Characteristics of Radiation Environments: Europa Orbiter

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Presentation at the OPFM Instrument Workshop, June 3, 2008

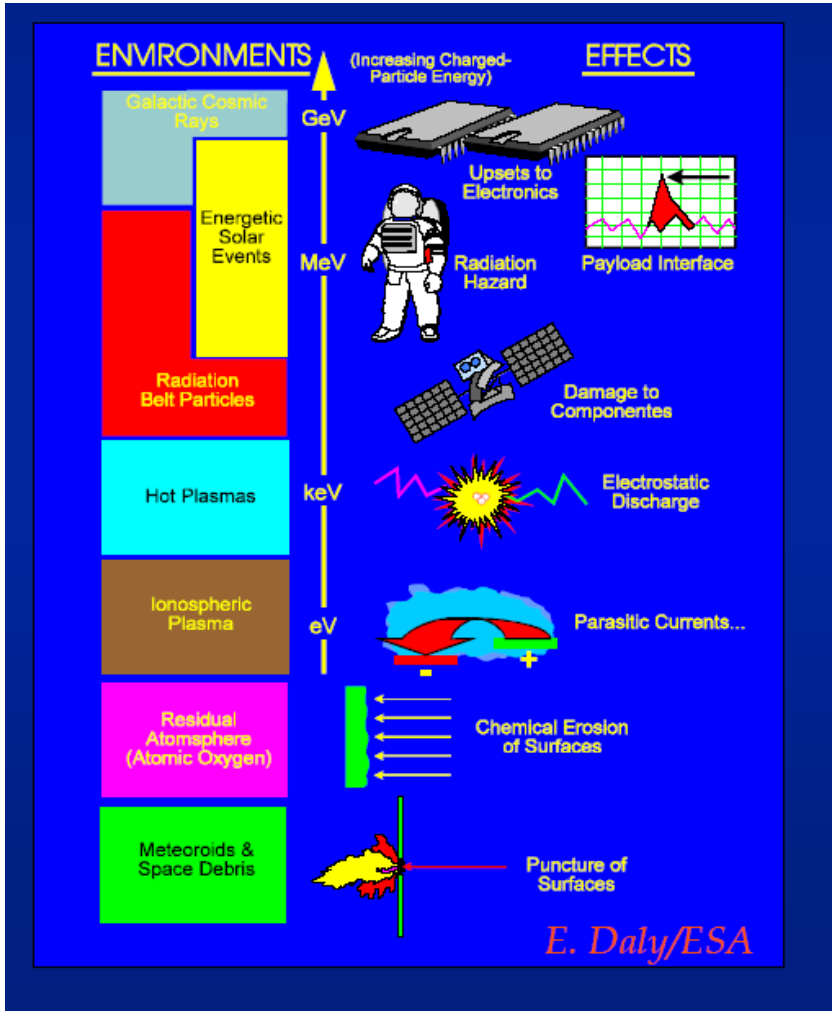
image credit: John Spencer, SwRI

Agenda

- Basics
  - Terminology
  - Constituents of radiation environments
- Radiation Environment for Europa Orbiter
- Summary

Overview

- Total Ionizing Dose
  - Cumulative long term ionizing damage mainly due to protons and electrons
- Displacement Damage Dose
  - Cumulative long term non-ionizing damage mainly due to protons, electrons, and neutrons
- Single Event Effects
  - Event caused by a single charged particle (heavy ions and/or protons) traversing the active volume of microelectronic devices
- Charging
  - Internal Charging
  - Surface Charging
- Material Degradation
- Noises in Science Instruments

