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Center for Radiation Engineering and Science for Space Exploration

Multifunctional Novel Boron-Carbon Fiber Polymer Composites for Mixed Radiation Field Space Applications

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(*deceased)

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Materials Modification Inc.

National Aeronautics and Space Administration

Prairie View A&M University:

- Historically Black College/University, founded in 1876.
- About 45 miles north-west of Houston, TX.
- Approximately 8,500 students – over 90% African-American.
- Offers MS in engineering and Ph.D. in electrical engineering.

NASA CRESSE:

- Managed by the Minority University Research and Education Program.
- Education through research for both undergraduate and graduate students.
- Encourage students toward advanced degrees in STEM disciplines.
- **Key URC advantage: Can stress methodical scientific approach, yet have flexibility to take advantage of new research opportunities.**

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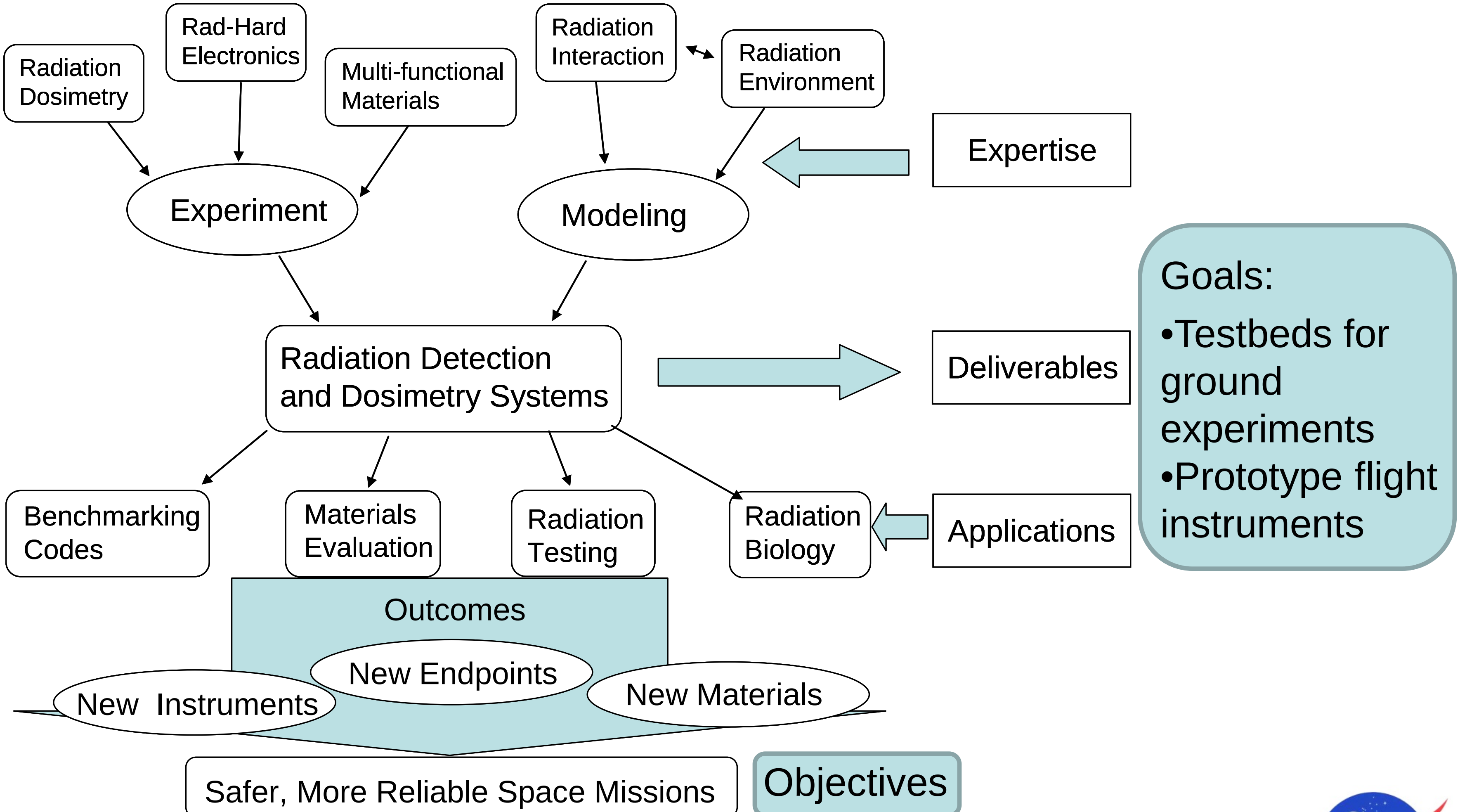
Research Program Overview
Center for Radiation Engineering and Science for Space Exploration (CRESSE)

