

A Deterministic Electrons and Protons Transport Suite for the Study of the Jovian System

Francis F. Badavi¹, Ryan B. Norman², John E. Nealy³

¹Christopher Newport University, Newport News, VA, USA

²NASA Langley Research Center, Hampton, VA, USA

³Old Dominion University, Norfolk, VA, USA

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Outline

- Coronal Mass Ejections (CME) and Corotating Interaction Regions (CIR) background information.
- Implemented electron, proton and heavy ion rad. environments at Jupiter.
- Implemented deterministic transport suite for electrons and photons (CEPTRN); protons and heavy ions (HZETRN).
- Sample simulation results:
graded-Z shields and optimization of shields.
- Concluding remarks.

CME and CIR background information

- Geomagnetic storms become a problem when solar wind and magnetosphere interaction is intensified by solar wind disturbances such as coronal mass ejection (CME) and corotating interaction region (CIR).
- CME-driven magnetic storms:
 - Mostly occur around solar max (e.g. ~ 2001).
 - Are a problem for Earth-based electrical networks.
- CIR-driven magnetic storms:
 - Mostly occur around solar min (e.g. ~ 2009).
 - Are a problem for orbiting spacecrafts.
- As for Jupiter, with the exception of most energetic component of CME and CIR, Jupiter's strong magnetic field shields against most magnetic storms and cosmic rays (GCR).
- For the upcoming Jupiter Europa Orbiter (JEO) (NASA) and Jupiter Ganymede Orbiter (JGO) (ESA) missions, we will show how spacecraft shielding in the Jovian system is done.
- At the design stage, an RDF=2 is used to account for potential CME, CIR and other anomalies. RDF=Radiation Design Factor.

Implemented environment and transport packages

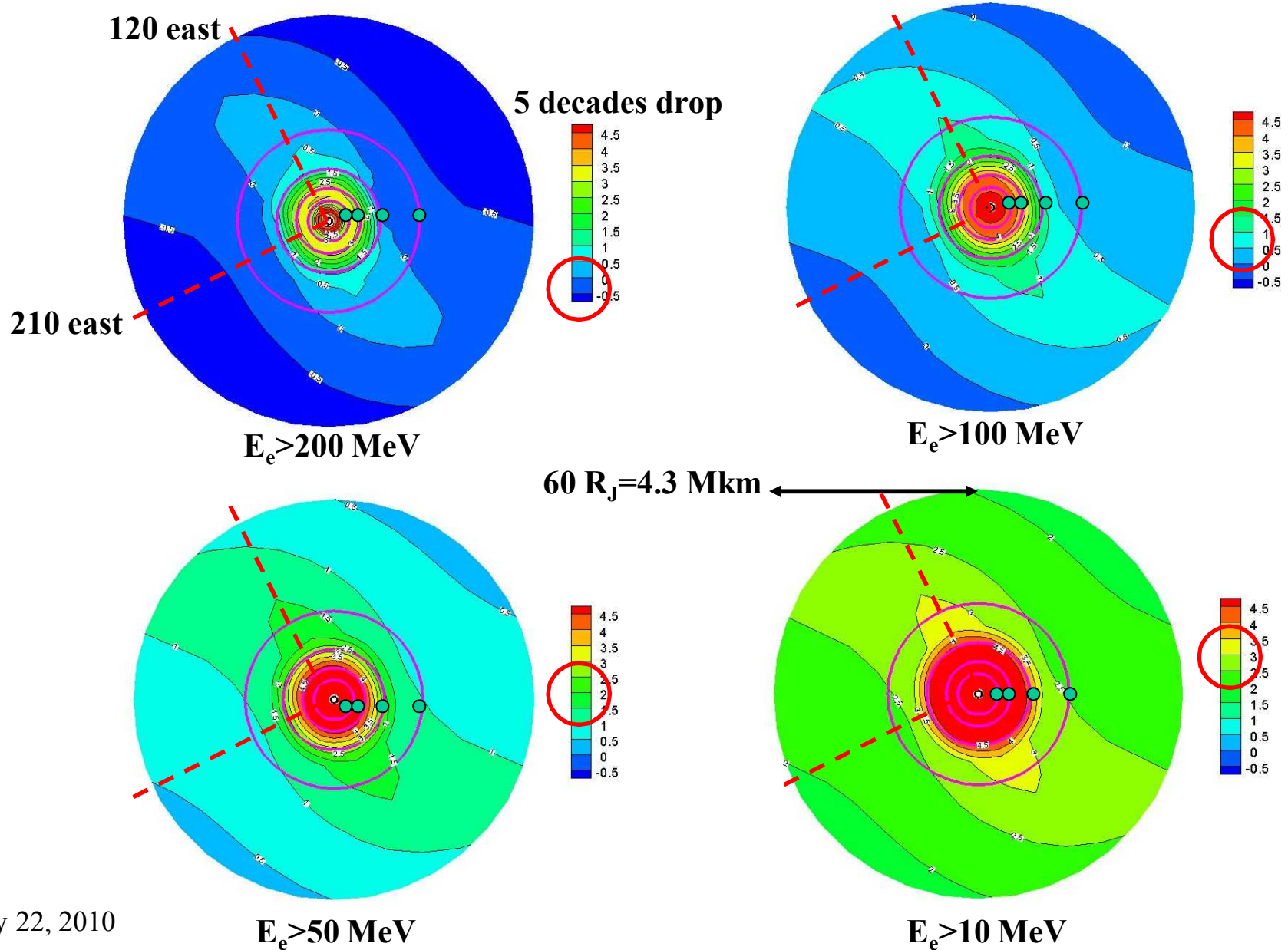
- Jupiter trapped electrons and protons environments are characterized by the NASA-JPL Galileo Interim Reference Electron GIRE model (circa 2003).
- Interplanetary heavy ions (GCR) environment around Jupiter and its moons is characterized by the NASA-JSC O'Neill model (circa 2004).
- Jupiter moons vertical magnetic cutoffs is calculated using Jupiter multipole magnetic field model of NASA-LaRC (circa 2005).
- Electrons and photons are characterized by the NASA-LaRC deterministic code CEPTRN (circa 2009).
- Protons and heavy ions are characterized by the NASA-LaRC deterministic code HZETRN (circa 2005).

