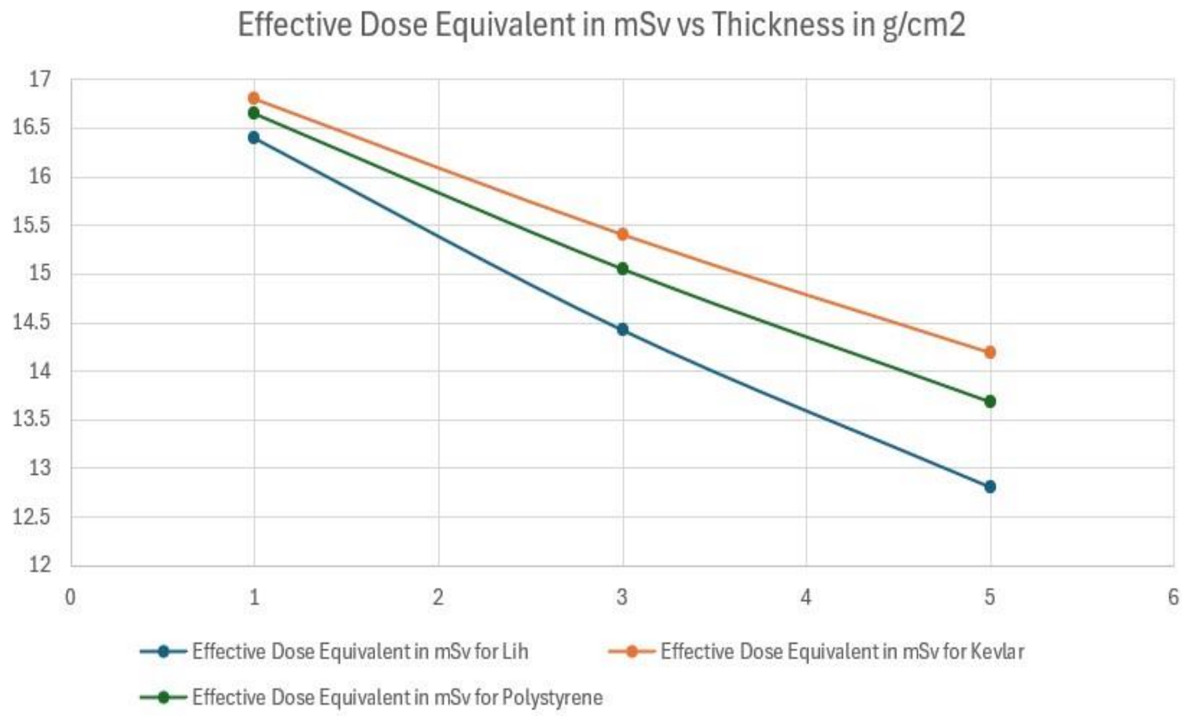

Figure 1: Effective Dose equivalent for different shielding materials.

From Figure 1, we can clearly see that LiH is more effective in reducing the effective dose equivalent than Kevlar and Polystyrene. Therefore, we prefer LiH to shield material for space suits and other space applications.
Figure 2 shows the average Dose equivalent for different body organs, such as the bladder and brain.

