Identifying neutron irradiation in space to mitigate bio-medical effects

*A. Sobel[1,2] and L. Forsley[3,4]
[1]Academician, International Academy of Aviation and Space Medicine, USA
[2]Texas Tech University, TX, USA
[3]NASA GRC, Cleveland, OH, USA
[4]GEC LLC, Annandale, VA, USA
Email: bigbitbucket@mac.com

One of the primary challenges to interplanetary human travel is mitigation of radiation exposure. As fast transit with LENR driven or conventional nuclear electric (NEP) or thermal propulsion (NTP) may be imminent, time and level of radiation exposure composing ALARA (As Low as Reasonably Achievable) must be ascertained rapidly and precisely. Since acute physiological effects are difficult to detect, and chronic effects on crew health are delayed and potentially trans-generational, improved detection technologies will be game-changing and an essential element of the crew health monitoring and environmental protection toolkit. Secondary Galactic Cosmic Ray (GCR) induced neutrons are an additional hazard.

The dose equivalent Q factor, which weighs an absorbed radiation dose against its biological effect, ranges from $Q=1$ for x-rays, gamma rays and betas to $Q=5$ for thermal neutrons and $Q=10$ for fast neutrons and alpha particles. Since neutrons only have a < 11 minute half-life, they are constantly produced by fast charged particles or photons shattering atoms terrestrially, in planetary atmospheres and on planetary surfaces. Figure 1 shows the terrestrial spallation neutron spectra originating from atmospheric GCR interactions.The effect is more pronounced on Earth in aircraft and in spacecraft including the International Space Station (ISS) and soon NASA's Lunar Gateway habitat. 95% of GCR are > .5 GeV/nucleon protons and alpha particles. The Earth's magnetic field reduces GCRs reaching the Earth and the Solar magnetosphere similarly reduces them throughout the solar system. Unfortunately, Figure 2 shows the relationship between solar maxima and GCR minima within the Earth's magnetosphere and probably beyond.

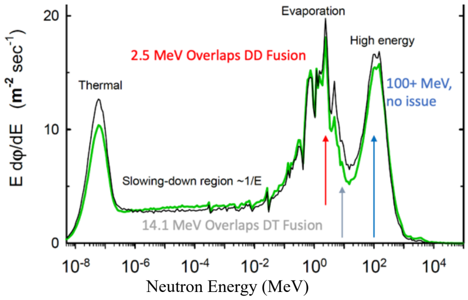

Figure 1 Cosmogenic Neutron Spectra[1]

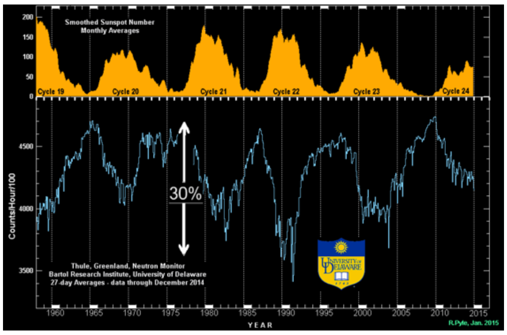

Figure 2 Sunspots vs GCR Flux[1]

Neutron diagnostics include BF_3 and ^{3}He counters, SSNTD and scintillator neutron spectrometers [2] as we have used in LENR/LCF research. However, since the Q value varies with energy, neutron spectroscopy, or at least an energy range, is necessary. Real-time measurements provide an awareness of immediate danger in space and record the heavy ion and secondary neutron doses and their current and future biological effects requiring countermeasures.[3] Once these have been characterized, mitigation strategies can be adopted ranging from spacecraft magnetic shielding against GCR to deploying regolith overburden. *Fast travel is necessary!* [4]

[1] P. Goldhagen, "Use of Cosmic-Ray Neutron Data in Nuclear Threat Detection and Other Applications", Neutron Monitor Community Workshop—Honolulu, Hawaii (October, 2015) pp. 11, 19.

[2] B. Barmasai, *et al.*, "Fast Neutron Spectroscopy With Organic Scintillation Detectors in a High-Radiation Environment", NASA/TM-20205008493 (December 2020) pp. 1 – 11.

[3] A. Sobel & R. Duncan, "Aerospace Environmental Health: Considerations and Countermeasures to Sustain Crew Health Through Vastly Reduced Transit Time to/From Mars.", Frontiers in Public Health, vol. 8 no. 327 (2020) https://doi.org/10.3389/fpubh.2020.00327

[4] L.P.Forsley, P.A. Mosier-Boss, T.L. Benyo, L.A. Dudzinski, "An Extremely High I_{sp} Spacecraft Propulsion System", *ANS NETS-22*, (Cleveland, OH) (May, 2022). https://www1.grc.nasa.gov/space/science/lattice-confinement-fusion/#american-nuclear-society-nuclear-and-emerging-technologies-for-space-nets22