CEPTRN (Coupled Electron and Photon TRaNsport)

HZETRN (High charge (Z) and Energy TRaNsport)

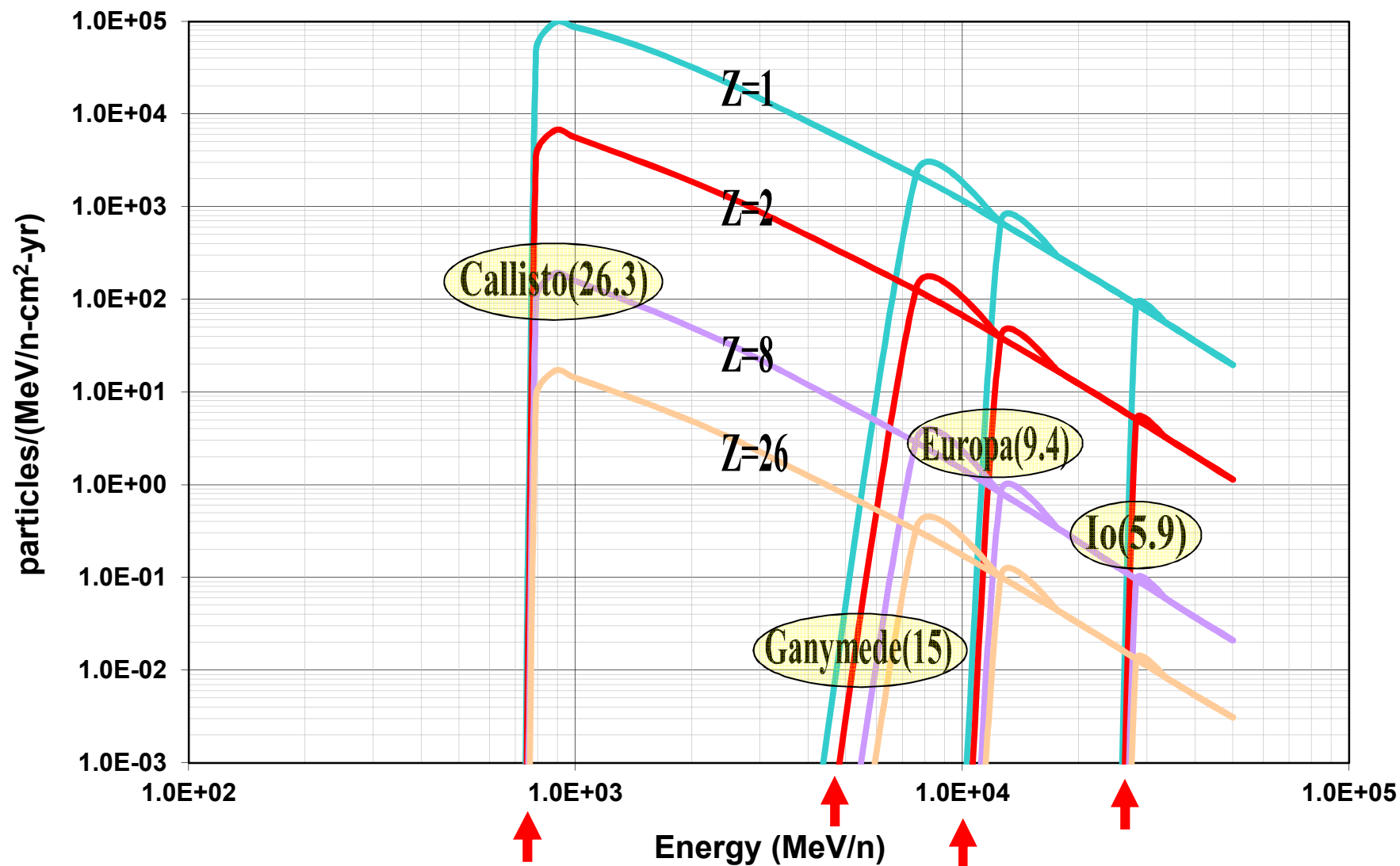
Jupiter Trapped Environment (GIRE 2003 model)

