Shielding Design

Insoo Jun

EJSM Instrument Workshop
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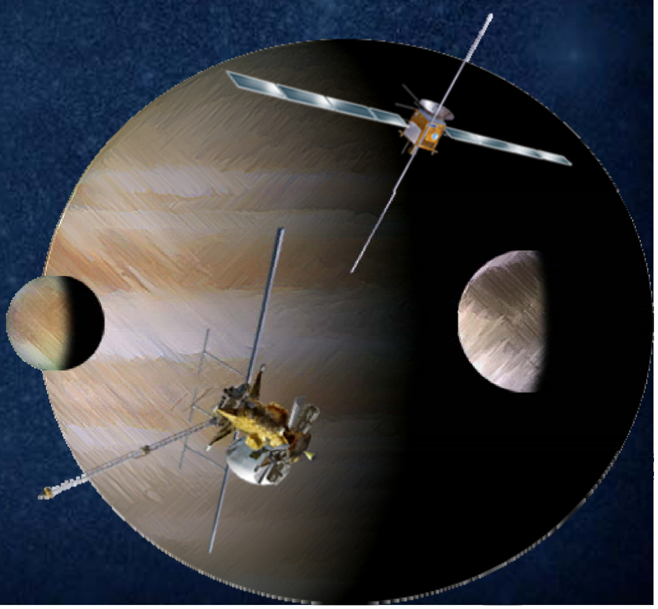
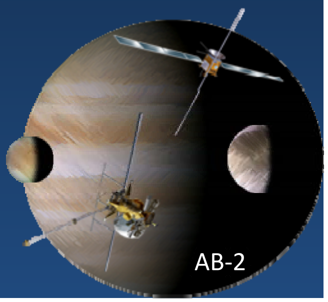


Topics

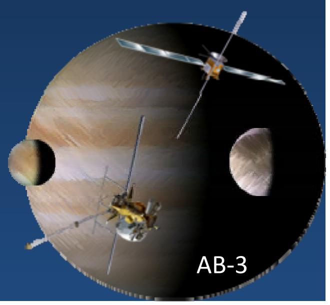
- General shielding considerations for JEO
- Shielding design process
- Lesson learned from Juno shielding design experience
- Shielding benchmarking study
- Summary



Shielding Consideration

- Particle species to be included in shielding design
  - High energy electrons from Jovian magnetosphere
  - High energy protons from Jovian magnetosphere and solar energetic particles (SEP)
  - Heavy ions from galactic cosmic rays (GCR) and SEP

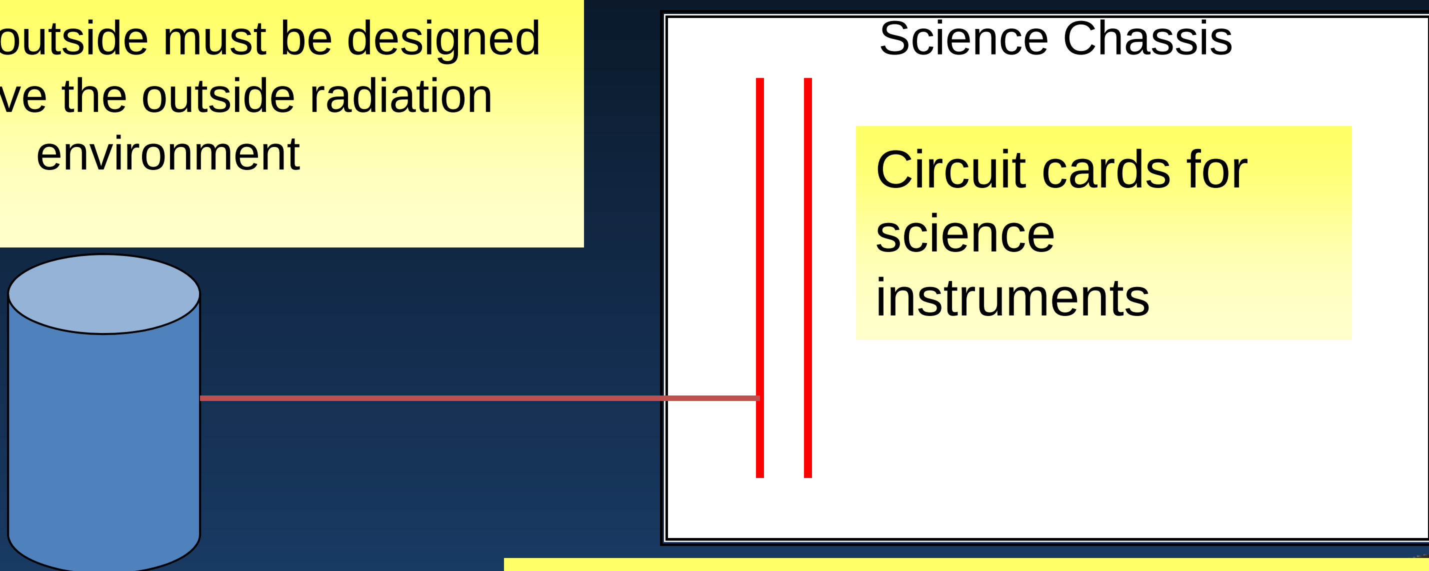
- Radiation effects to be considered in shielding design
  - Total ionizing dose (TID)
  - Displacement damage dose (DDD)
  - Single event effects (SEE)
  - Internal electrostatic discharge (IESD)
  - Radiation induced noise in sensors and detectors