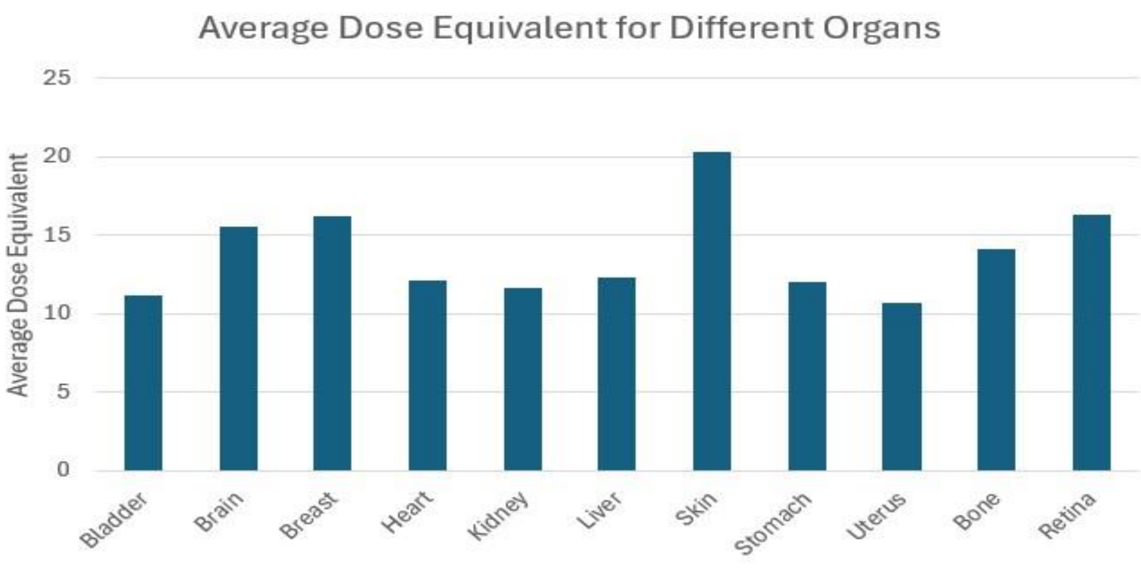

Figure 2: Average Dose Equivalent for different organs.

From Figure 2, it can be seen that the skin absorbed the highest dose as compared to other organs of the body. The brain, breast, and retina absorbed approximately the second highest and equal dose in the body as compared to other organs.
In order to see the effect on average dose for different shielding materials in the skin organ, we simulated Average dose profile as a function of thickness of shielding materials from 1-5 (g/cm^2) for skin. We observed that LiH reduces higher average dose as compared to other two shielding materials such as Polystyrene and Kevlar.

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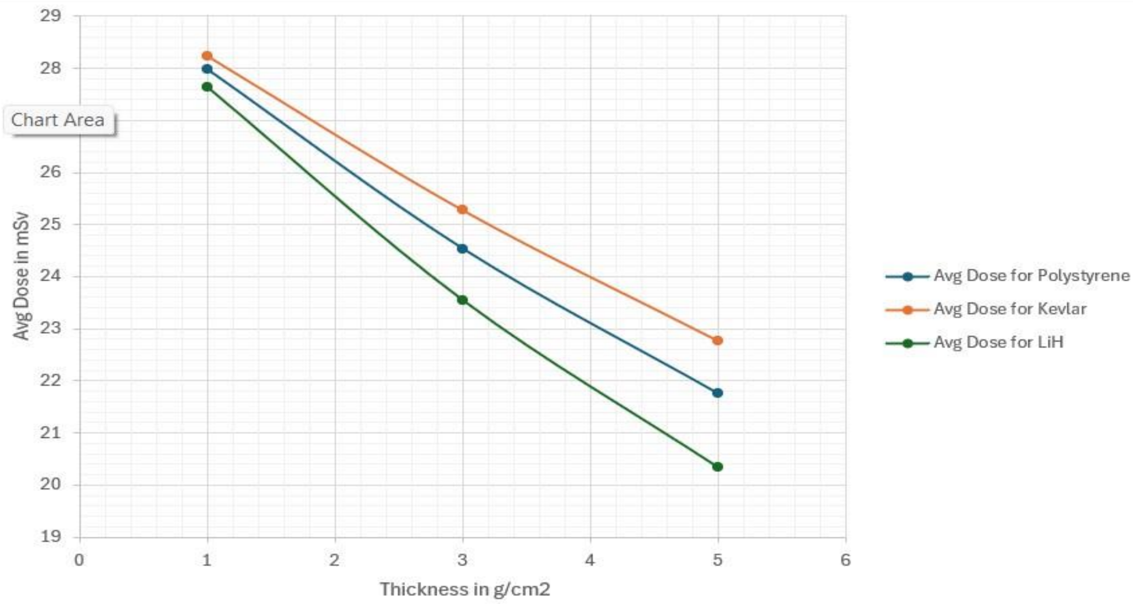

Figure 3: Average Dose in different shielding materials.

3.3 Fluence vs Energy

The simulation for fluence spectra of SPE particles such as proton, alpha and iron is carried out for the October 1989 event. The results are shown in figure 4. As expected, the proton has higher fluence spectra as compared to alpha and iron in SPE environment.