(electron integral flux, $\log_{10}(\text{cm}^2\text{-sec})^{-1}$ in equatorial plane)

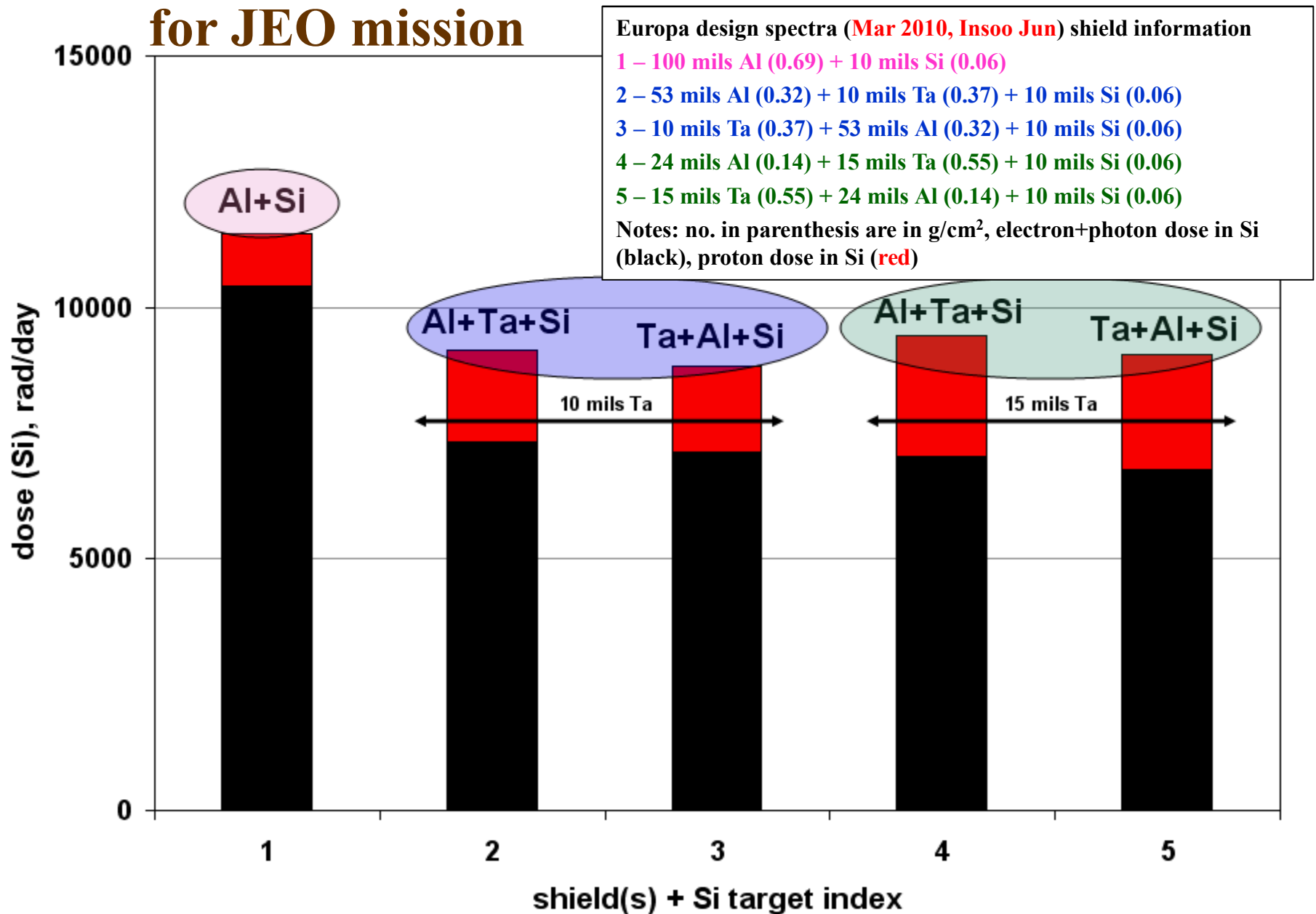