Radiation Shielding Design Approach

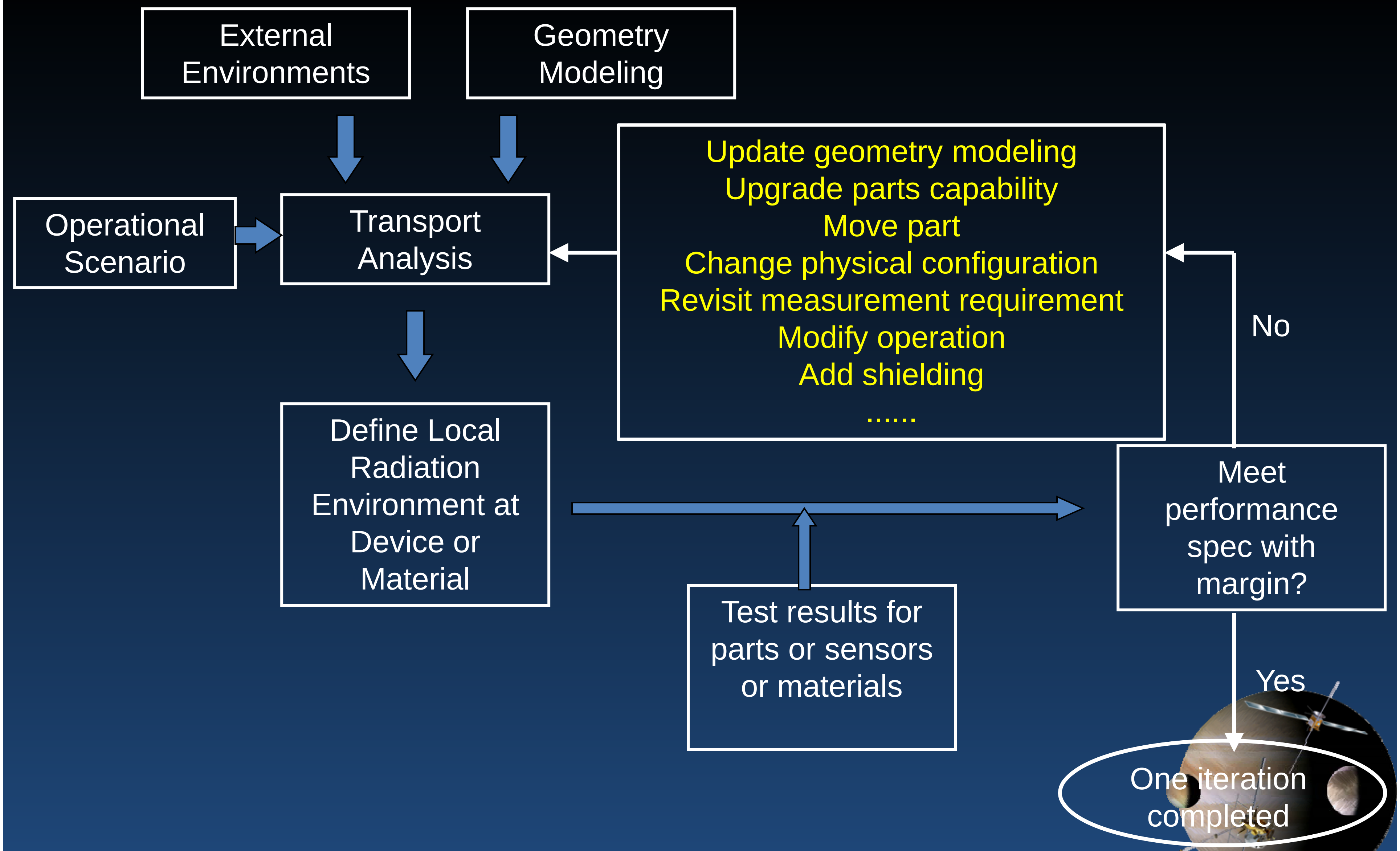
- Electronics/instruments/materials must meet the RDF=2 requirement.
  - For example, if there are 300 krad parts used in the electronics, the shield should brings the dose down to 150 krad.
  - The RDF=2 requirement also applies to displacement damage dose and materials.