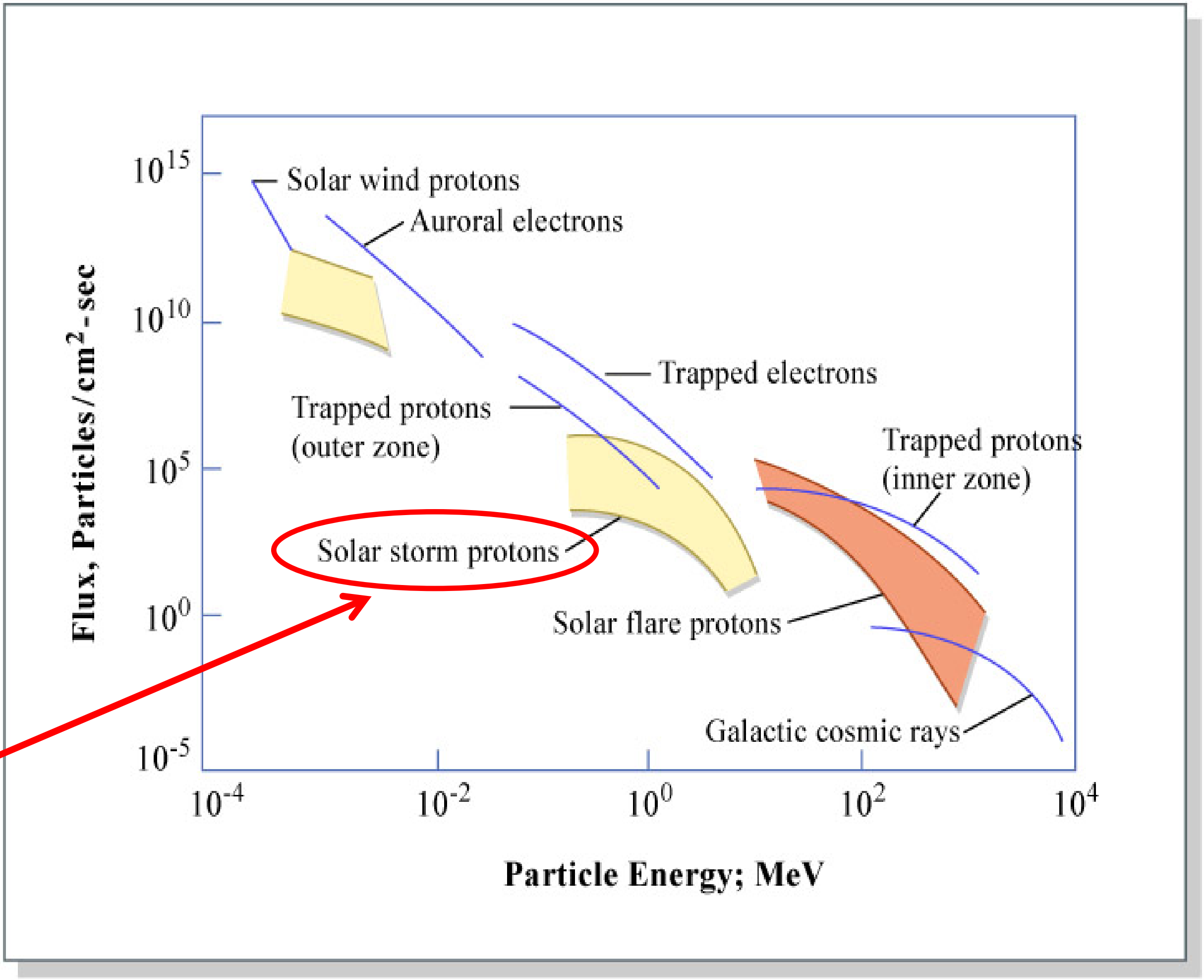


National Aeronautics and Space Administration

Radiation Environment and Risk

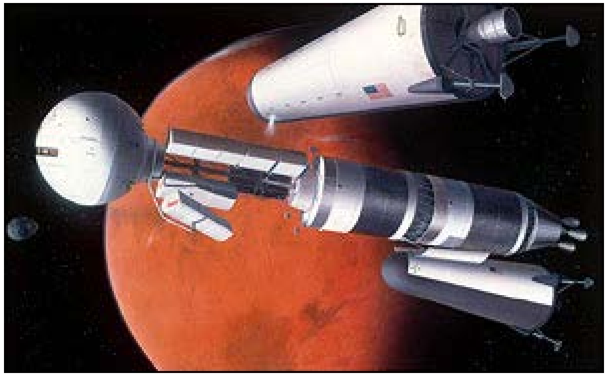
Radiation Shielding:

- Limited effectiveness for GCR.
- More effective for solar particle events: "Storm" shelters.
- CRESSE has been studying the use of *in situ* regoliths for habitat & storm shelter applications.
- Have done extensive work with SBIR companies on various shielding materials.



Posses greatest risks to astronauts and their instruments.

Nuclear power for long term human missions:



- Considered for both spacecraft and planetary habitats for propulsion and spacecraft power.

- NASA follows ALARA "as low as reasonably achievable" radiation dose policy

- Nuclear reactor and/or radioisotope thermoelectric generator (RTG) will contribute to the mixed radiation field experienced by astronauts and their instruments.

- This mixed radiation field may include thermal neutrons from these power sources.

