Lunar Habitat Radiation: Quantification, Mitigation, and Simulation

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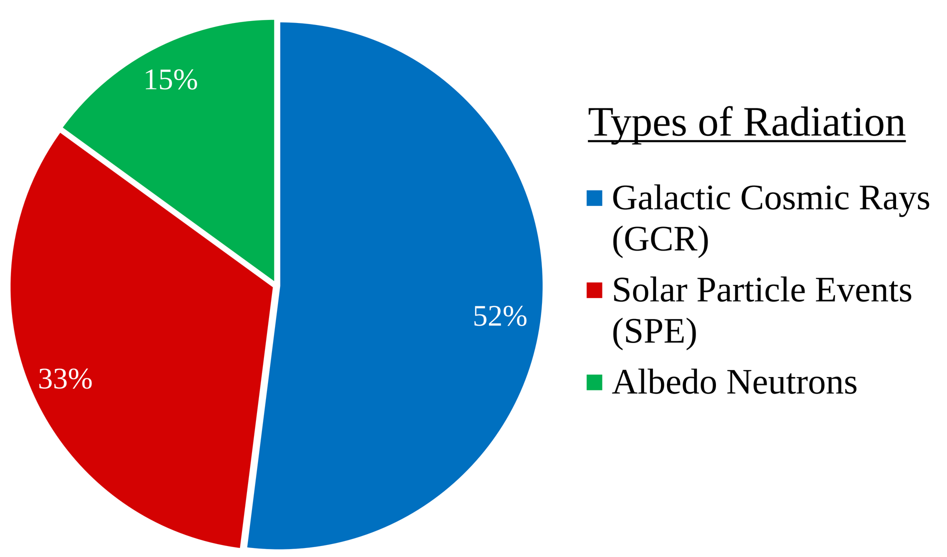
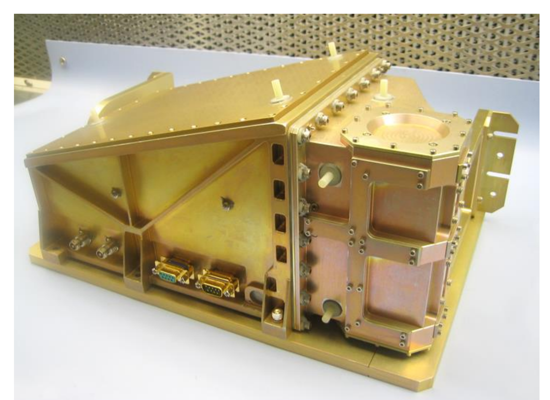
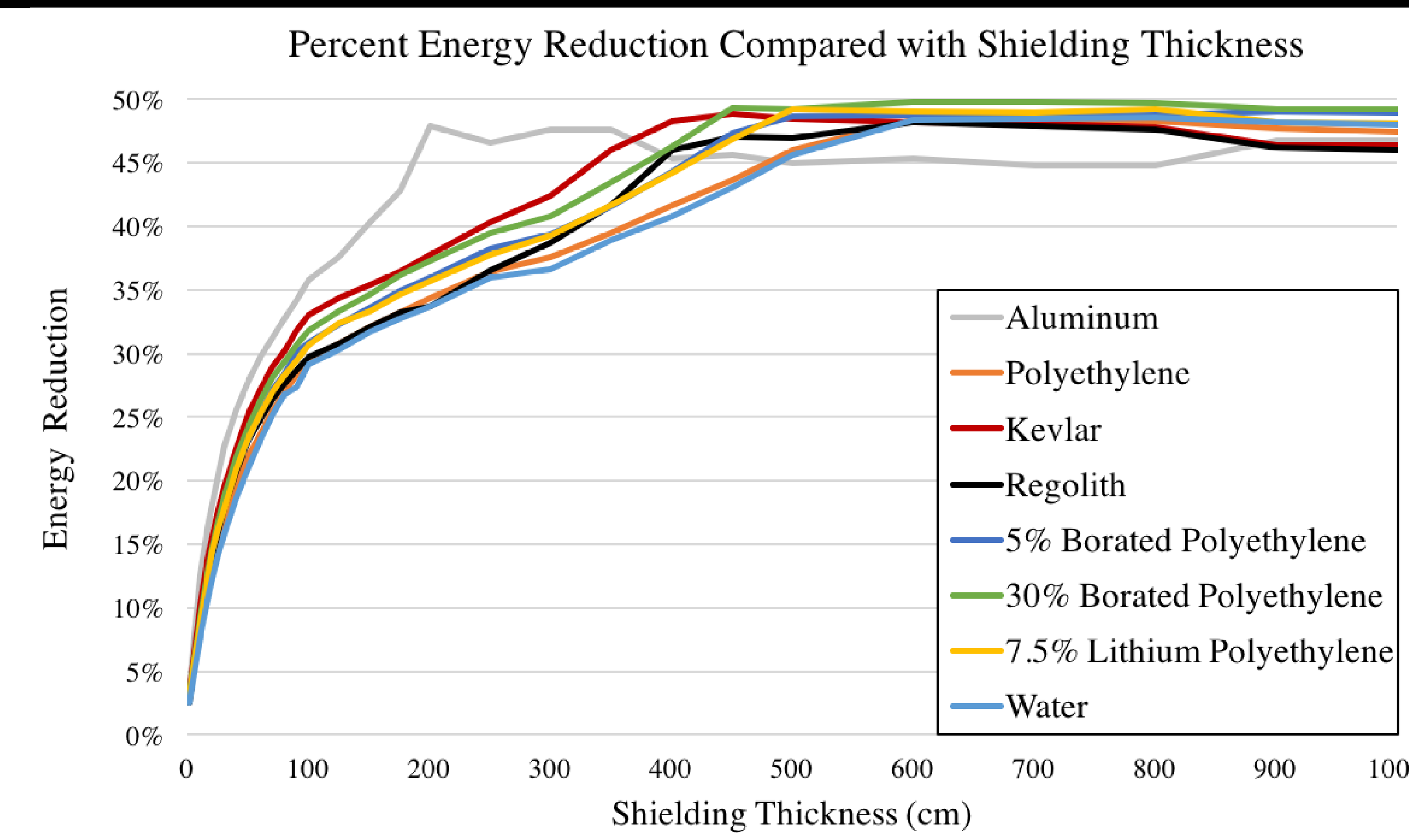
Quantification

