Radiation Study of Boron Nitride Nanotube (BNNT) and BNNT Composites

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Overview

- Challenge
  - Space Radiation
- Objective
  - Radiation Shielding
  - Literature Review
- Approach
  - Indium Foil experiments
  - Online tool for assessment of radiation in space
- Results
- Analysis
- Next Steps
- Acknowledgements

Challenge

There are 3 main sources of radiation in space: galactic cosmic radiation (GCR), solar particle events (SPE), and trapped radiation belt particles (Van Allen Belts).

GCR
High energy particles from outer space

SPE
Events containing a high number of high energy charged particles from sun

Van Allen Belts
Outer belt: High energy particles from Sun trapped in Earth's magnetic field
Inner Belt: interactions of GCR with Earth's atmosphere

When radiation interacts with matter it causes secondary neutrons.

Radiation presents risk to not only humans but also electronics and materials.

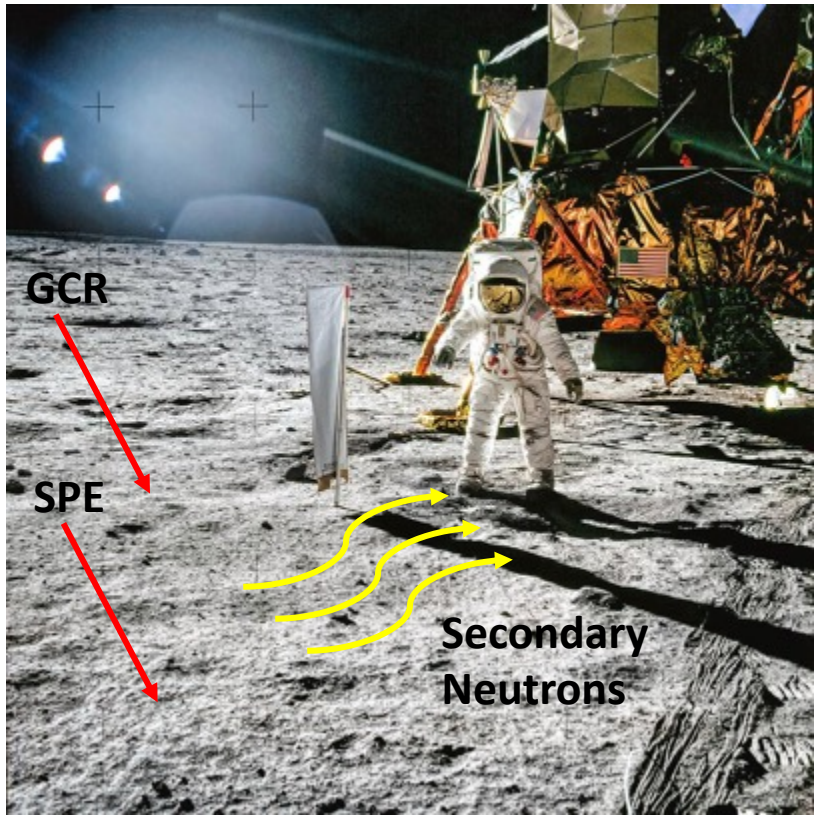


Image Credit: NASA

Thibeault, Sheila A., et al. "Nanomaterials for Radiation Shielding." *MRS Bulletin*, vol. 40, no. 10, 2015, pp. 836–841., doi:10.1557/mrs.2015.225.

Objective

- Understanding shield effectiveness against secondary neutron radiation is an important factor regarding future space trips to prevent excessive radiation exposure.
- Testing BNNTs, BNNT composites, and other materials to discover shielding properties and effectiveness.

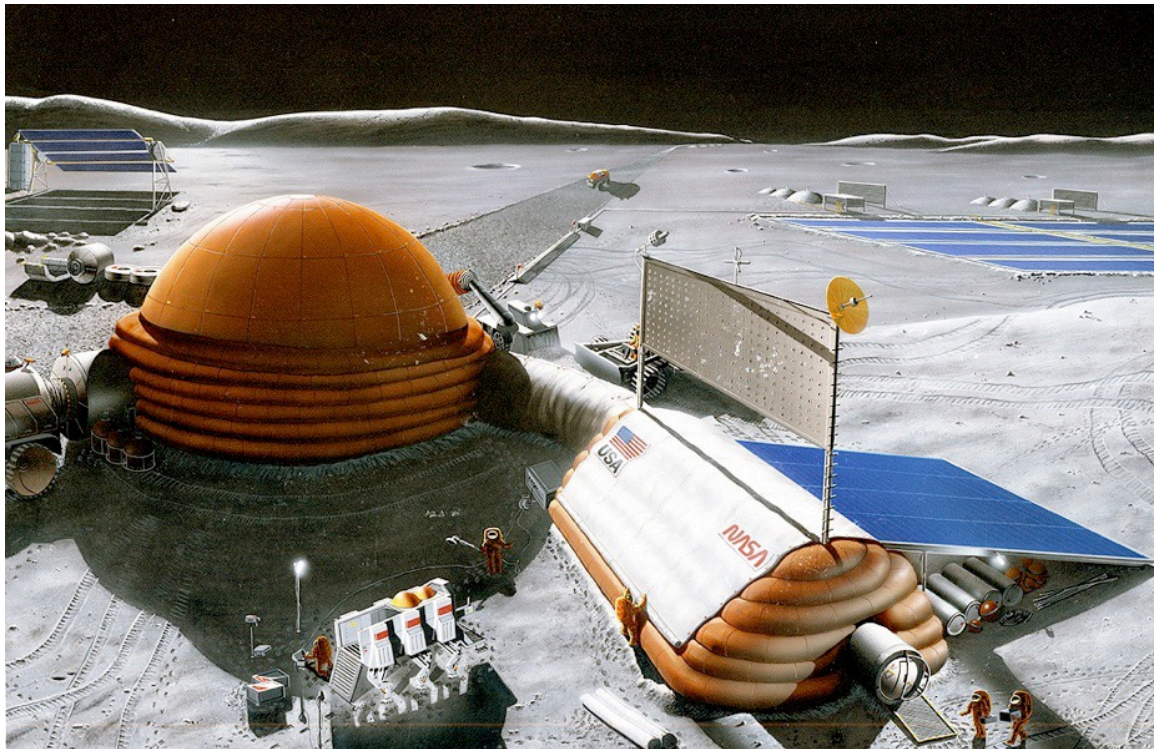


Image Credit: NASA

BNNT for Radiation Shielding

Nanomaterials for Shielding from Neutrons

- High thermal neutron absorption: boron, lithium, and gadolinium
  - Can't use heavier elements because of fragmentation leading to secondary radiation
- Hydrogen is best shielding against GCR
  - Liquid hydrogen is not practical