3.3.1 SPE Oct 1989 Event [2]

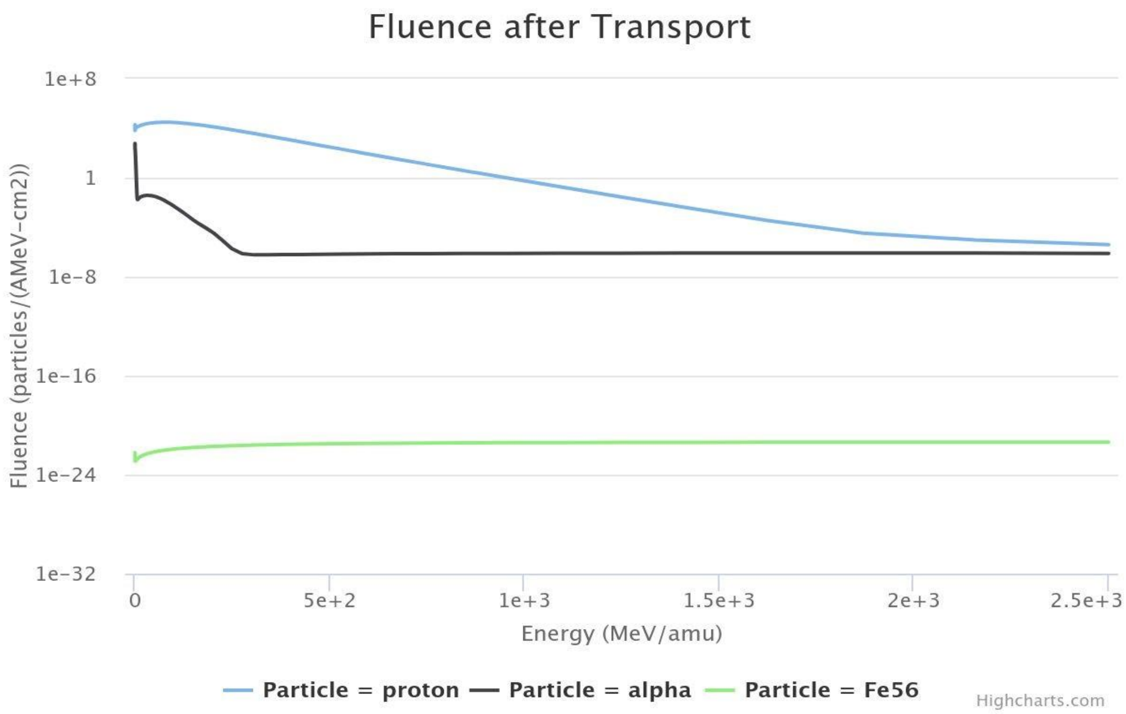

Figure 4: Fluence vs Energy for different SPE Particles.

3.3.2 Fluence vs Energy for SPE 1972 Event [2]

The simulation for fluence spectra of SPE particles such as proton, alpha and iron is carried out for the August 1972 event. The results are shown in figure 5. As expected, the proton has higher fluence spectra as compared to alpha and iron in SPE environment. On comparing the two events Oct 1989 and August 1972, the proton fluence has different shape while fluence for alpha and iron have similar shapes for both the events.

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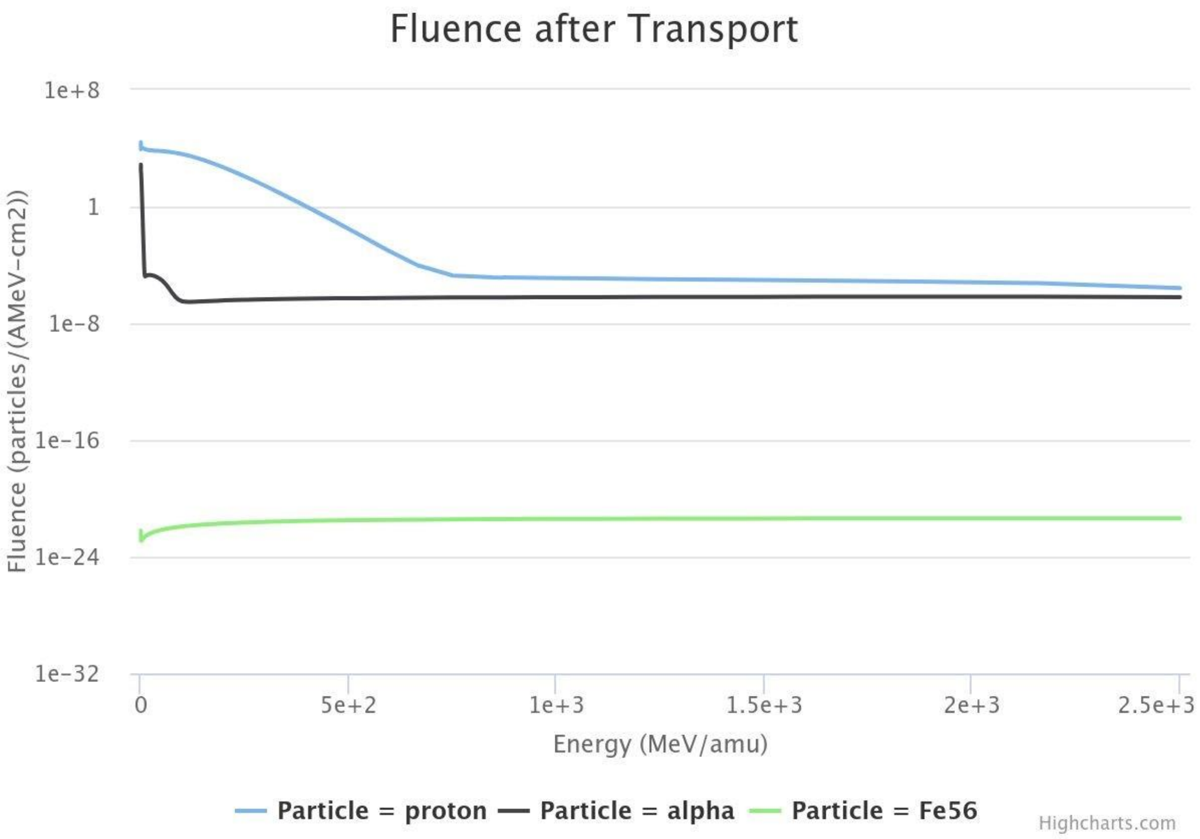