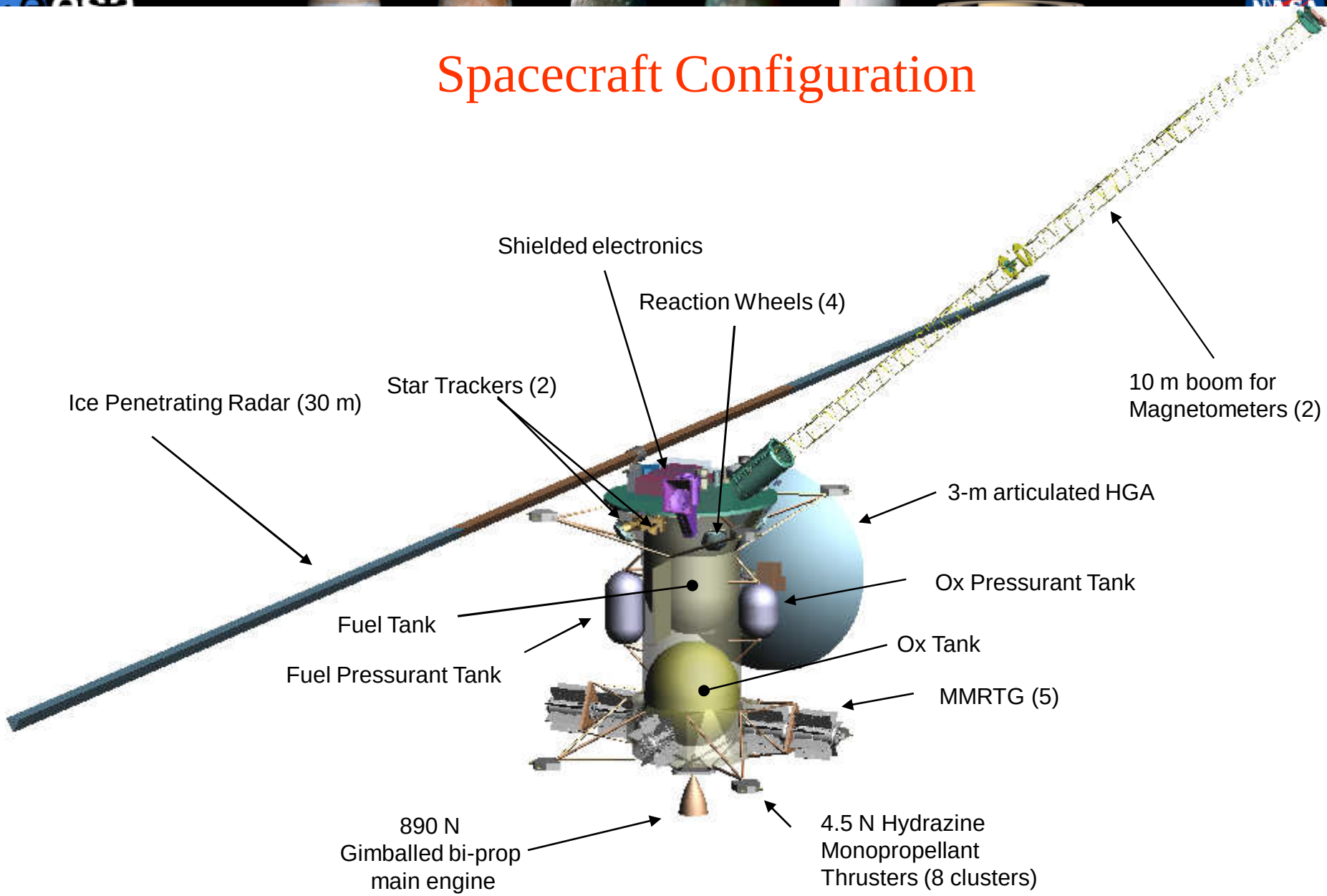


Definitions…..

- Flux, $\phi(E,t)dE$:
  - Number of particles crossing unit area per unit time in $(cm^2\text{-}s)^{-1}$.
  - peak flux, dose rate, SEU rate….
- Fluence, $\Phi(E)dE$:
  - Integral of the flux over a given time interval (i.e., one hour, one year, etc.) in cm^2.
  - mission fluence, total ionizing dose, displacement damage dose….
- Integral Fluence:
  - Number of particles with an energy E1 or greater, $I(E \geq E1) = \int_{E1}^{\infty} \Phi(E')dE'$
- Linear Energy Transfer (LET):
  - Energy transferred to material as an ionizing particle travels through it in MeV/cm.
- Mass LET
  - LET/ρ in MeV-cm^2/g, where ρ is the density of shielding material.
- Rad = 6.25E7 MeV/g

$$Ionizing\ \ Dose = \int_{E} \Phi(E)LET(E)dE$$

Spacecraft Configuration



Radiation Environments for EO

- Solar Energetic Particles (SEP)
  - TID, DDD, SEE
- Galactic Cosmic Rays (GCR)
  - SEE
- Neutrons from RTG or ASRG
  - DDD, SEU
- Photons from RTG or ASRG
  - TID
- Low-energy (<100 keV) trapped particles in the Jovian magnetic field
  - Surface material degradation, surface charging
- High energy (>100 keV) trapped particles in the Jovian magnetic field
  - TID, DDD, SEE, IESD

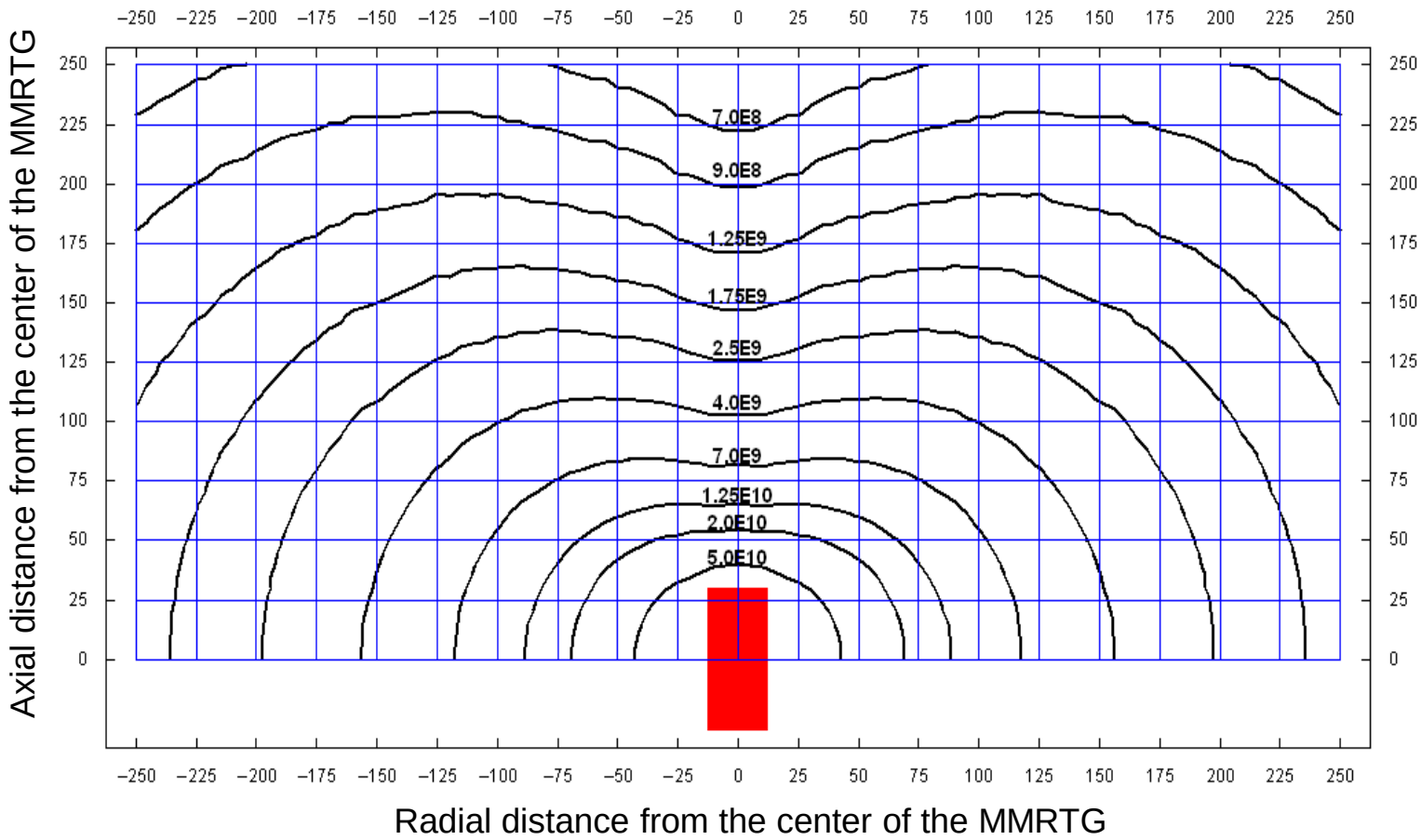
MMRTG 1 MeV Eq. Neutron Fluence Level for 1-Year Operation (Computed by the DOE provided MMRTG Fuel Data)