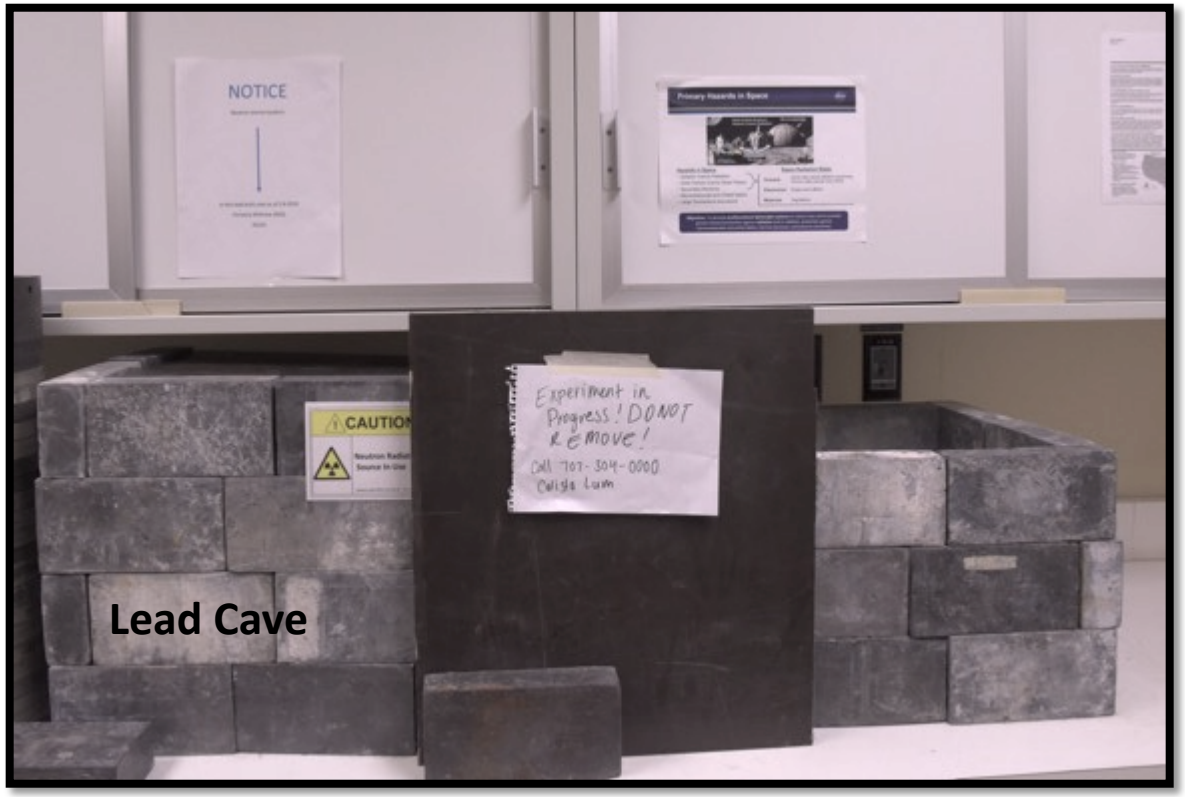
Hydrogen Containing Nanostructures

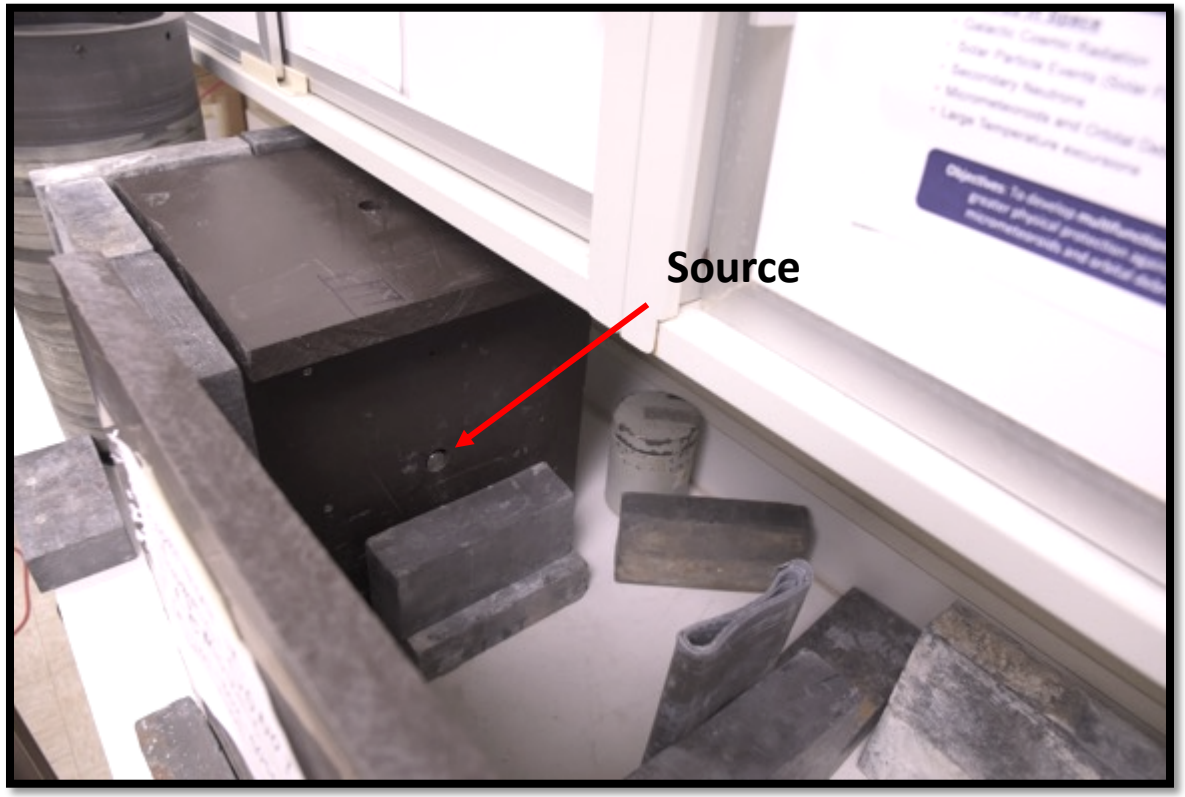
- Nanotubes favored to store hydrogen over particles and sheets because the greater surface area and higher hydrogen bonding energies
- CNTs and BNNTs theoretical capacity to store hydrogen and improve other materials properties
  - Ideal for radiation shielding