Figure 5: Fluence vs Energy for different SPE Particles.

3.4 Linear Energy Transfer (LET) Spectra: Linear energy transfer (LET) [4] is the average (radiation) energy deposited per unit path length along the track of an ionizing particle. Its units are keV/µm. Figure 6 shows the integral flux as a function of LET.

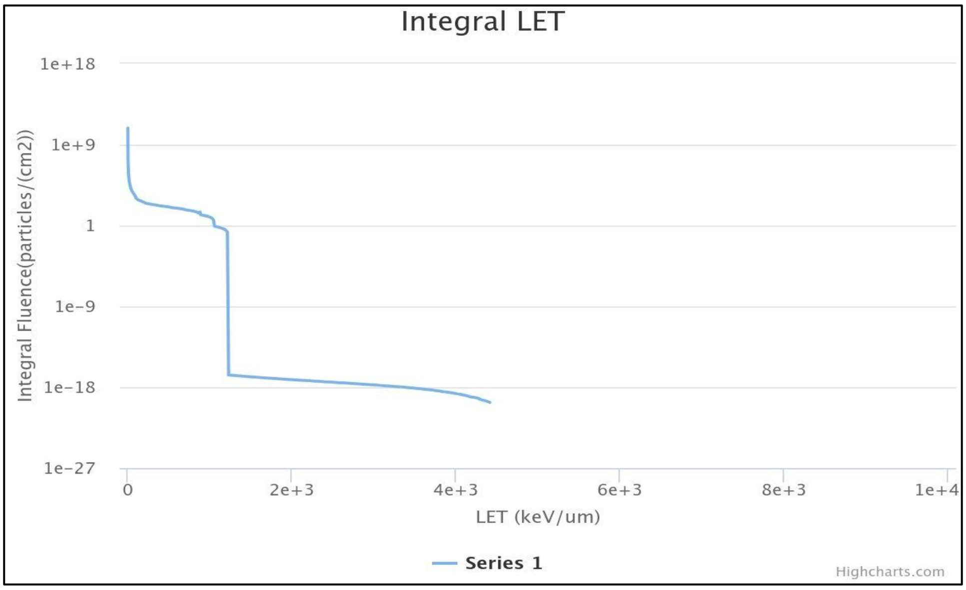

Figure 6: Integral Fluence vs LET in SPE environment.

4. Summary and Conclusion

In this work, we optimize shielding materials for Mars Surface in SPE environment. We have used three shielding materials, Kevlar, Polystyrene, and LiH, for the Mars surface. The LiH is one of the best shielding materials with less absorbed dose than Kevlar and polystyrene. Further, the effective dose equivalent is simulated for different components of the human female phantom (FAX) using Oltaris simulation. In addition, LET spectra are also simulated in the FAX for all shielding materials. The radiation flux as a function of the energy of incoming radiation/particles, namely proton, alpha, and iron, is simulated, and it is observed that proton radiation flux is higher than alpha and iron, which is expected for the SPE environment.

5. Acknowledgements
We are grateful for the support from MNIT Jaipur, RBS Engineering Technical Campus Agra, and for publishing our work.

6. References

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