- Other possible sources of thermalized neutrons are solar proton and GCR interactions with spacecraft/habitat walls and from albedo neutrons from a planetary surface.

Materials for future space missions:

• “Multi-functional” – combine desired structural, chemical, thermal, electrical, and shielding properties.

• Lightweight to reduce mission costs.

• Structural, chemical, thermal and electrical properties like aluminum.

• Shielding properties like polyethylene.

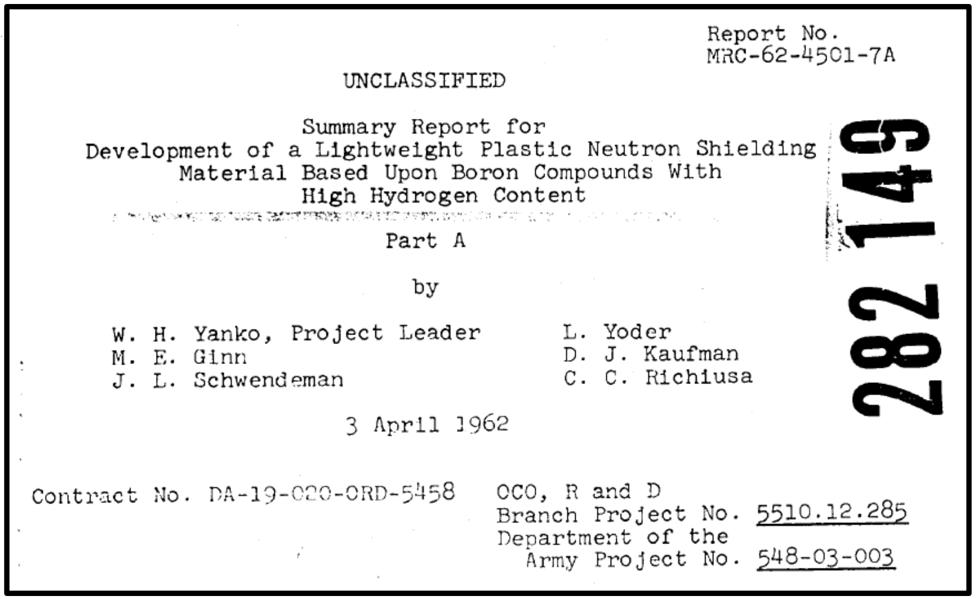
• NASA has funded programs to develop new materials systems, such as polymer composites, to meet these requirements:

- Space Radiation Program
- SBIR and STTR Program
- NASA University Research Program
- Others.

Thermal neutron shielding with boron:

Measurements of the thermal neutron capture cross-section where done at the beginning of the Nuclear Age (See for example H. Pomerance, *Physical Review* 83, 641-645 (1951).)

This included work with materials with boron and high hydrogen content:



Report No.
MRC-62-4501-7A

UNCLASSIFIED

Summary Report for
Development of a Lightweight Plastic Neutron Shielding
Material Based Upon Boron Compounds With
High Hydrogen Content

Part A

by

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D. J. Kaufman
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3 April 1962

Contract No. DA-19-020-ORD-5458

OCO, R and D
Branch Project No. 5510.12.285
Department of the
Army Project No. 548-03-003

282 149

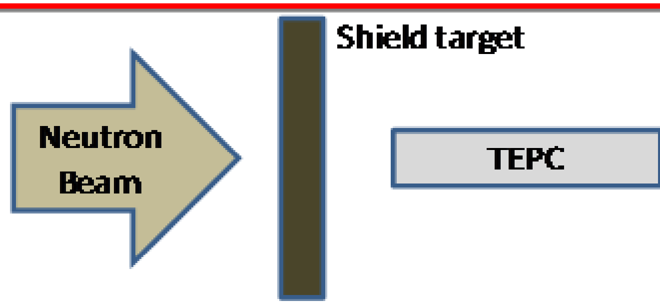
Our work shows that novel boron-carbon polymer composites have desired aerospace multi-functional properties and are effective shields for thermal neutrons such as would be expected from spacecraft nuclear power and/or propulsion.

http://www.dtic.mil/dtic/tr/fulltext/u2/282149.pdf

Materials and Methods

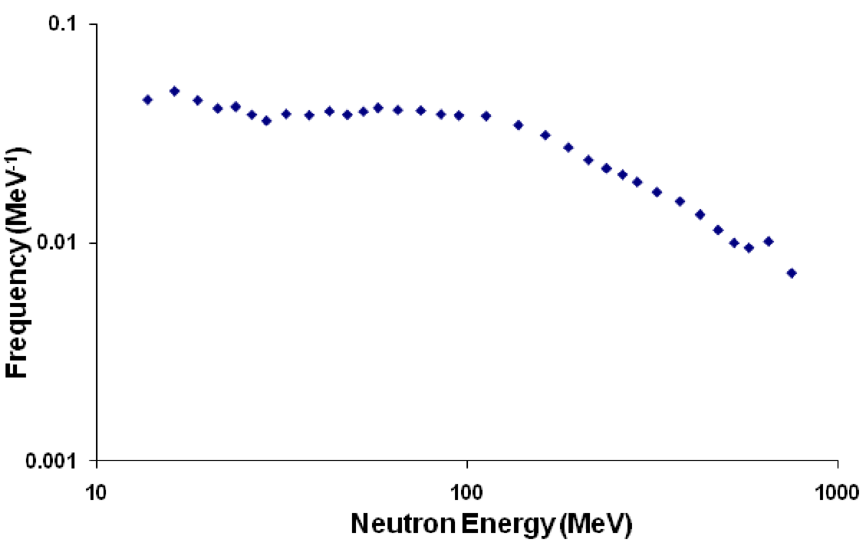
B/C/UN-10 hybrid composite panel (18” x 18”)