Thibeault, Sheila A., et al. "Nanomaterials for Radiation Shielding." *MRS Bulletin*, vol. 40, no. 10, 2015, pp. 836–841., doi:10.1557/mrs.2015.225.

Approach: Neutron Source

- Americium Beryllium fast neutron source
- Source is a mixture of Am-241 and Be-9
- Emits ~800 mrem/hr directly at source

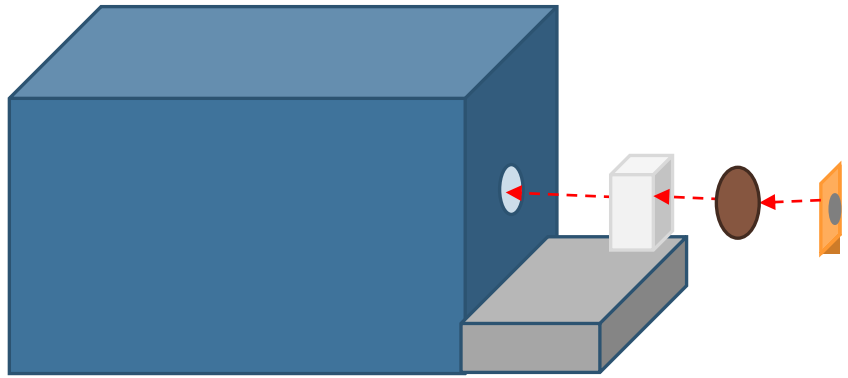




Approach: Experimental Setup



Radiation source with shielding sample.



Polyethylene block 25mm < Shielding Sample (opt) < Indium Foil < Kapton Film

- Using the source's current orientation within the lead cave
- Indium foils placed in front of source become activated
  - $^{115}In(n, \gamma)^{116}In$
- Analysis method with Geiger Mueller counters used