Interplanetary heavy ions (GCR) environment around Jupiter moons

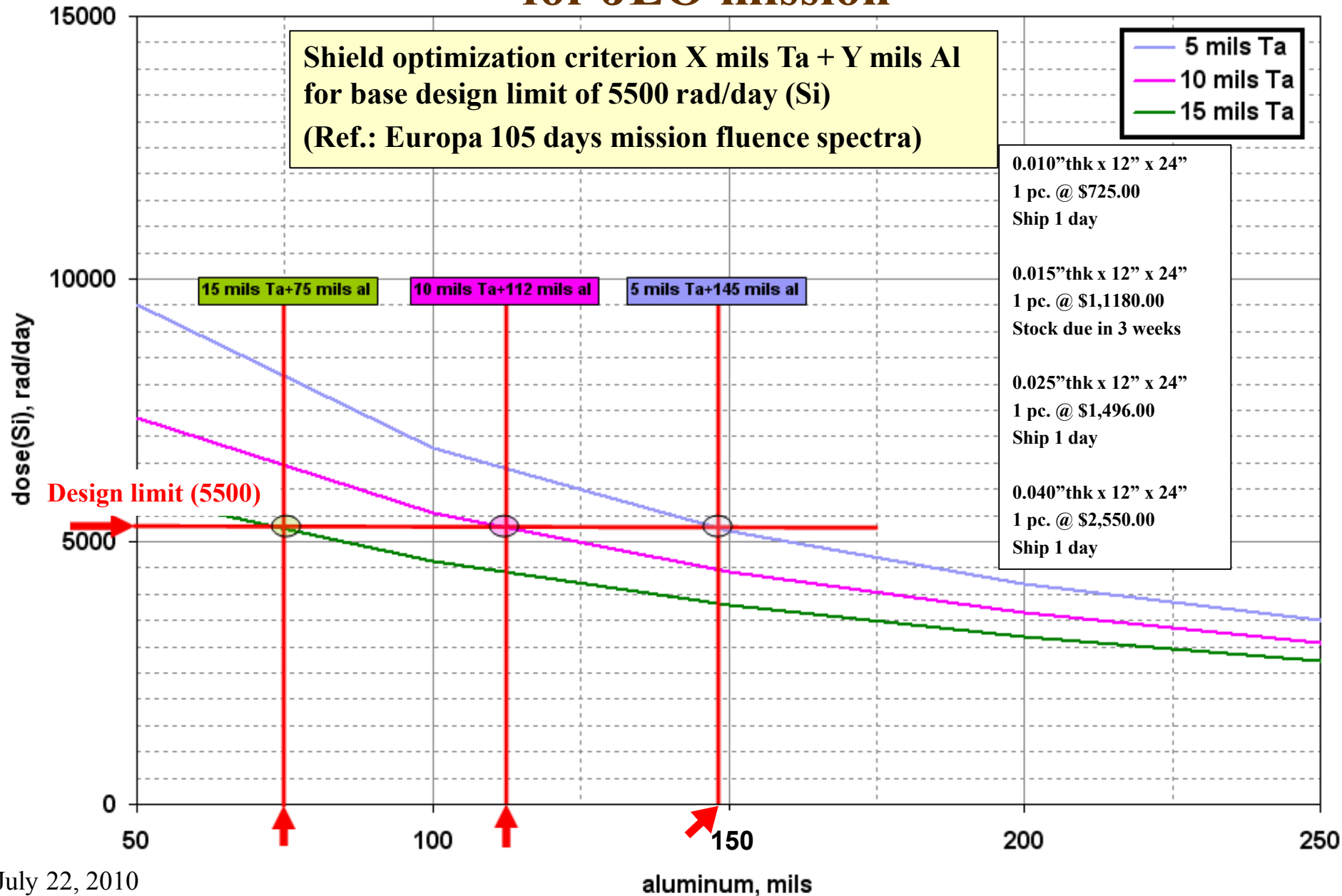
GCR environment at Jupiter moons for 2008 (solar min)