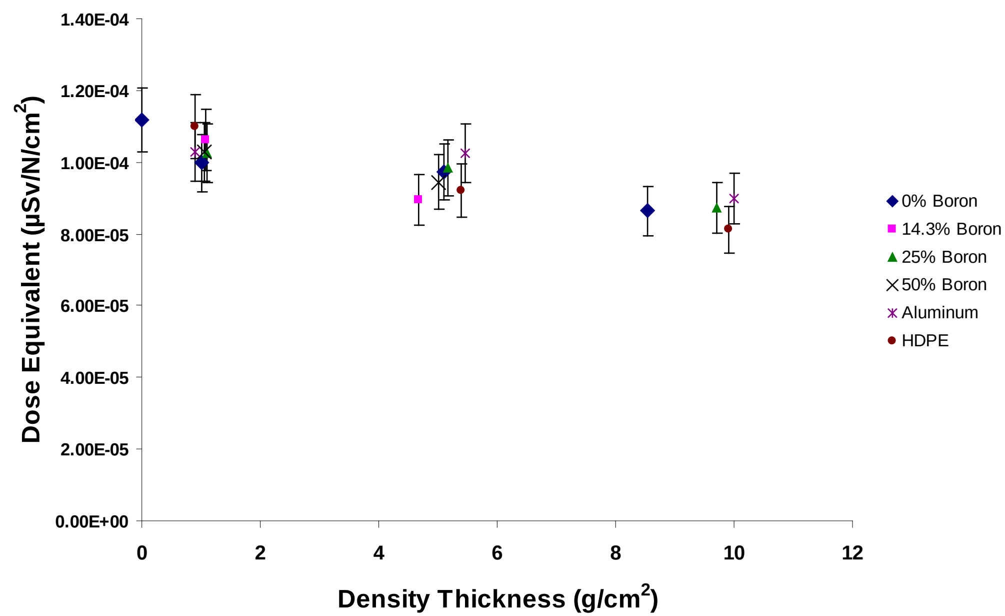
The boron-carbon composites:



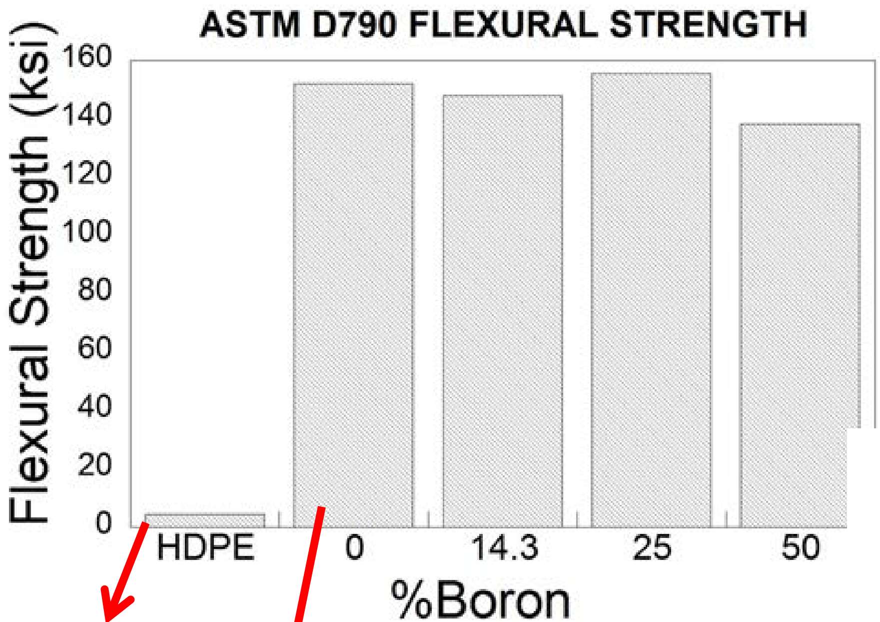
Phase I Materials: Four composites (0%, 14.3%, 25% and 50% boron content compared to aluminum and high density polyethylene (HDPE).

Radiation Shielding experiment performed for high energy (10 – 800 MeV) neutrons. Result: Shielding for the composites was similar to the Al and HDPE –as expected.