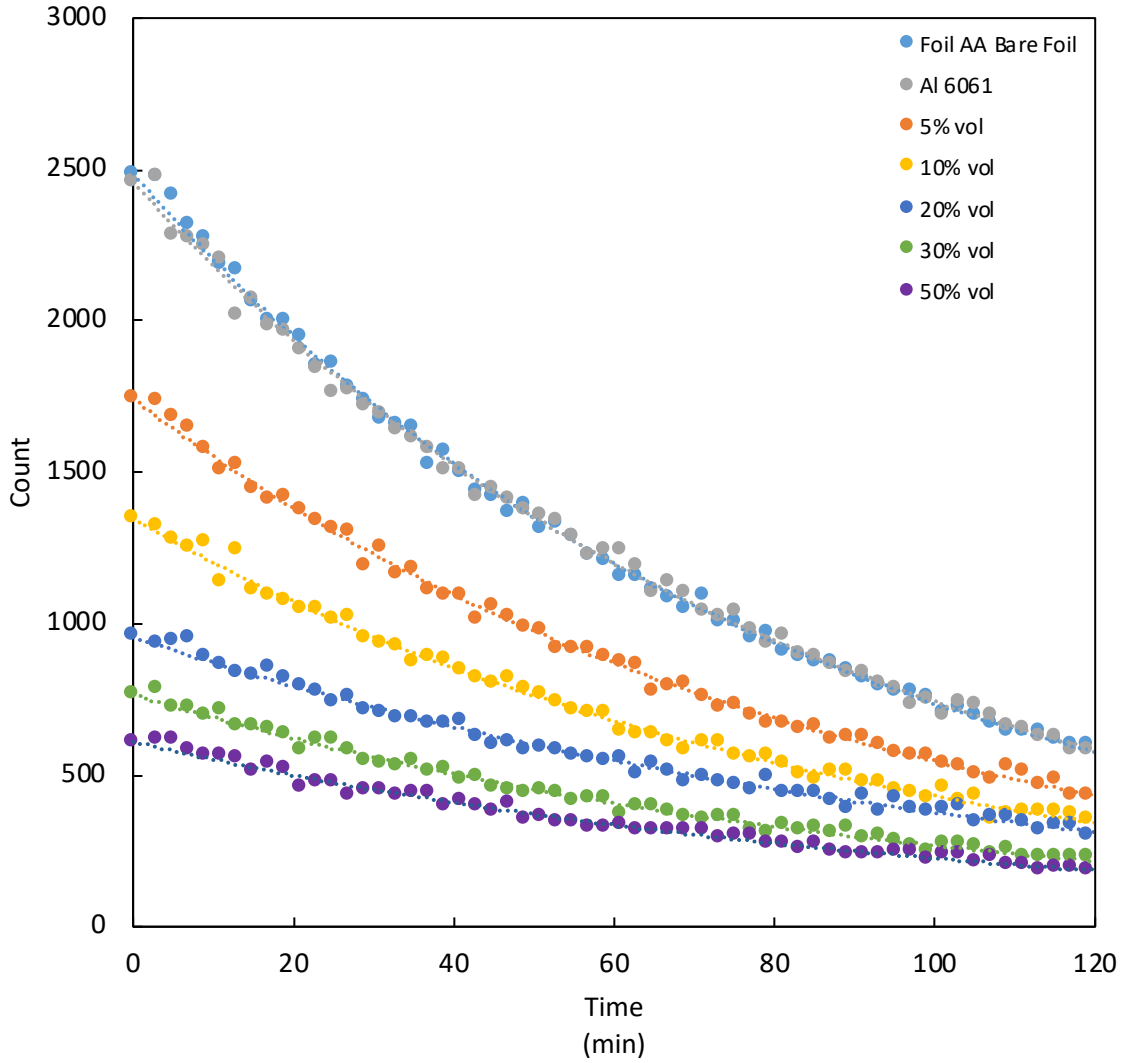
Results: Indium Foil B4C Al6061

Description	Average A_0	Trial 1 A	Trial 2 A	Average A	Areal Density (g/cm2)	Linear Absorption (cm-1)	Linear Absorption (mm-1)	% shielded
Bare Foil	2486.2	-	-	-	-	-	-	-
Al 6061	-	2455.8	2462.5	2459.2	0.4256	0.07	0.01	1.1
NIA B4C 5 % vol	-	1788.0	1696.1	1742.1	0.4741	2.01	0.20	29.9
NIA B4C 10% vol	-	1384.3	1309.8	1347.1	0.4750	3.42	0.34	45.8
NIA B4C 20% vol	-	947.8	964.6	956.2	0.4773	5.18	0.52	61.5
NIA B4C 30% vol	-	755.1	776.5	765.8	0.4300	6.94	0.69	69.2
NIA B4C 50% vol	-	600.1	620.3	610.2	0.4269	8.18	0.82	75.5



Parameters
Indium Foil AA
Detector 1, 960V
300 mrem setup

NIA B4C Al6061
Radioactive Decay

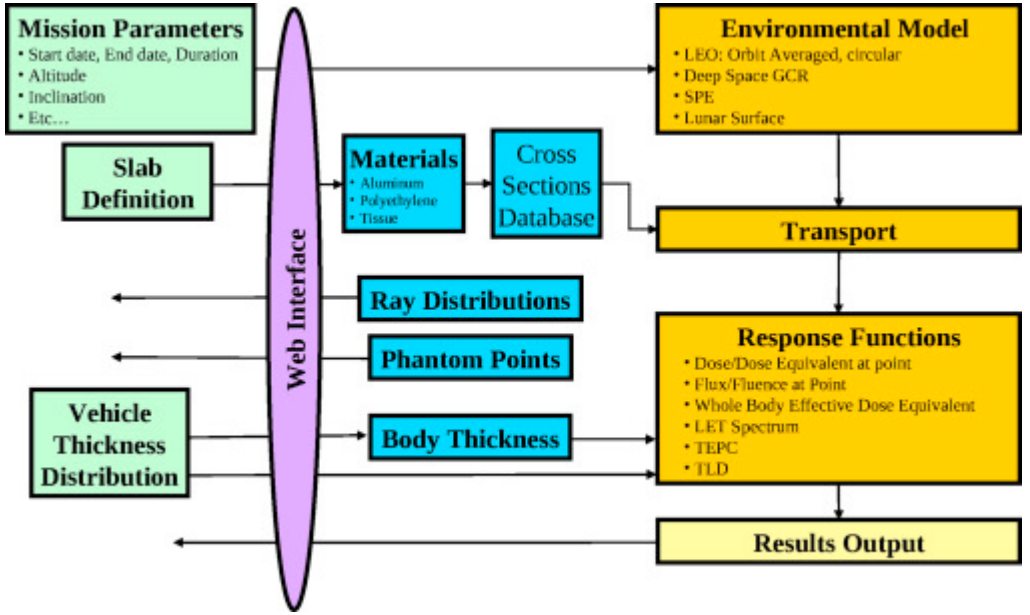


OLTARIS: On-Line Tool for the Assessment of Radiation In Space

OLTARIS is an online system used for the analysis of in space radiation.

Transport based on HZETRN (High charge (Z) and Energy TRaNsport) code and the input nuclear physics model NUCFRG2 (NUClear FRaGmentation).

For this project, the tool was used primarily to model different shielding materials under varying GCR and SPE scenarios.