Graded-Z shield optimization and swapping for JEO mission



Shield optimization through thickness variation for JEO mission



Conclusions

- Even without CME and CIR storm consideration, spacecraft shield design is a challenging task for the Jupiter's four inner moons (especially at Io and Europa).
- Coupled graded-Z materials swapping and shield optimization trade study is a powerful design tool for minimizing radiation exposure for solid state devices.

Backups

Jovian satellites

Io

5.9 R_J

Europa

9.4 R_J

Ganymede

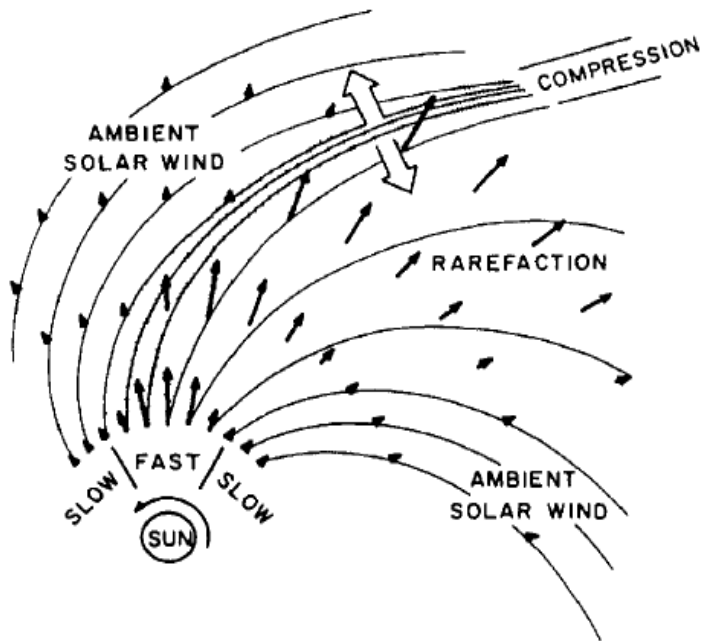
15.0 R_J

Callisto

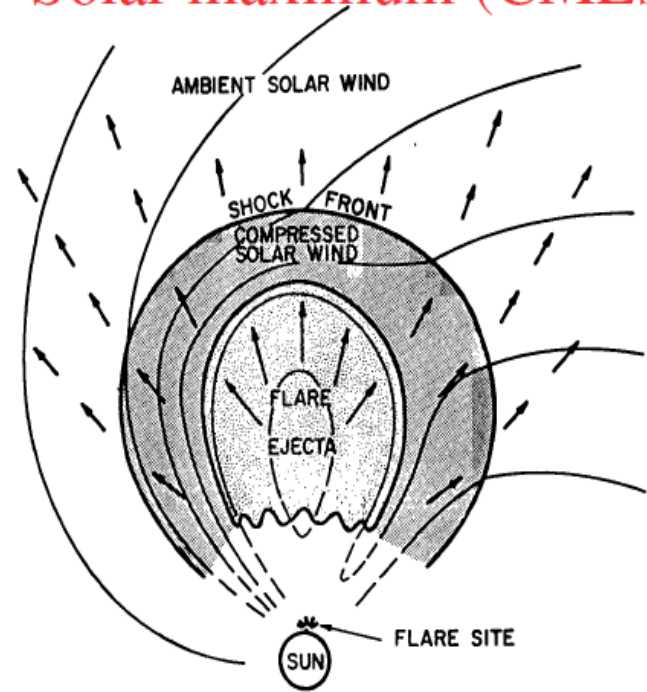
26.3 R_J



Solar minimum (CIRs)