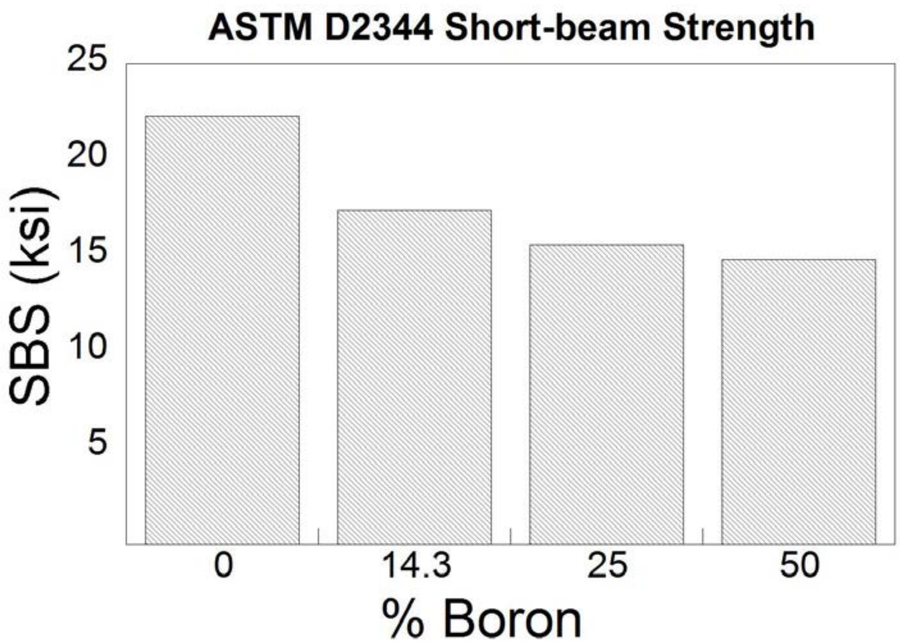
Mechanical Properties



Data from:
http://www.boedeker.com/polye_p.htm

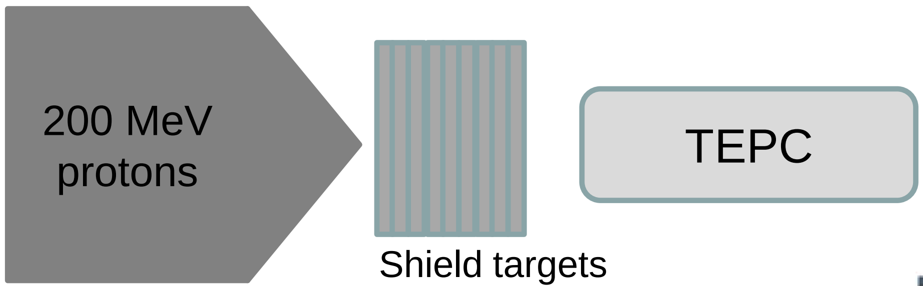
Carbon/UN-10 Composite

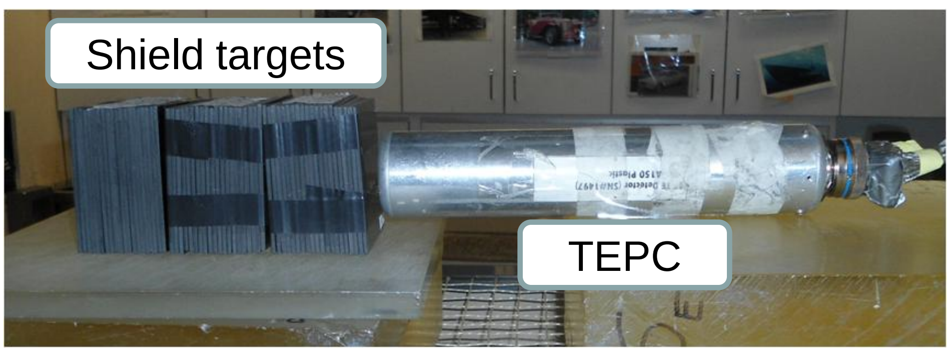
Note that the lower percent-weight boron composites have as good or better mechanical properties compared with higher boron content composites.

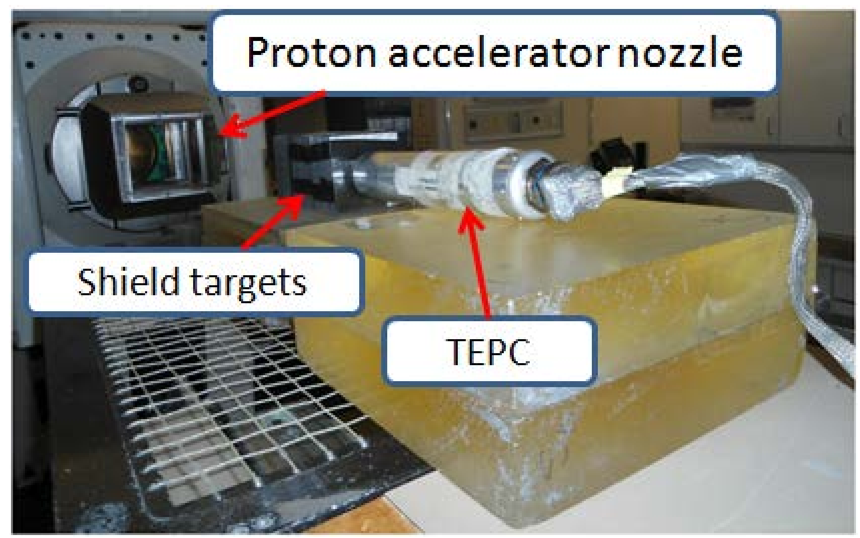


Data for non-irradiated materials.