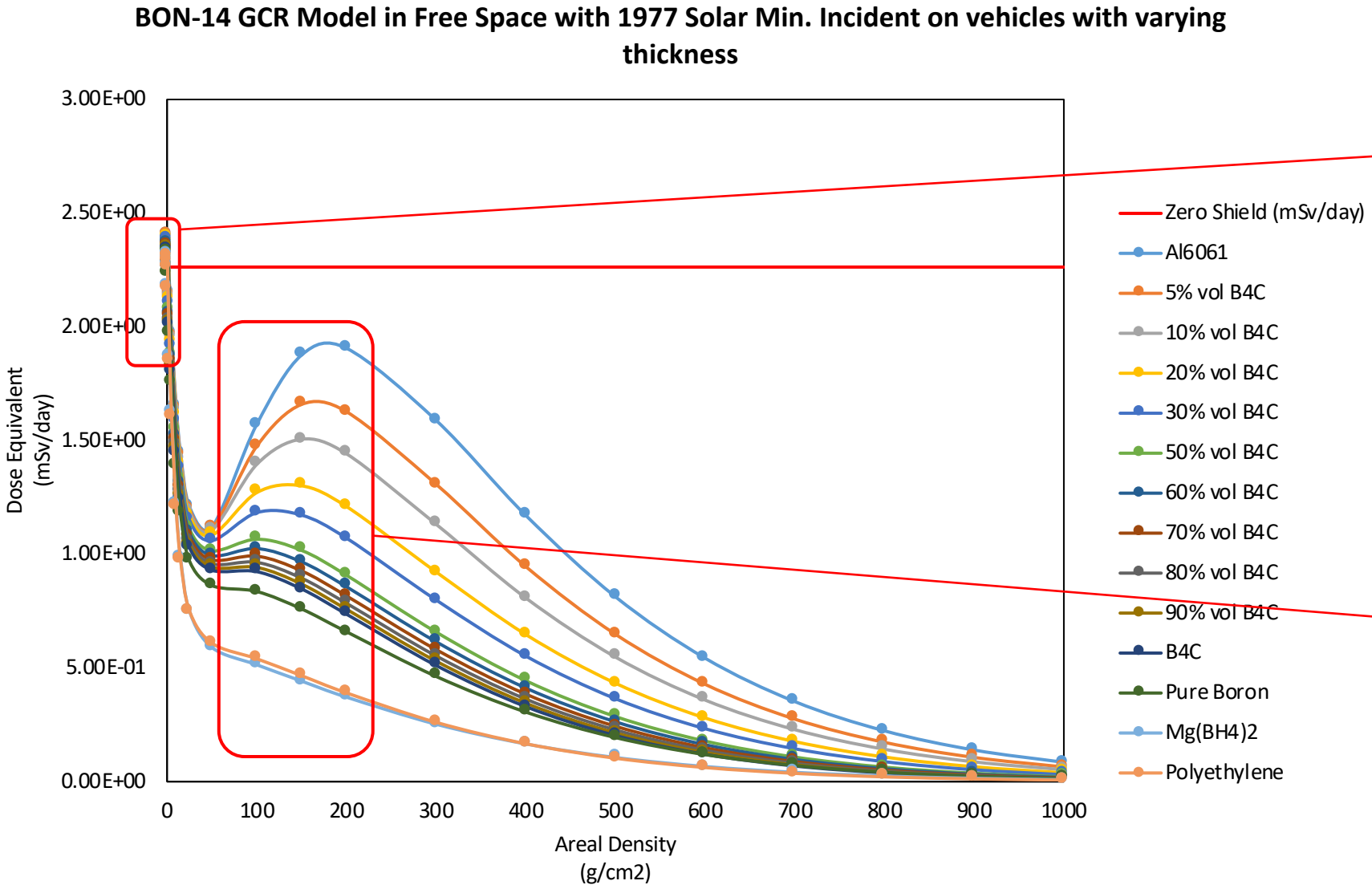


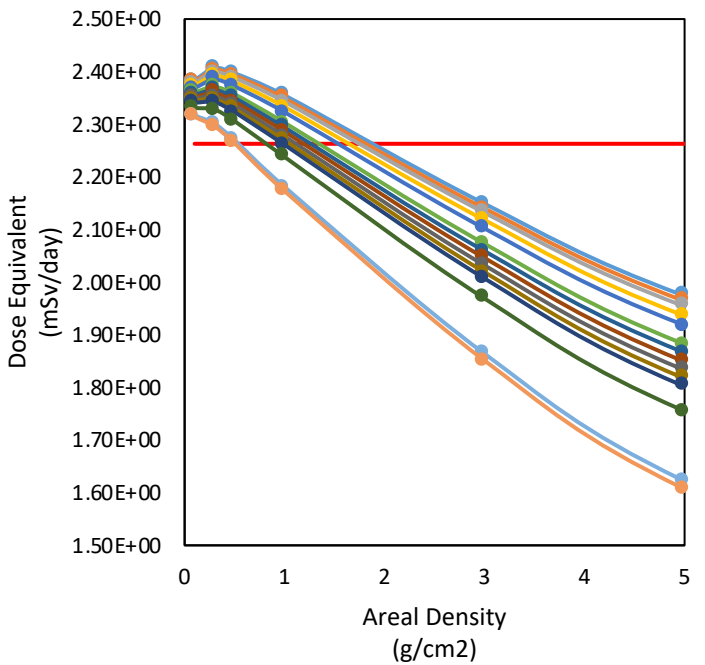


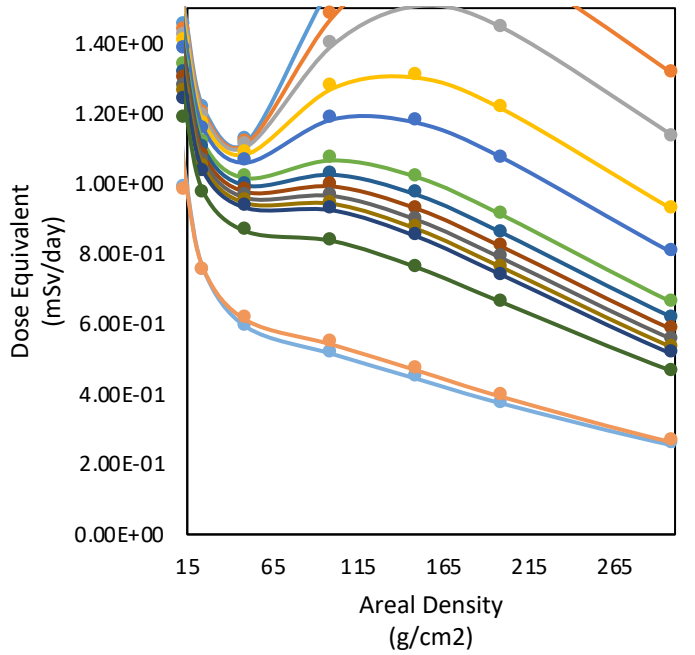


Singleterry, Robert. "OLTARIS: On-Line Tool for the Assessment of Radiation In Space." *AIAA SPACE 2009 Conference & Exposition*, 2009, doi:10.2514/6.2009-6645.