Understanding the radiation environment on the lunar surface is vital to lunar habitation. At least three types of ionizing radiation bombard the Moon and provide a significant threat to astronauts. The Cosmic Ray Telescope for the Effects of Radiation (CRaTER)[1] has gathered radiation data since 2009.





Cosmic Ray Telescope for the Effects of Radiation (CRaTER). Currently part of the Lunar Reconnaissance Orbiter.



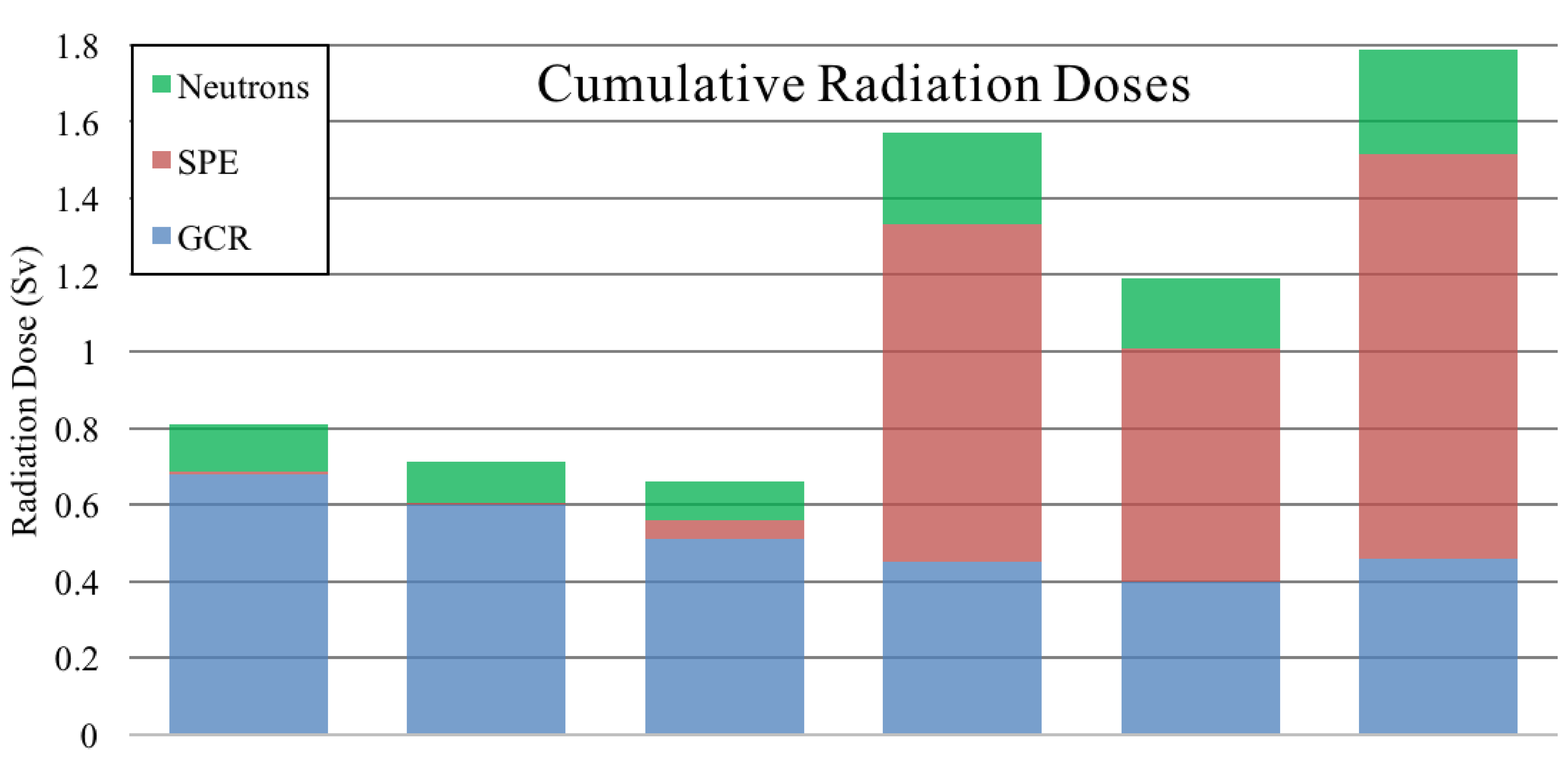
A comparison of initial materials showed that each reached a peak effectiveness at 50% reduction. As such, more simulations were needed to find effective material combinations.

Mitigation

In order to mitigate the hazard, a shielding material must be selected. Using Geant4 Beamline, simulations have shown that certain materials and combinations of materials are effective at reducing the absorbed radiation. SPE are highly variable in their intensity and frequency[2], and shielding may not be an effective strategy. The energy and flux of protons in GCR is well understood[2] and considered in this project. Dose limits[3] are shown below for reference with cumulative doses.