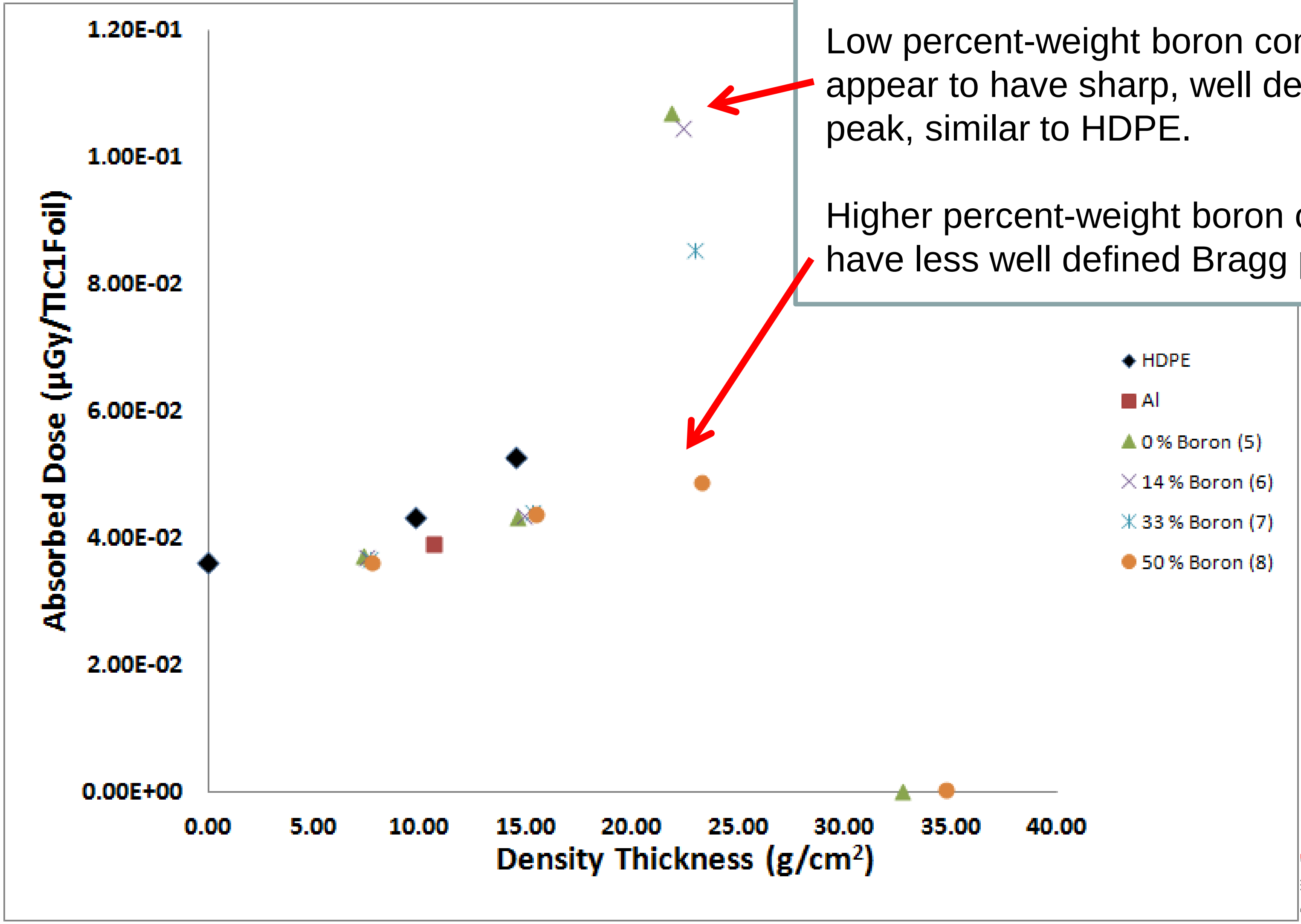
Initial charged particle experiments:
200 MeV protons at Loma Linda, June 2012







Results, 200 MeV protons, June 2012



HDPE data indicates sharp Bragg peak.

Low percent-weight boron composites appear to have sharp, well defined Bragg peak, similar to HDPE.

Higher percent-weight boron composites have less well defined Bragg peak.

The data from the 200 MeV proton experiments indicate:

➢At low density thicknesses (<15.5 g/cm^2):

•HDPE shows highest adsorbed dose and dose equivalent because it is the most efficient at slowing the proton.

•Boron-carbon composites are similar to HDPE.

➢At high density thicknesses (>15.5 g/cm^2):

•Bragg peak seems better defined for those boron-carbon targets with the lower boron content – they are more "poly-like".