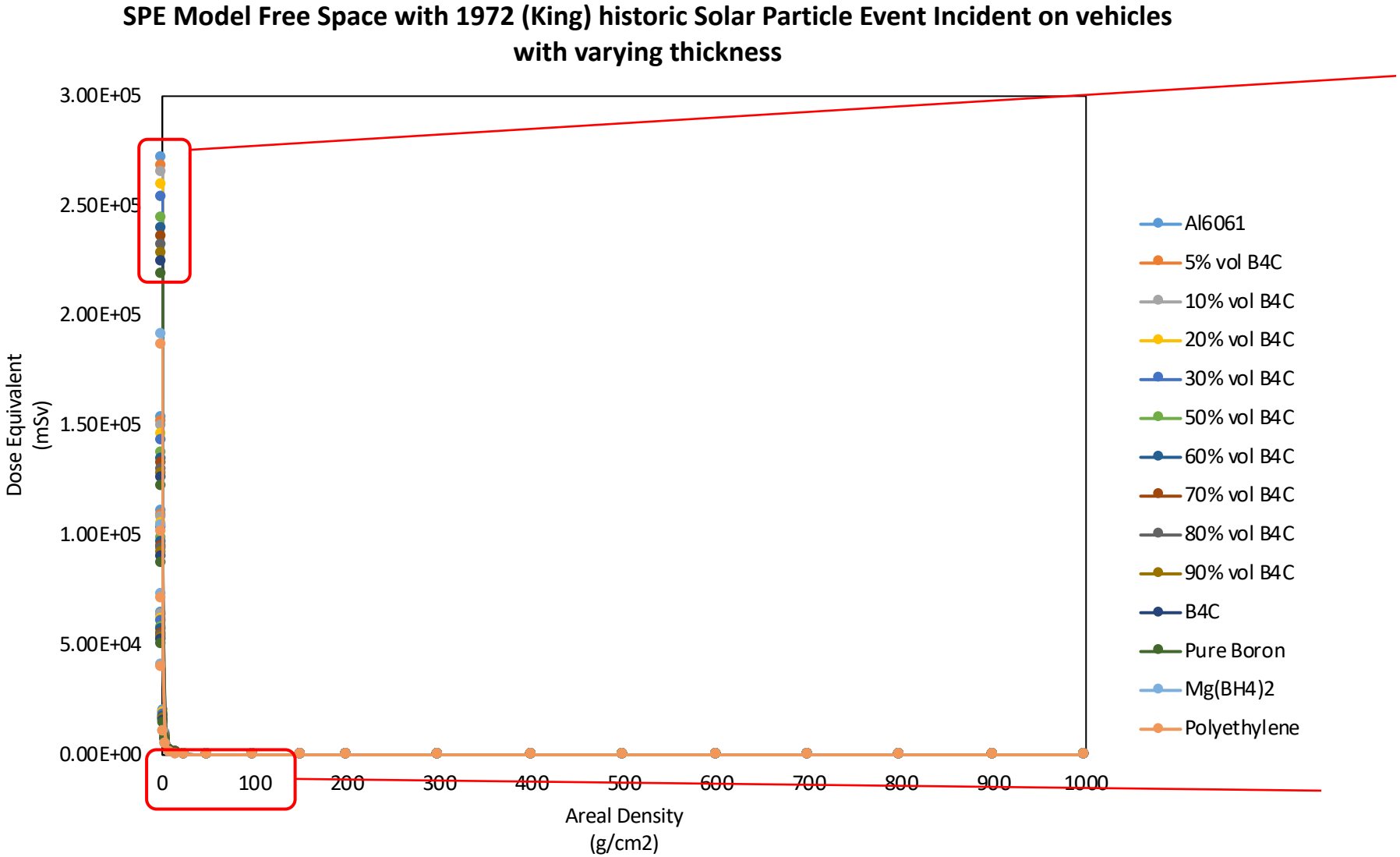
OLTARIS: GCR Free Space Environment

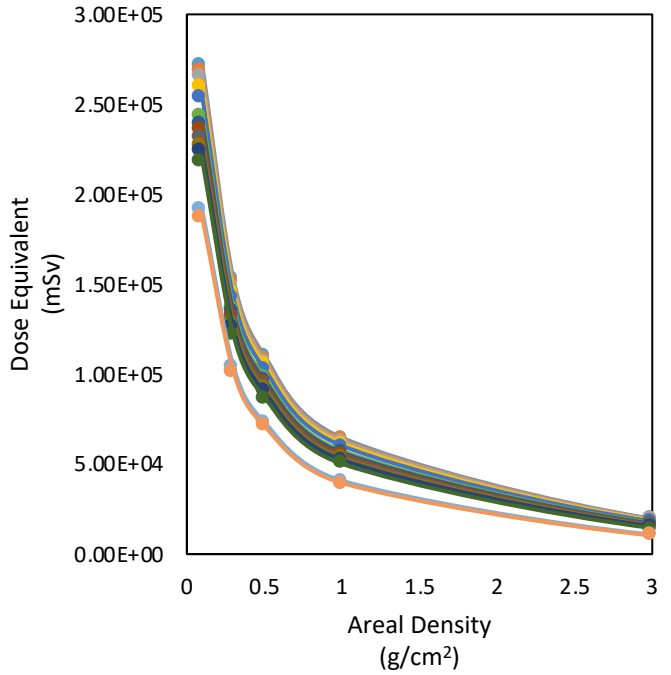


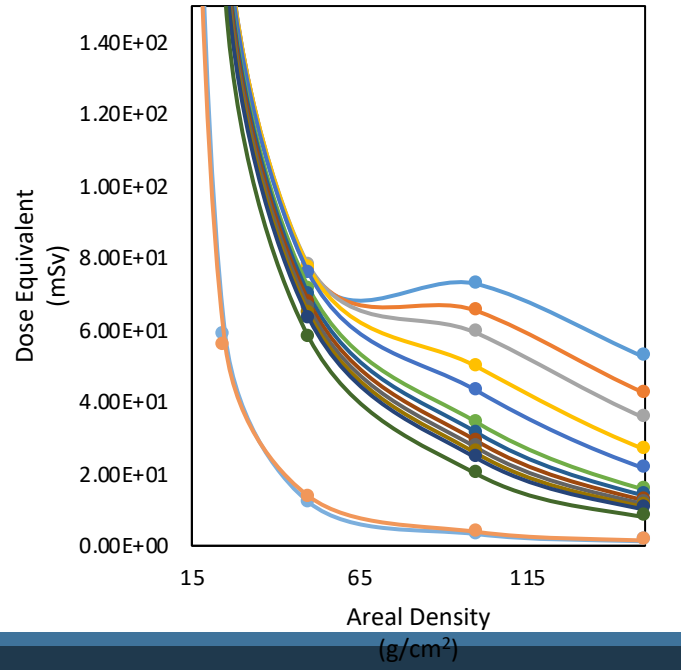




OLTARIS: SPE Free Space Environment

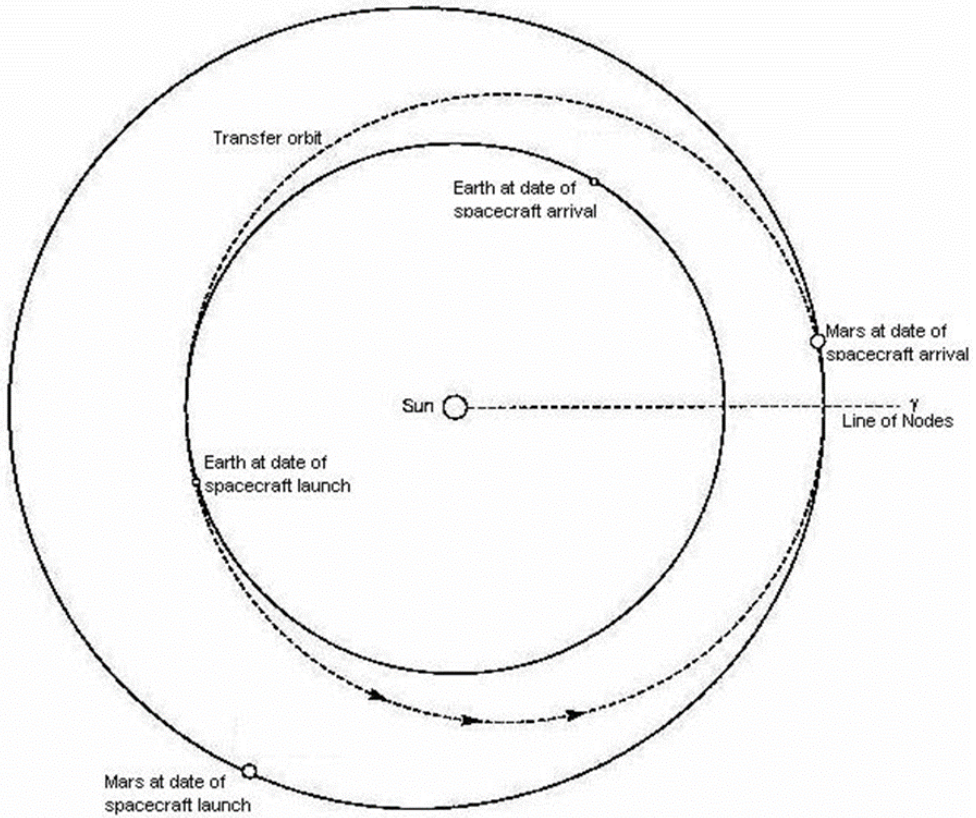






OLTARIS Mission to Mars: Past Mission Totals

Career Exposure Limits for NASA Astronauts by Age and Gender*				
Age (years)	25	35	45	55
Male	1,500 mSv	2,500 mSv	3,250 mSv	4,000 mSv
Female	1,000 mSv	1,750 mSv	2,500 mSv	3,000 mSv