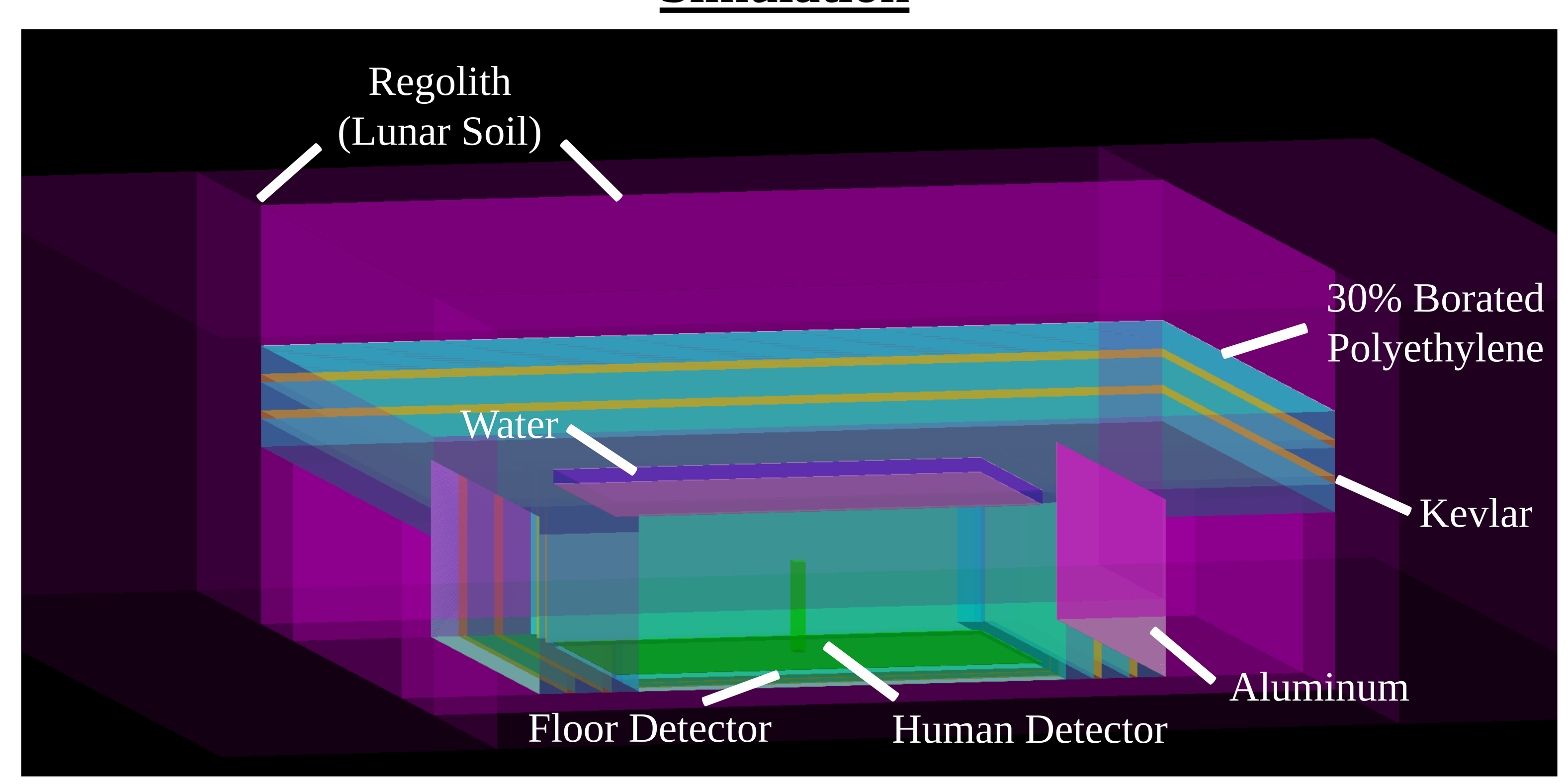
Age	Male (Sv)	Female (Sv)
25	0.7	0.4
35	1.0	0.6
45	1.5	0.9
55	3.0	1.7

Career Dose Limits (in Sieverts) Corresponding to a 3% Excess Cancer Mortality for 10-year Careers as a Function of Age and Sex, as Recommended by the NCRP (NCRP, 1989; 2000)