•For boron-carbon targets with higher boron content – the Bragg peak seems broader and less well defined – they are more "metal-like".

-Appears that more secondary neutrons and other particles are contributing to the adsorb dose and dose equivalent.

-Likely due to larger content of higher Z elements.

-This and previous experiments on the Phase I targets suggest the presence of high Z elements – a component of the composites has tungsten content.

-For very thick targets (>32 g/cm^2), the "50% boron" quality factor for the residual secondary field was more than a factor of 2 higher than the "0% boron".

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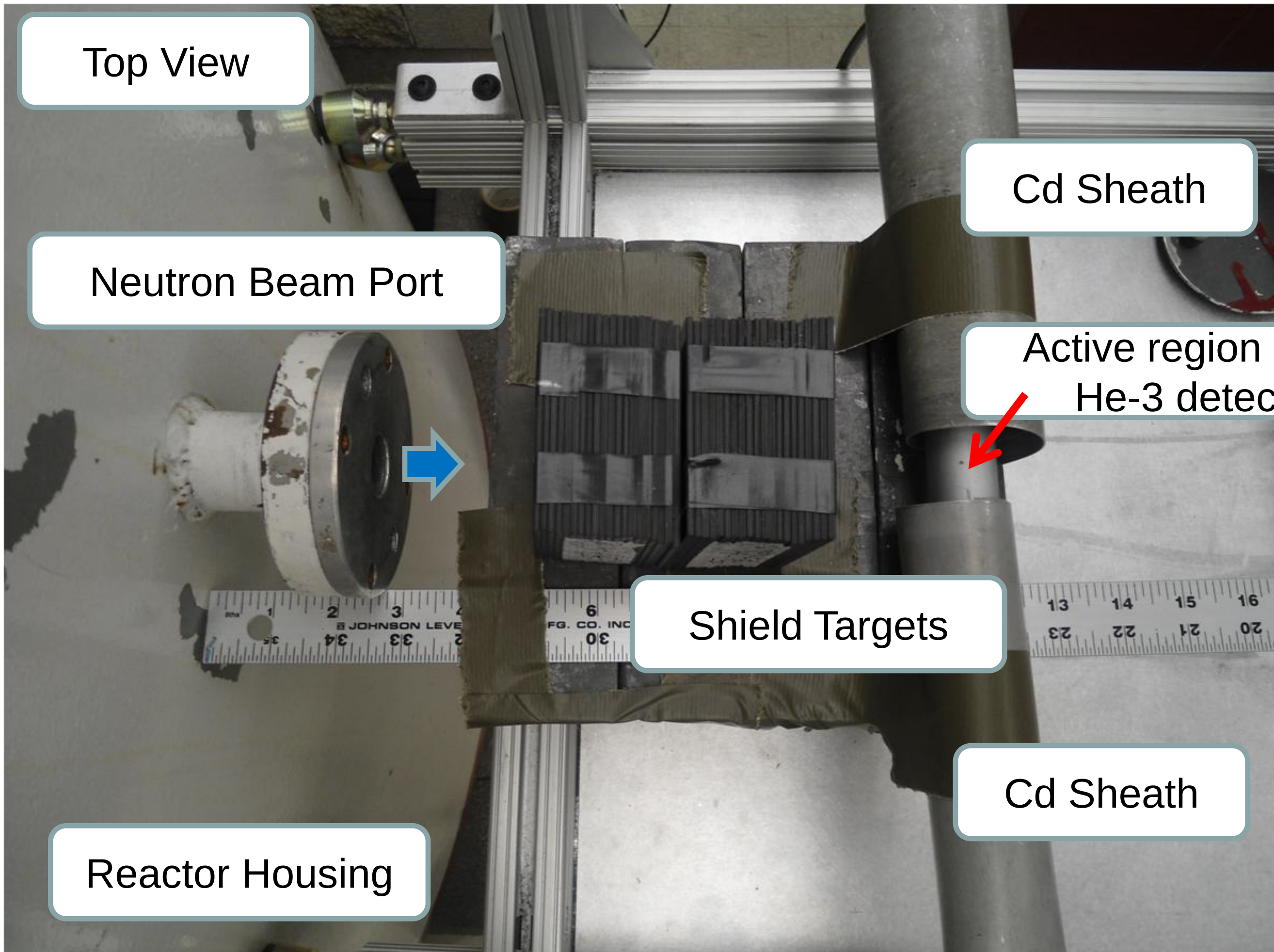
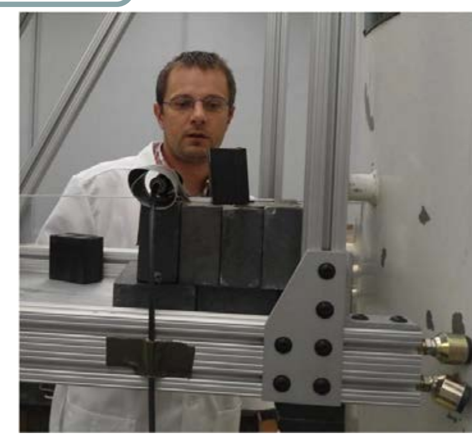
Nuclear Reactor Experiments at the Texas A&M Nuclear Science Center



The experimental configuration with the Cd sheath is a standard method for He-3 measurements in the reactor environment.