1 Year Fluence

# of 1MeV neutron/cm^2

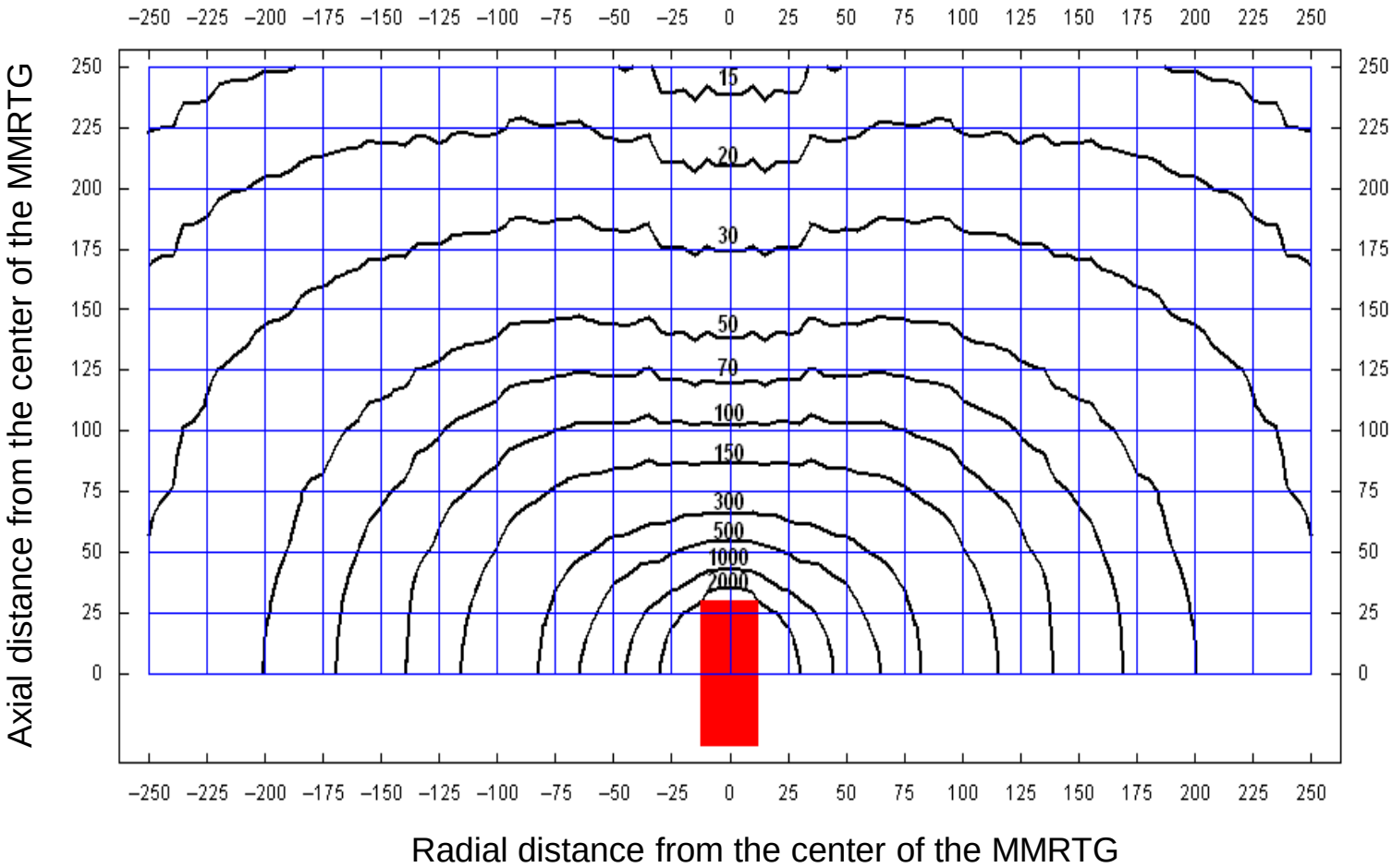
RDF=1

Neutron Displacement Damage, 25 cm grid

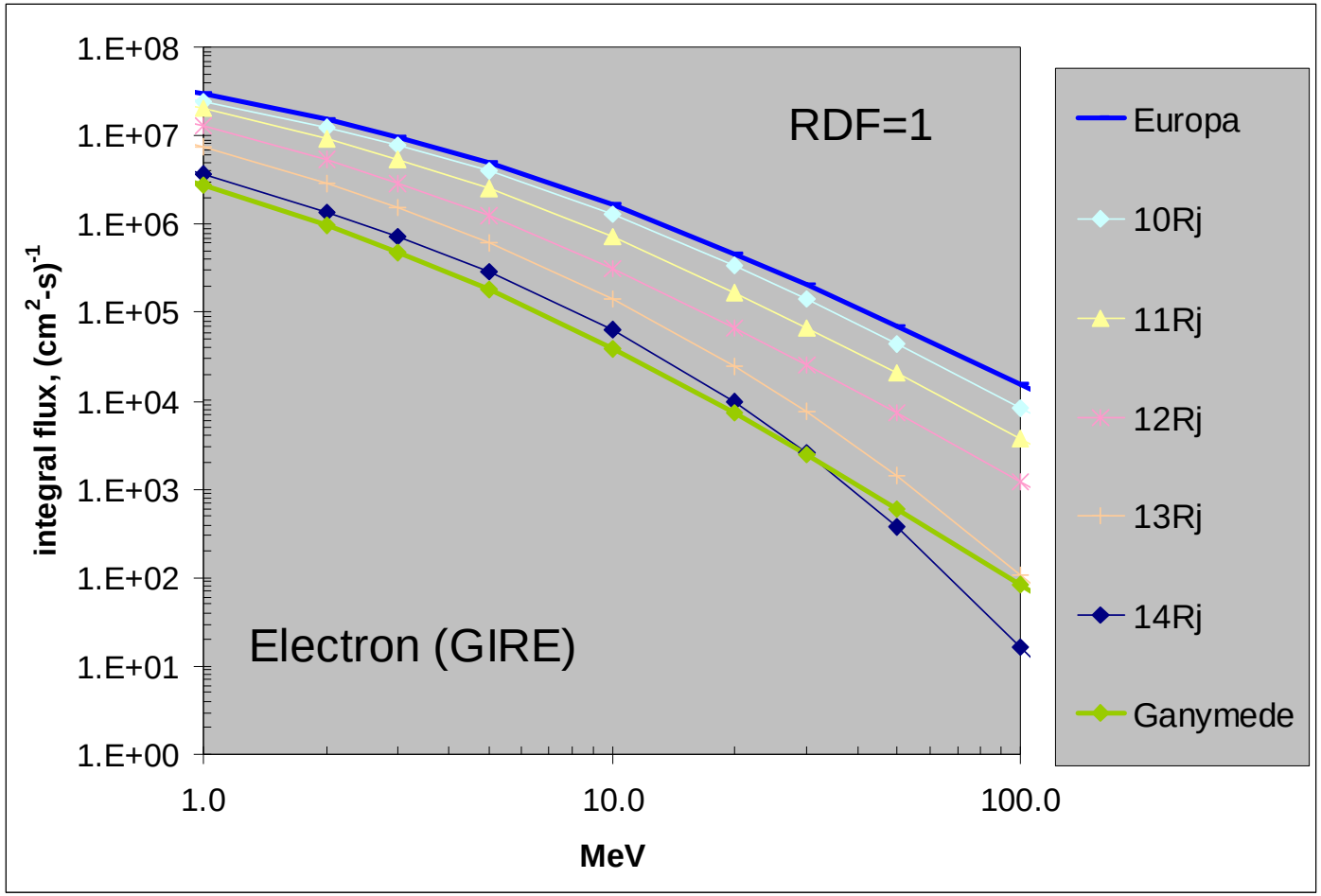