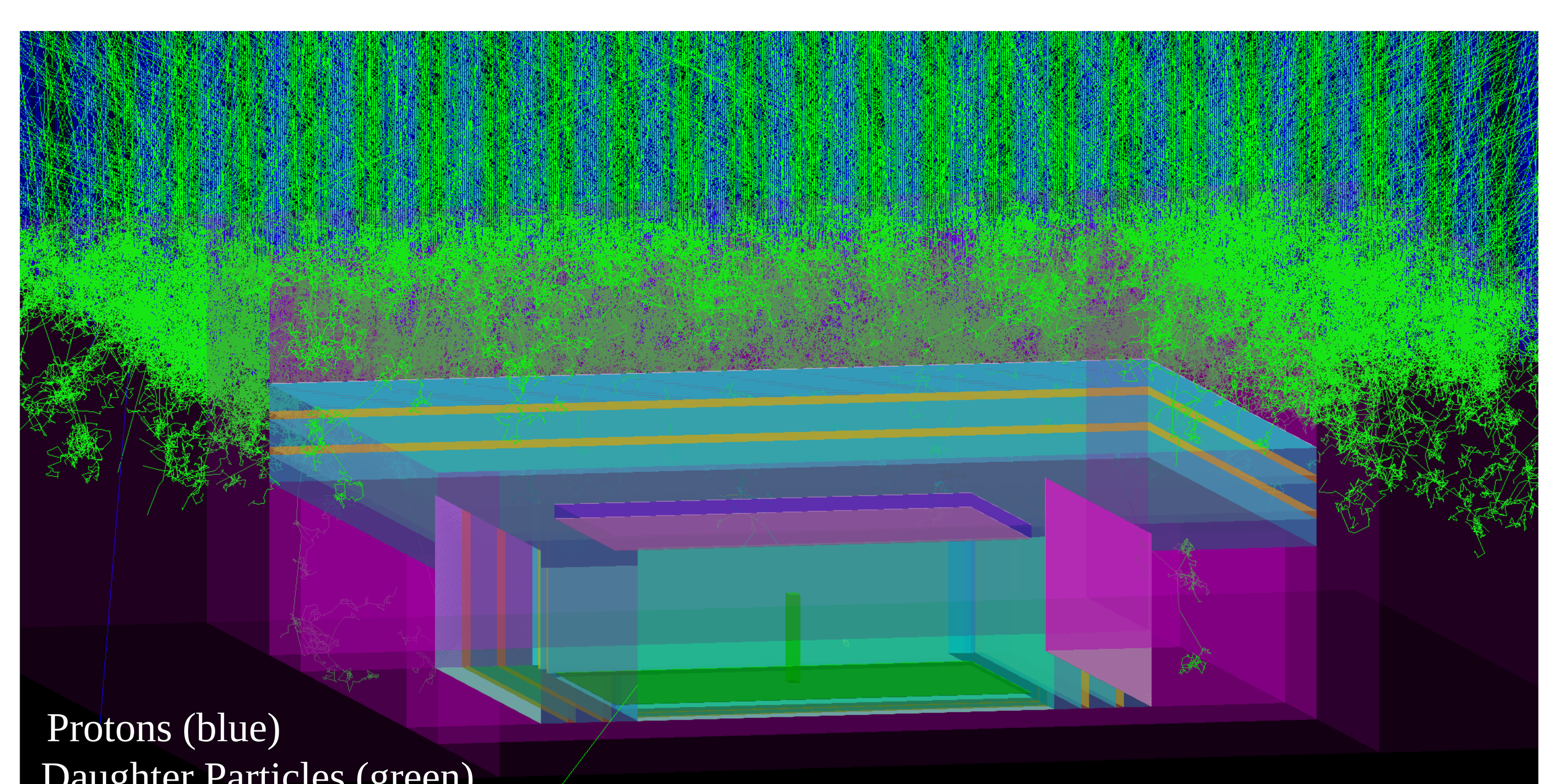


CRaTER data for GCR and SPE with estimated albedo neutron contribution[4].
A typical terrestrial dose is 0.05 Sv every three years!

Simulation



Simulated habitat consisting of various materials and a human detector.



Visual representation of particle interaction with habitat, reduced by a factor of 50.