Anything outside must be designed to survive the outside radiation environment



Electronics for science instruments can be placed into the science chassis and must be designed to 300 krad.

Generic Shielding Design Process

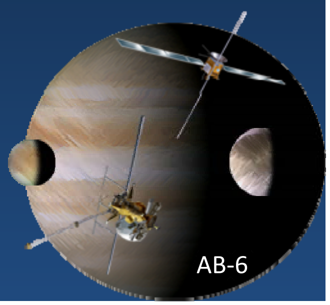


Example: Progress of Geometry Modeling

- The fidelity of shield geometry model will increase as the instrument design matures

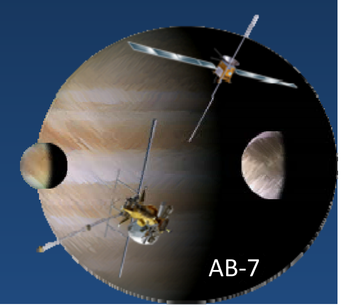
- The radiation shielding design will require many rounds of iterations or trade-offs during the instrument development phase
  - Material selection
  - Re-configuring internal component

- Iterations or trade-offs of the shielding design will be also required for the overall shielding mass optimization at the S/C system level
  - Shielding effect by S/C or other neighboring hardware



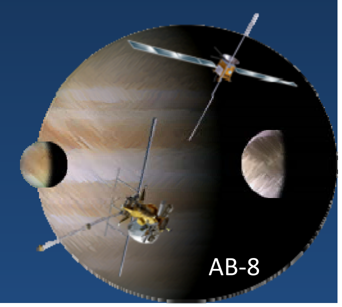
Near Term Release Schedule

Timeline	Information Available
This workshop	Mission fluence energy spectra Flux energy spectra Dose-depth curve for aluminum
At the release of AO	Dose-depth curves for other representative shielding materials (e.g., tantalum, WCu, titanium, etc.) Shielding design guideline for JEO instruments Simplified (or equivalent) spacecraft geometry model Study report on the benchmarking experiment
By October, 2011	JEO IESD mitigation design guideline Updated spacecraft geometry model



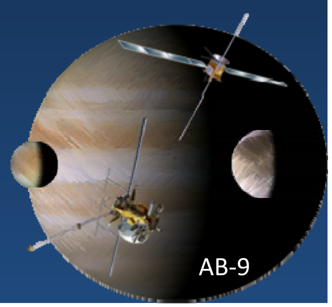
Shielding Design Lesson Learned from Juno

- SNR shielding analysis and testing required multiple iterations
- SNR analysis required transport analysis tool with comprehensive physics package (i.e., correct treatment of secondary particles)
- Shielding enclosure of instruments required multiple design iterations to optimize implementation and shielding effectiveness
- Board and component level analyses were required to optimize shield mass
- Graded shielding approach sometimes turned out to be difficult to implement