MMRTG Ionizing Dose Level for 1-Year Operation (Computed by the DOE provided MMRTG Fuel Data)

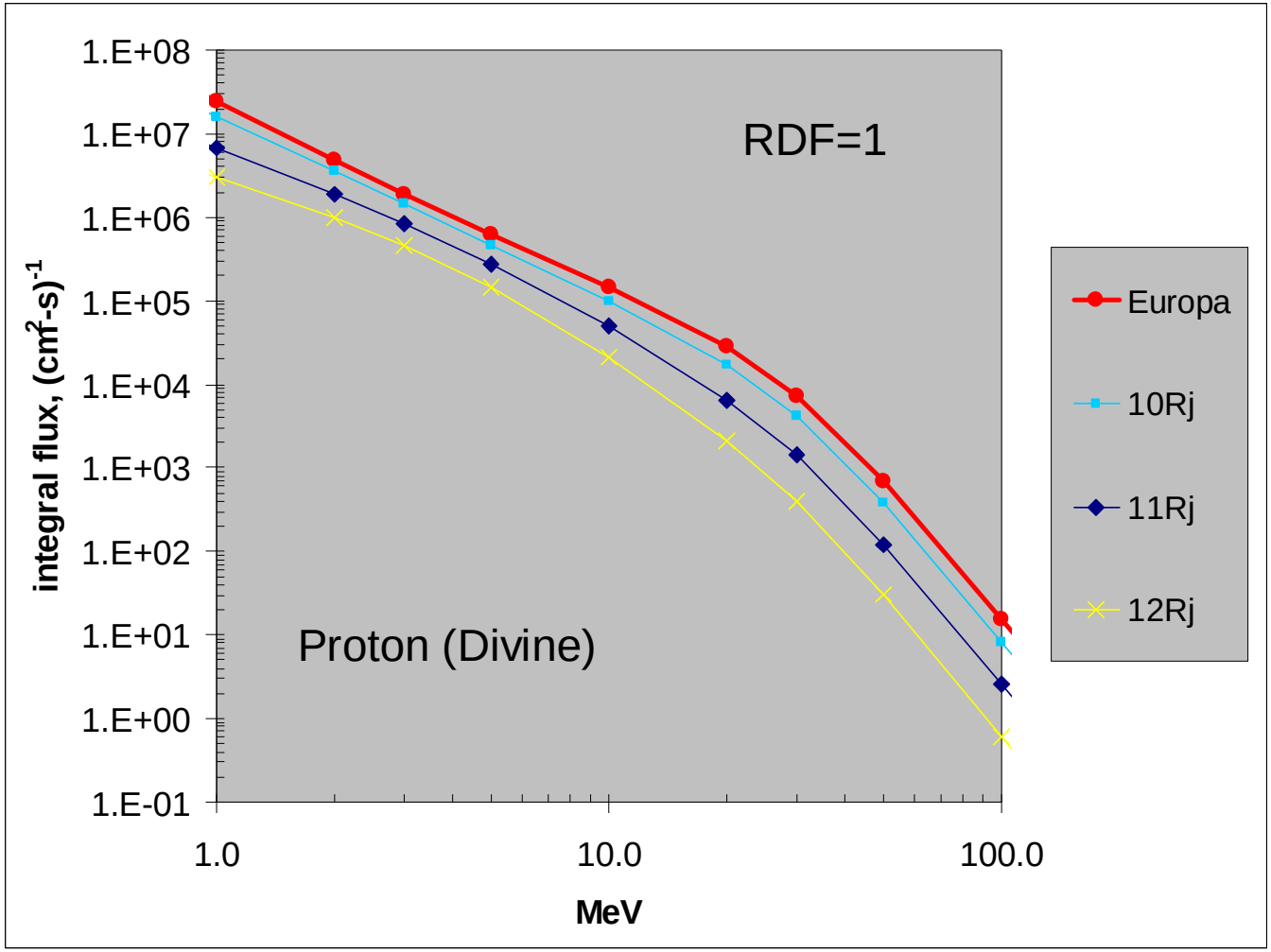
Rad(Si)/year RDF=1 Gamma Dose in Silicon, 25 cm grid