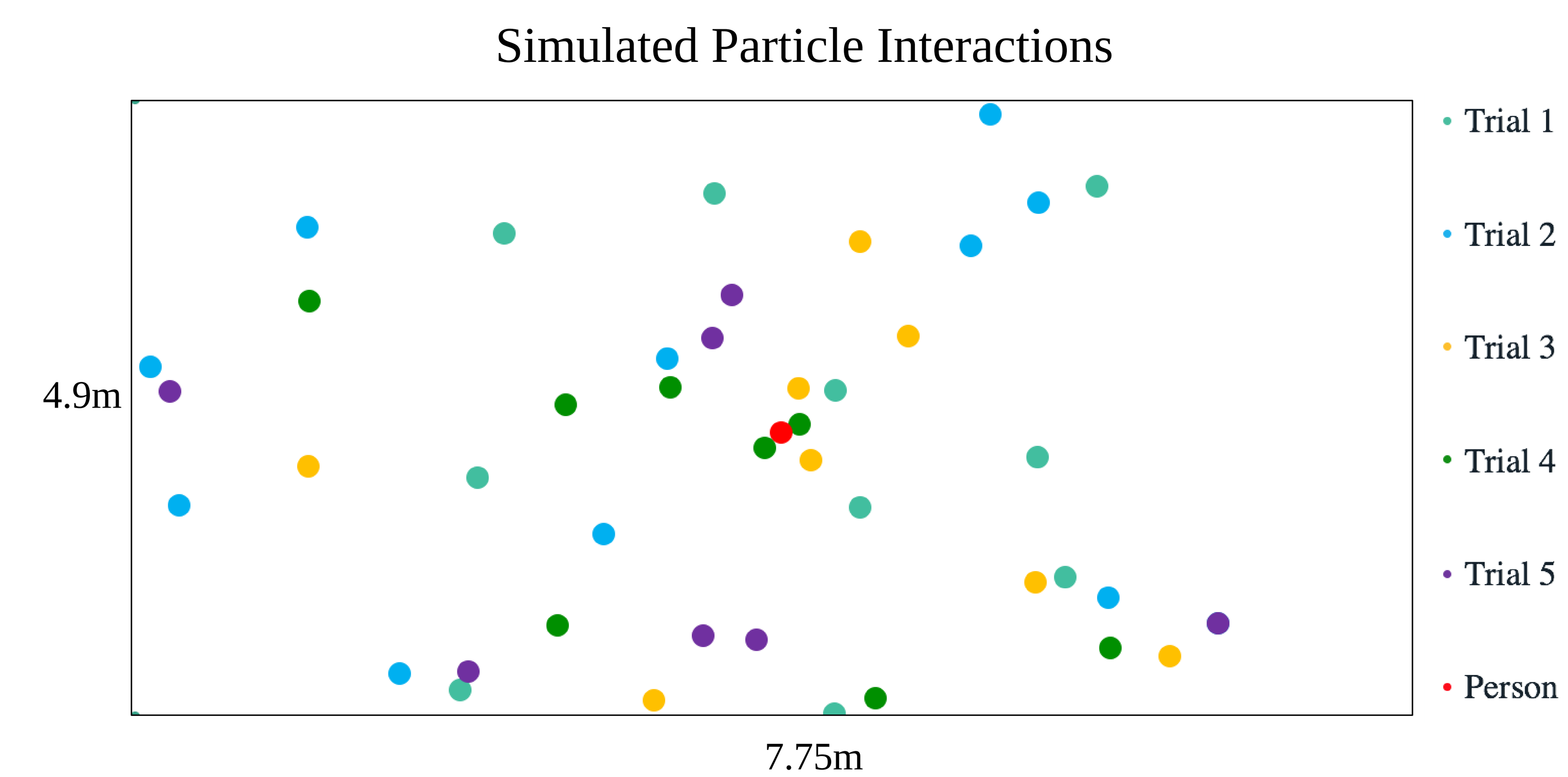
Results

Component	Thickness (m)
Regolith	2.5
Aluminum	0.01
30% BPE	0.5
Kevlar	0.15
30% BPE	0.5
Kevlar	0.15
30% BPE	0.5
Glass	0.01
Water	0.25
Glass	0.01

The simulations were constructed using the components and thicknesses shown on the left. Due to the significant amount of computational power necessary to run each simulation, we have only been able to complete 5 trials.

According to the results in the graph below, only 1 particle interacted with the human-sized detector, and 44 particles interacted with the floor detector. As each run of the simulation corresponds with one second, an individual can expect to be traversed by a high energy proton every 5 seconds inside the habitat.

This corresponds to 10mSv of radiation per year. Compare this to the typical dose received on Earth: 6.2 mSv.



Representation of particle interactions with the floor detector in the simulated habitat. The single red dot in the center represents the single particle which interacted with the human detector.

Citations

[1]Schwadron, N. A. (2015) University of New Hampshire. CRaTER Cosmic Ray Telescope. Retrieved from http://crater.unh.edu/.

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[4]Adams, J., Bhattacharya, M., Pendleton, G., and Lin, Z. (2007). "The ionizing radiation environment on the moon." 40.

[5]Brown, K. M. (2015). "Analysis and Design of a Frame-Membrane Habitat Subjected to Extreme Temperatures on the Lunar Surface Extreme Temperatures on the Lunar Surface.

Acknowledgments

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