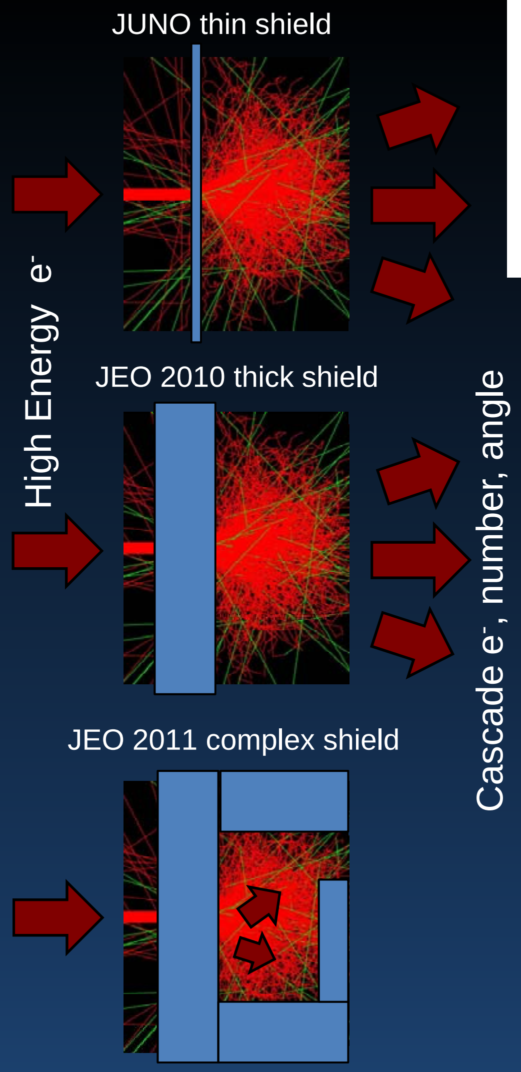


Shielding Benchmarking Study
(International EJSM Radiation Environment Panel)

- Objectives:
  - To compare and better understand the predictive capability of commonly used radiation transport tools
  - To provide a set of benchmark problems that potential instrument providers can use to validate their own choice of transport tools
  - To provide the radiation environment behind various shielding materials and thicknesses so as to estimate nominal background noise levels expected in detectors and sensors
  - To provide a guideline of using graded shield (i.e., low-Z/high-Z) materials
- The study will continue through September 2011
  - Initial results will be published in early 2011
  - Final report will be released in September 2011



Overview of the JEO Shielding Benchmarking Effort



Secondary particle environment behind shields

Objective: Develop and validate by test, physics-based models to predict

- The secondary environment behind thick shields
- The transient response that would be encountered by detectors to high energy electrons

Assessment of Radiation Effects on Science and Engineering Detectors for the JEO Mission Study (2008)

Juno Thin Slab Shield Experience

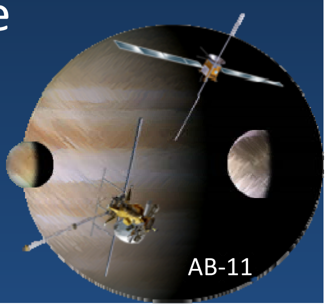
- Spatial and temporal noise distribution difficult to predict in general
- Modeling of the instrument specific shield and detector design followed by test as flown is critical for mission success

On-going and Near-Term Efforts for Thick and Complex Shielding

- Develop models and methodology based on Geant4 and MCNPX to describe radiation environment behind the shield
  - Model outputs provide particle type, energy spectrum and deposited energy
- Conduct beam tests at LINAC facilities to verify the methodology and models for the interaction of high energy e^- with thick slab shields
- Validate the secondary environment under more complex geometries

Benchmarking Problem Summary (First JEO Experiment)

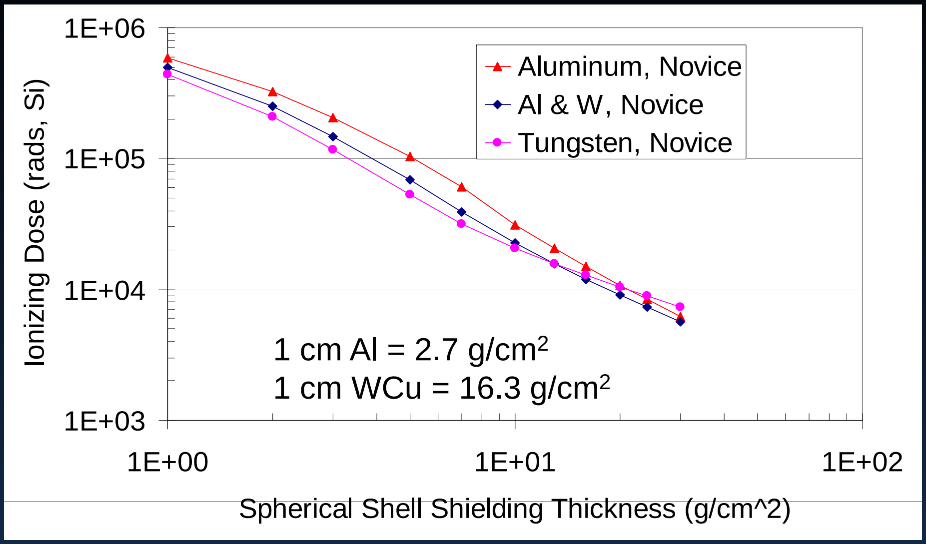
- Problem set-up
  - Al slab: 7, 14, and 20 g/cm2
  - Ta slab: 20 g/cm2
- Beam test at Idaho LINAC
  - 23 MeV electron
- Simulation Tools
  - MCNPX
  - Geant4
- Output:
  - Electron/photon energy spectra behind shields
- Tests have been performed recently and the data are being analyzed
  - The results will be published on the EJSM website
- Once validated against the benchmarking results, tools then can be used to estimate the radiation environment behind shields of different materials and different configurations