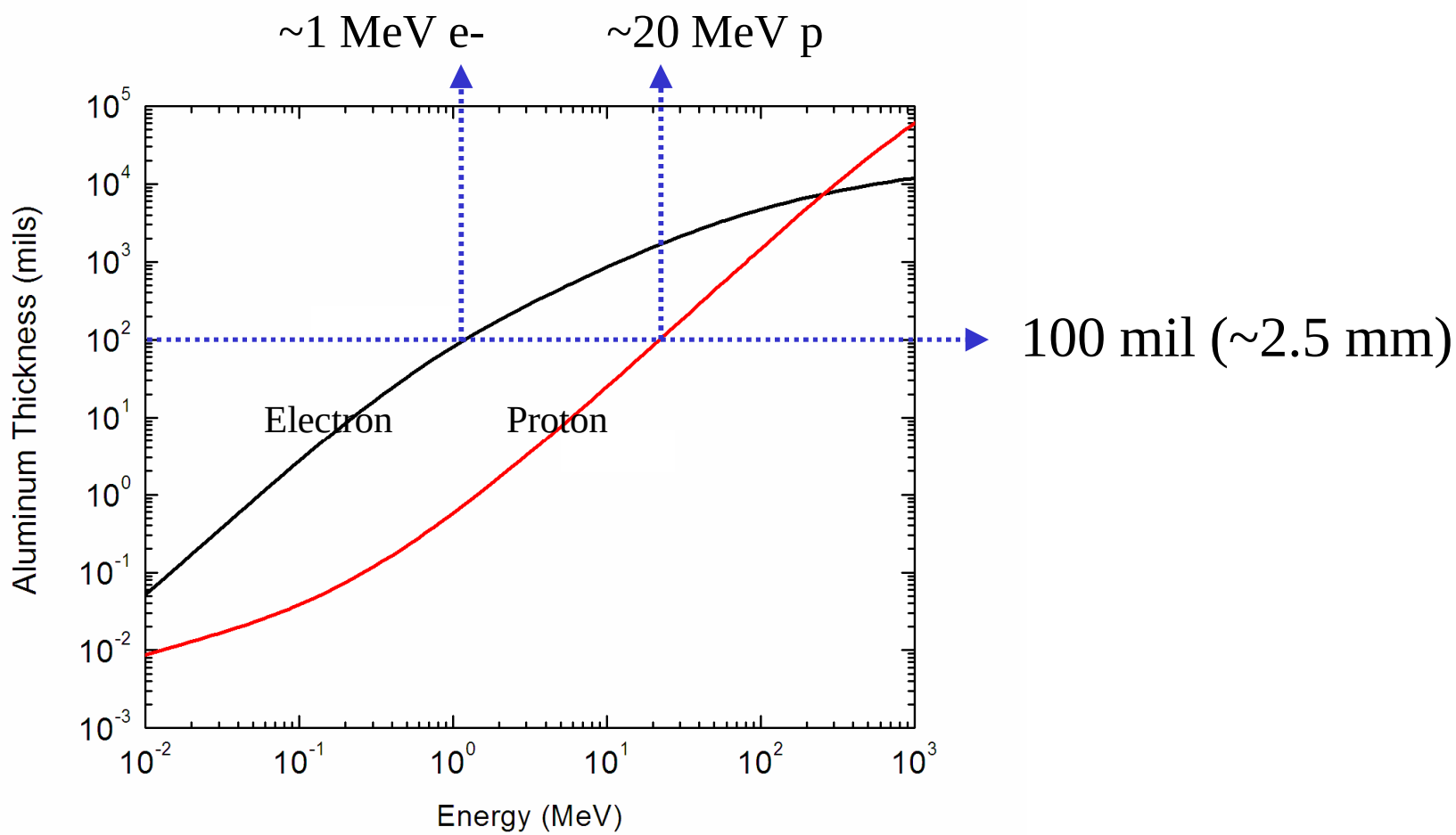
Electron Environment Energy Spectra (Free Space)



Proton Environment Energy Spectra (Free Space)