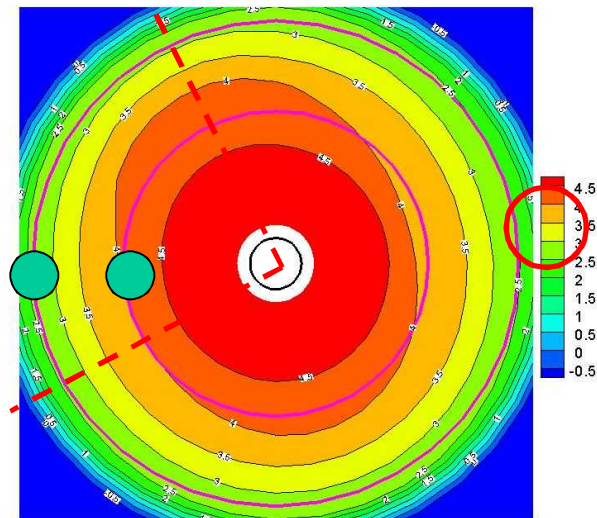
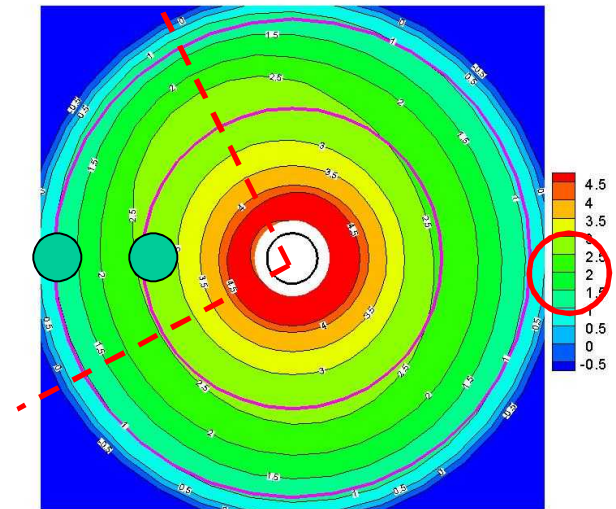
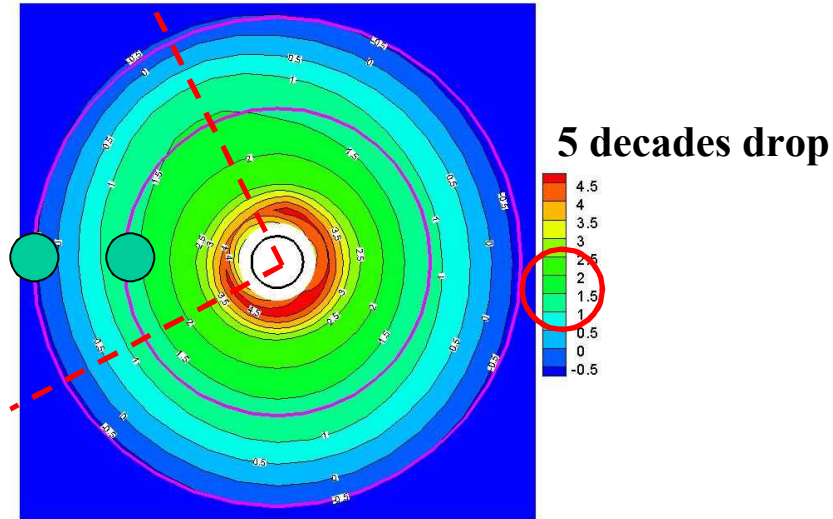


Solar maximum (CMEs)



Jupiter Trapped Environment (GIRE 2003 model) (proton integral flux, $\log_{10}(\text{cm}^2\text{-sec})^{-1}$ in equatorial plane)

120 east



12 $R_J = 0.86 \text{ Mkm}$