Shielding Material Consideration (Simulation)

- If sensors or detectors are sensitive only to TID, then high-Z materials are more effective
- However, high-Z materials will produce more secondary particles:
  - Photons
  - Neutrons

-> These will increase DDD, transient, and background noise levels

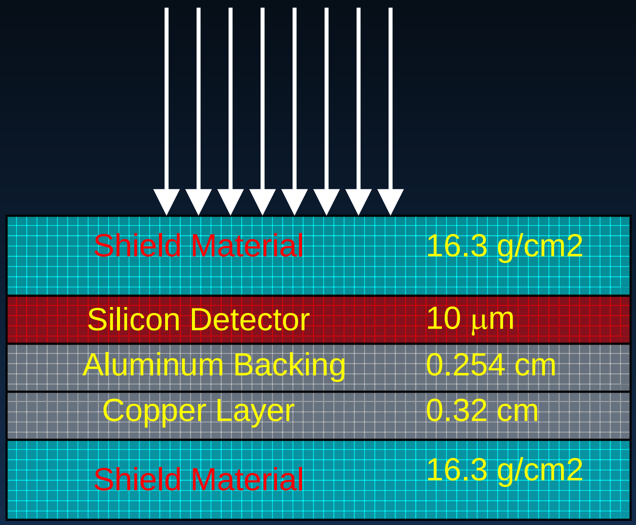


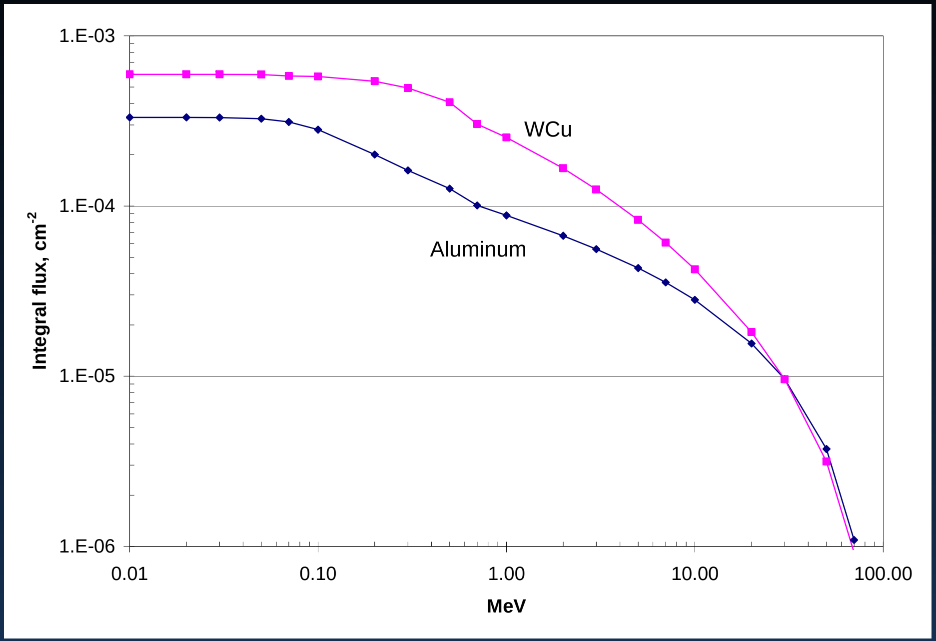
Example: Aluminum and Tungsten Shielding in a Jovian Environment (not JEO environment)

Trades should be made to find shield material combinations (e.g., low-Z/high-Z/low-Z combination) that optimize the instrument performance and shielding mass

Example: A Simple Geometry
Photon Environment Behind Shield

100 MeV Electron Broad Beam





Photon energy spectra at the silicon detector behind Aluminum or WCu shield

High-Z shielding materials will produce more secondary photons than low-Z materials

Summary

- Shielding design is a key for instrument design in the radiation environment expected for the mission
  - High energy electrons are the dominating contributor
- High energy electrons can induce TID, DDD, and transient noise to sensors and detectors
  - The 2008 detector working group study indicated the necessary shielding amount is dictated by transient requirement, rather than TID or DDD requirement
  - For Juno, shielding design for 5 out of 8 science instruments and SRU were actually driven by transient (or flux) shielding requirement.
- The Project is working on a benchmarking study and a shielding guideline for instrument providers