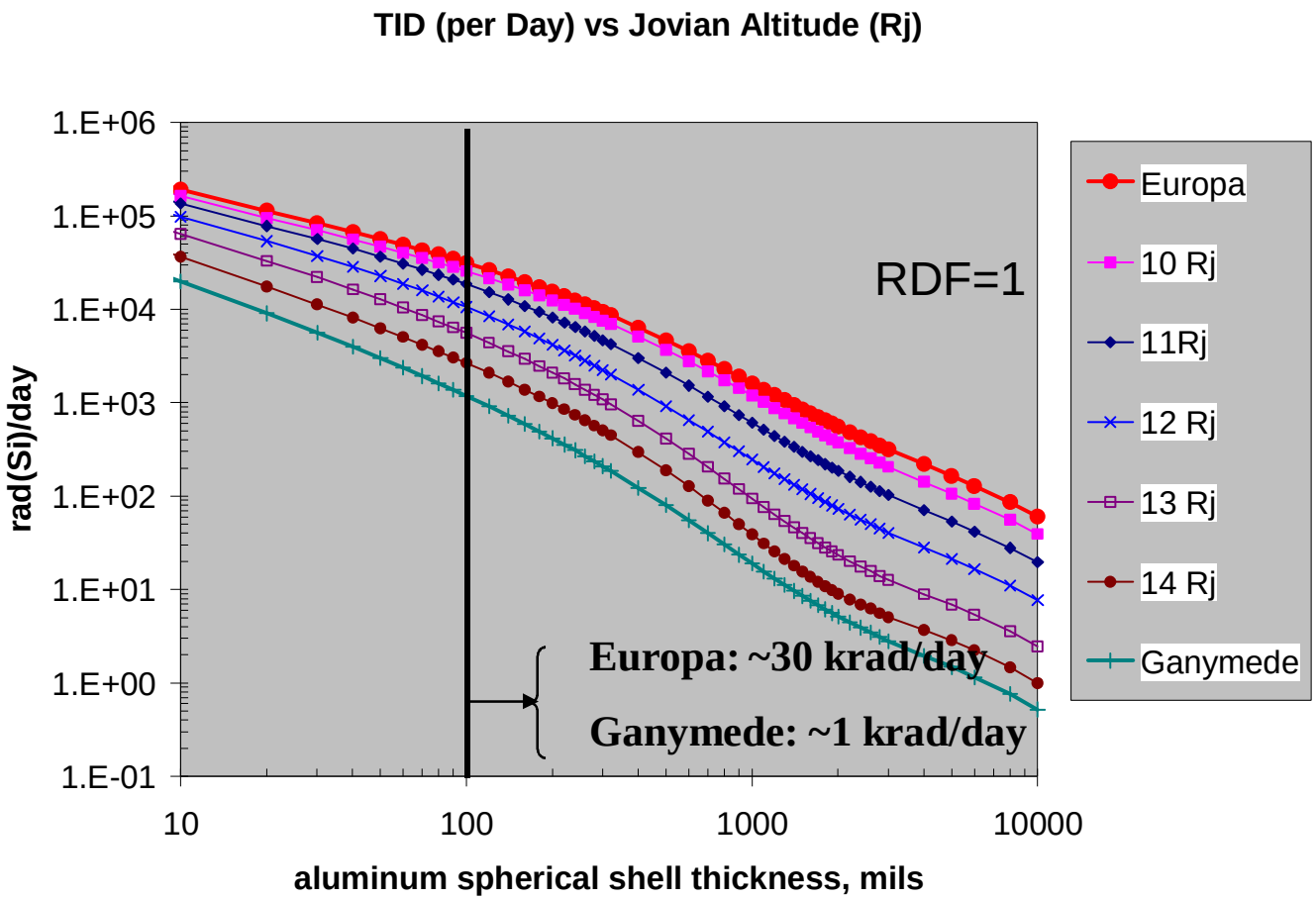


Electron and Proton Range in Aluminum

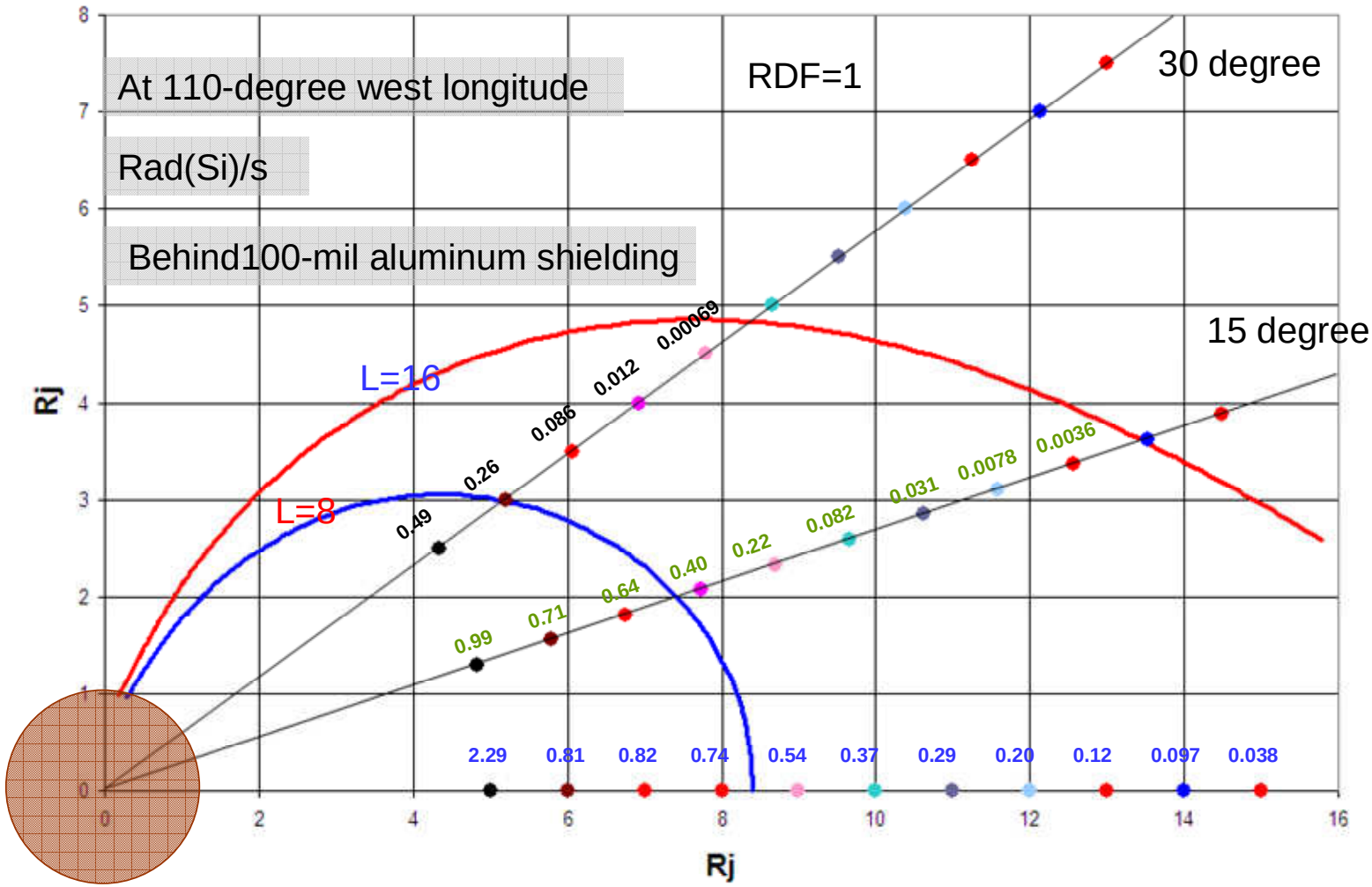


It requires ~1 MeV electrons or ~20 MeV protons to penetrate 100-mil of aluminum.