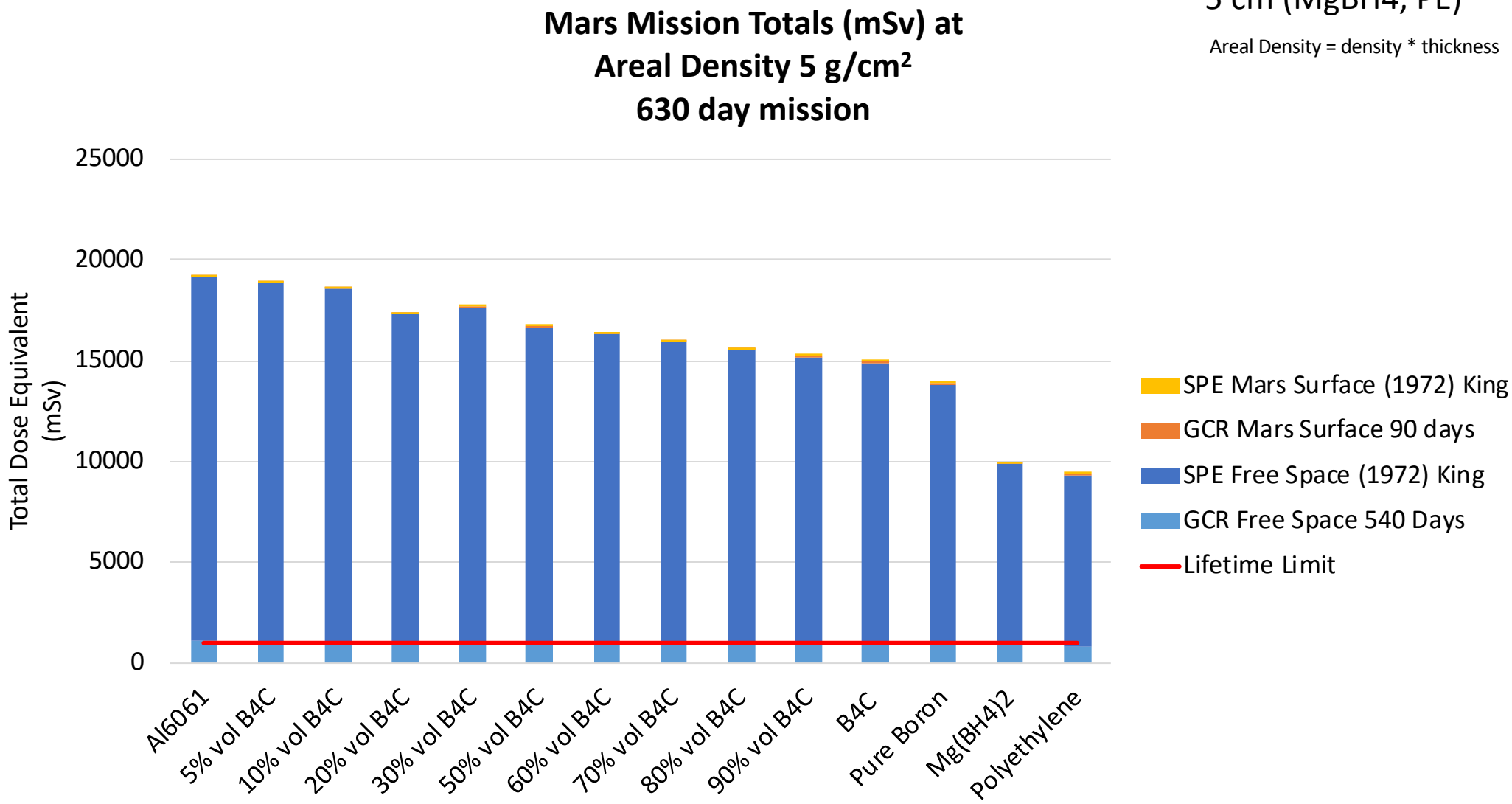


- Earth and Mars's orbits meet ideal alignment every 26 months.
  - The outgoing trip to Mars would take 9 months, once at Mars there would need to be a wait of either a few weeks or a year before alignment is correct for return.
  - Return flight would take an additional 9 months.
- Total of ~630 mission days

OLTARIS Mission to Mars: 5 g/cm^2 Dose Totals

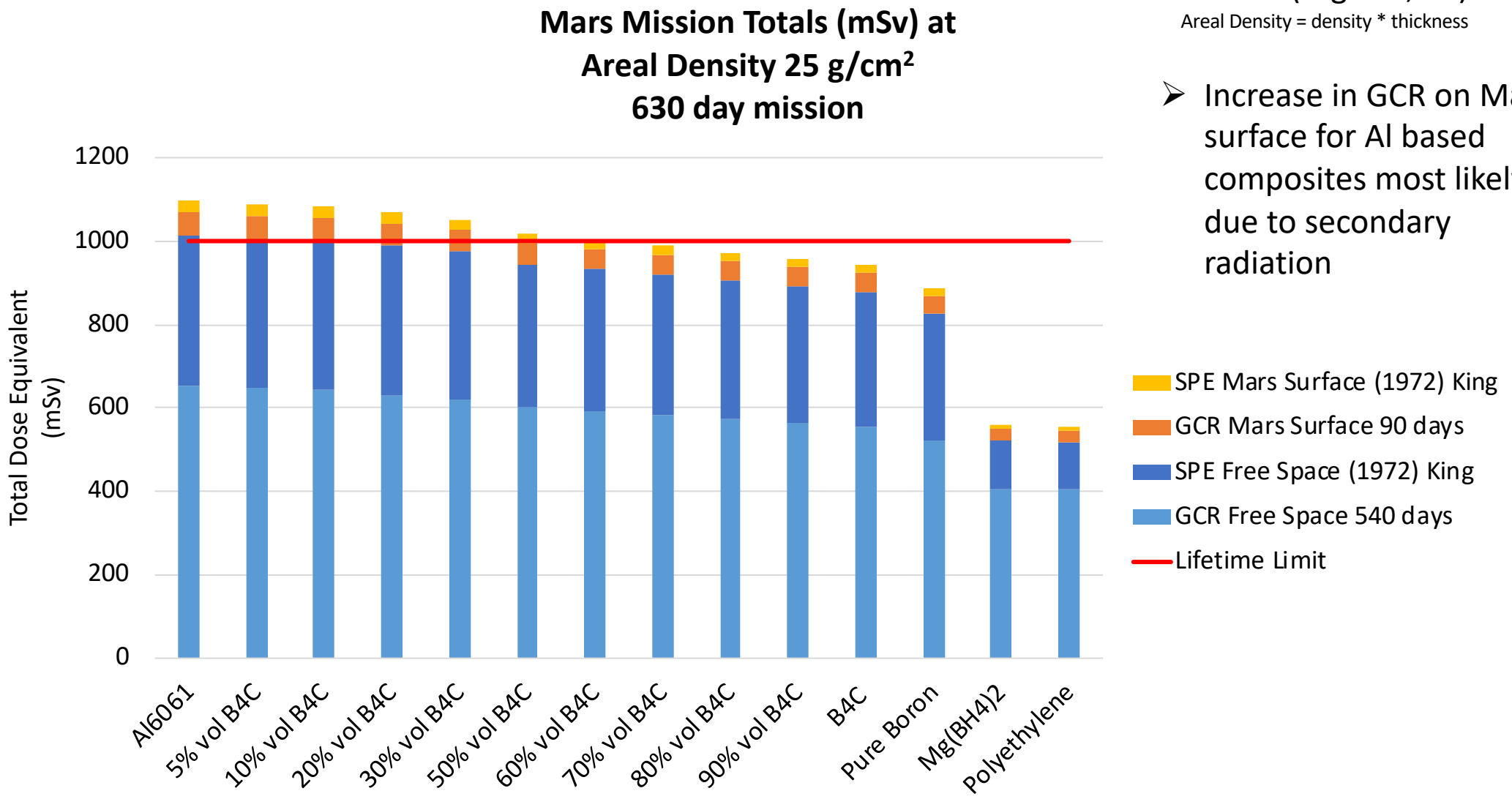
5 g/cm2 thickness
2 cm (Al6061, B4C, B)
5 cm (MgBH4, PE)

Areal Density = density * thickness



OLTARIS Mission to Mars: 25 g/cm2 Dose Totals

25 g/cm2 thickness
10 cm (Al6061, B4C, B)
25 cm (MgBH4, PE)
Areal Density = density * thickness



- Increase in GCR on Mars surface for Al based composites most likely due to secondary radiation

Conclusions and Future Remarks

My time at NASA Langley Research Center has been key in my development as a student and individual. Through my work over the past year we have been better able to understand the relationship between different materials and radiation. The indium foil results show B4C to be an effective shielding material which could be further investigated. Also, modeling shows the negative effect some materials may have and shows the importance of areal density.

Next Steps:

- Further analysis of B4C samples potentially using B10 enriched material
- Further use of OLTARIS modelling
- Attempt to understand the effect of secondary neutron

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