R. Skoda during the experiments.

National Aeronautics and Space Administration

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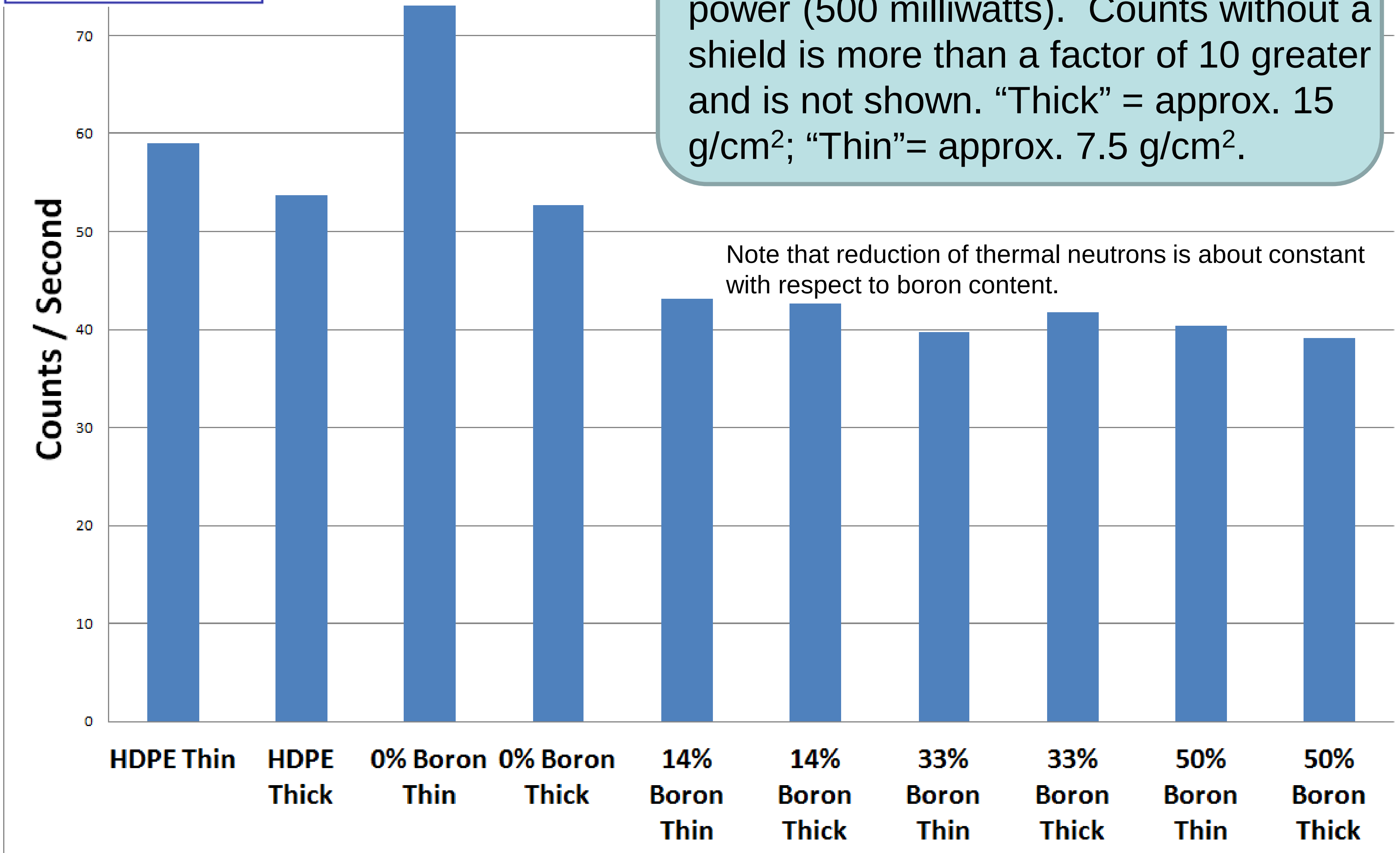
He-3 thermal neutron counts behind various shield targets at constant reactor power (500 milliwatts). Counts without a shield is more than a factor of 10 greater and is not shown. “Thick” = approx. 15 g/cm^2; “Thin”= approx. 7.5 g/cm^2.



Note that reduction of thermal neutrons is about constant with respect to boron content.

Conclusions:

1. The composites have shielding properties similar to that of HDPE with the 200 MeV protons; similar to HDPE and Al in a high-energy neutron environment.
2. Even the lowest boron level shows significant shielding of reactor neutrons, with higher boron levels not providing significantly better shielding;
3. The composites with the lower boron content have the better structural properties.
4. These results indicate that composites, such as the one studied, are potential candidates for future deep space missions using nuclear propulsion and power.

Acknowledgements: Personnel at the Loma Linda Medical University proton facility and the Texas A&M Nuclear Science Center.

Thank you!