Dose-Depth Curves (Free Space)

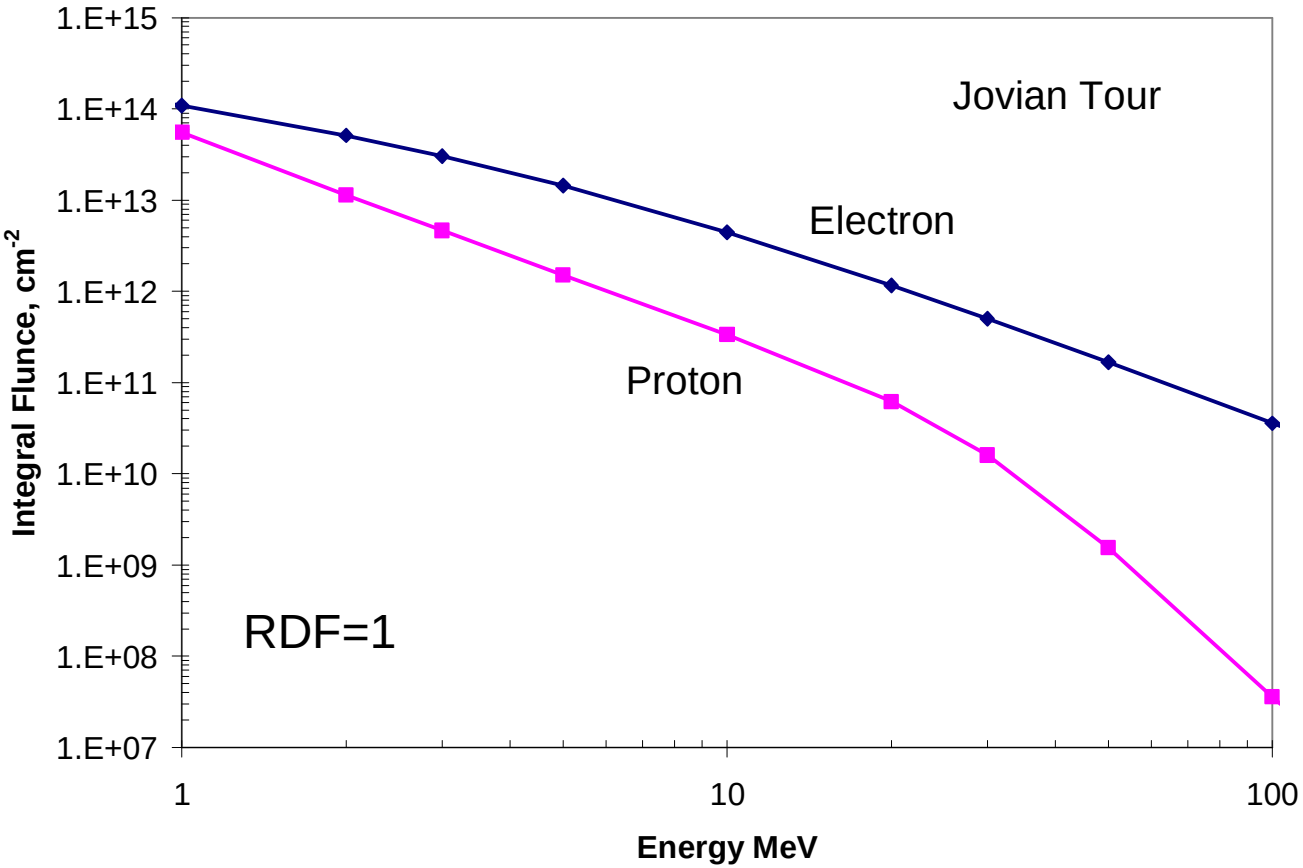


This dose-depth curve provides the dose level at the center of aluminum "spherical shell" spacecraft



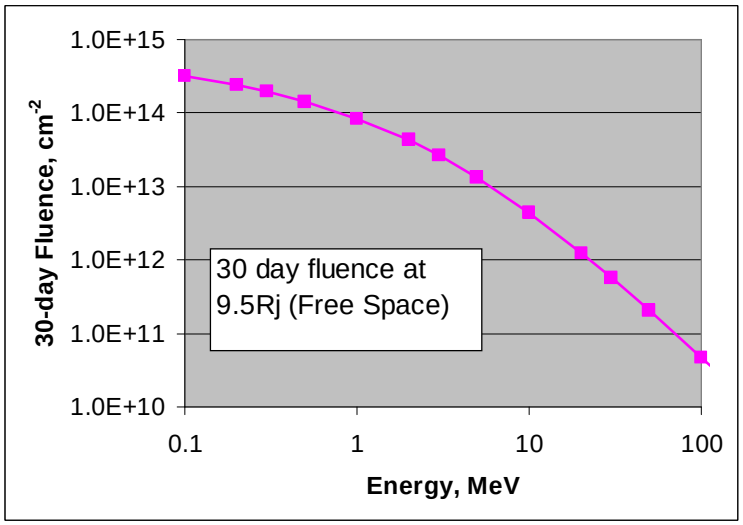
This dose "rate" map can be used as a simple tool for trajectory design, optimizing radiation environment.

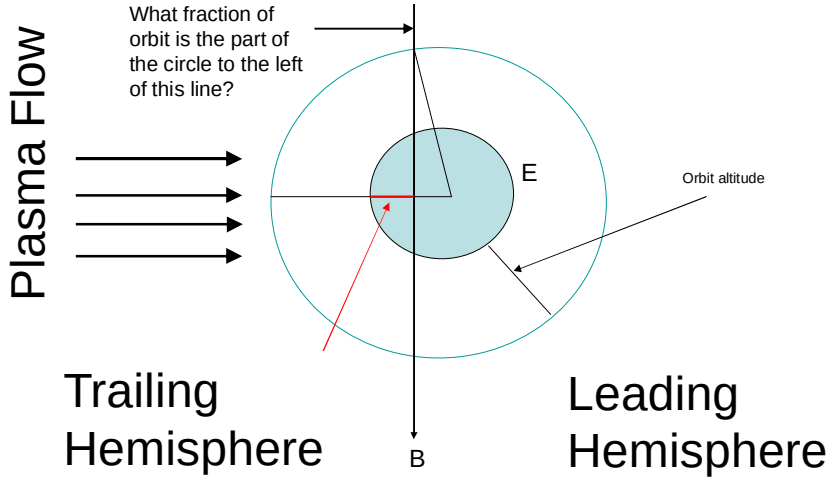
EE2007 Energy Spectra for the Jovian Tour



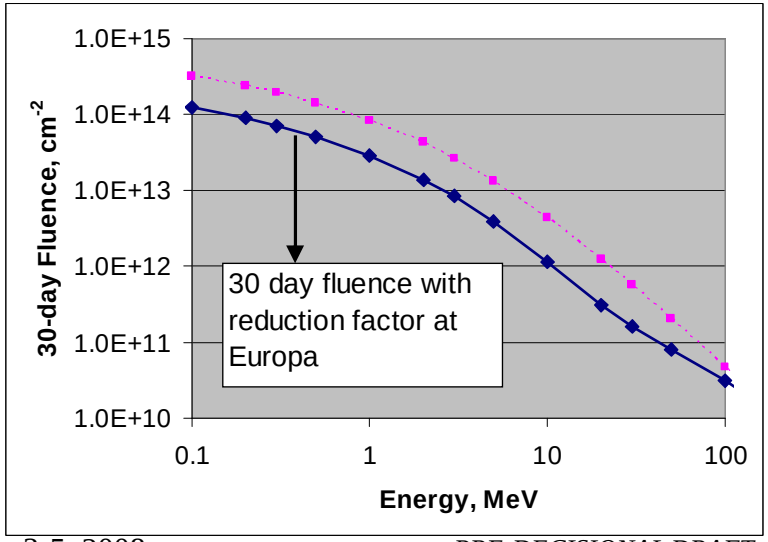
This figure shows the integral energy spectra of fluence during the jovian tour phase of the mission.

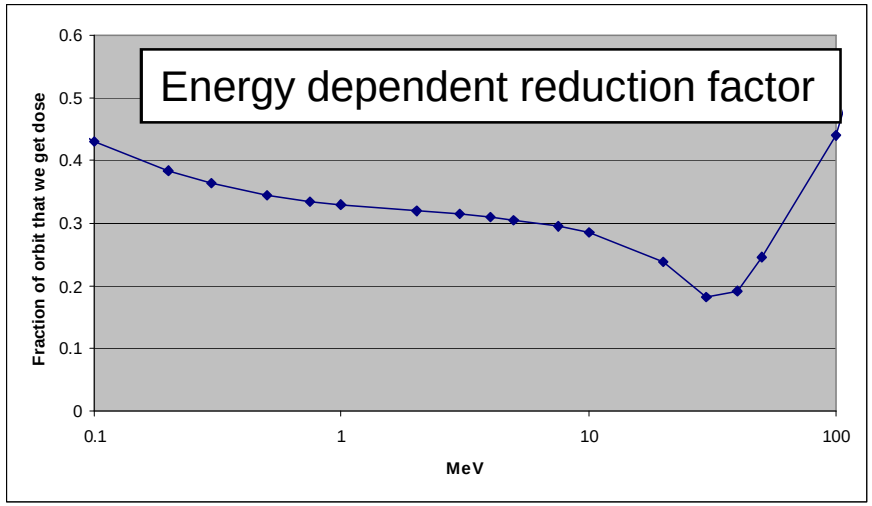
Radiation Environment at Europa with the "Computed" Reduction Factor



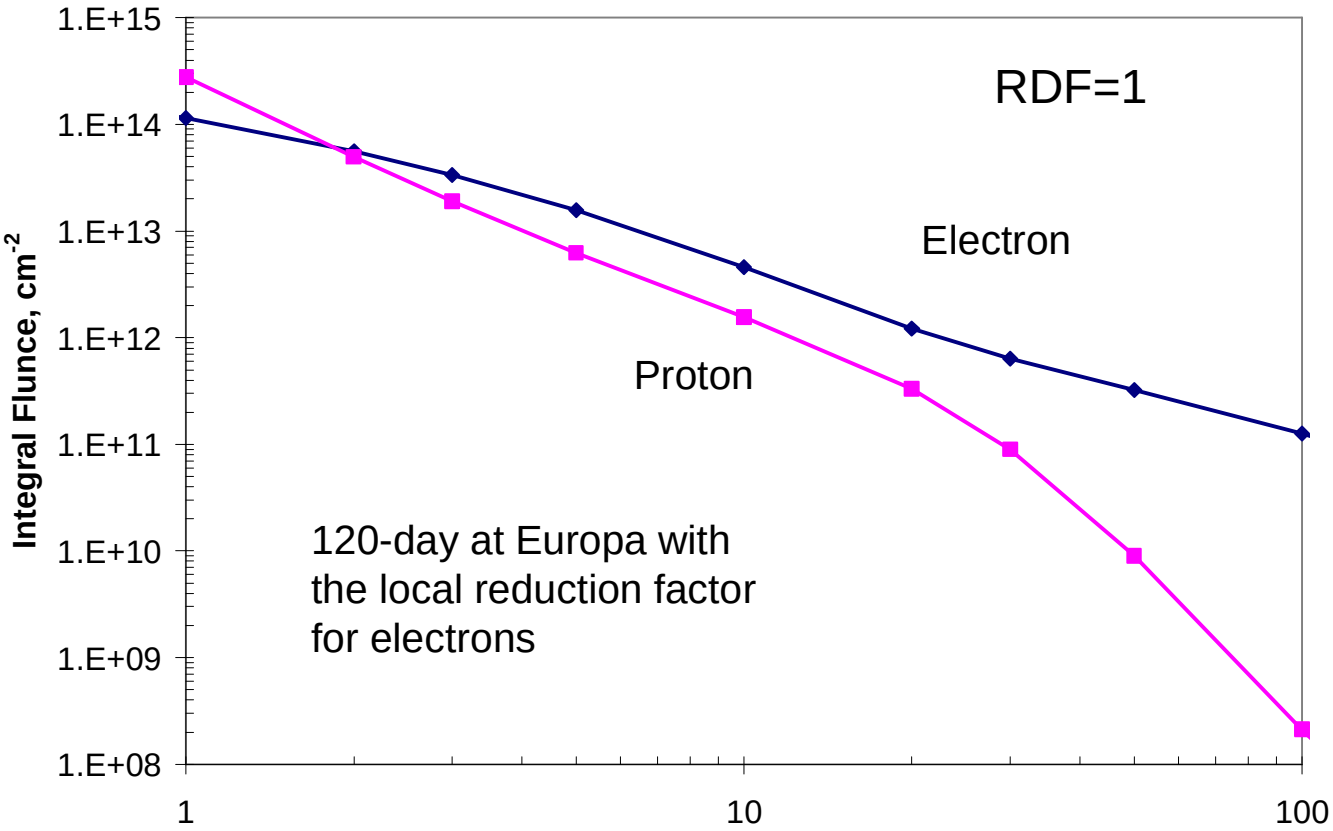


Paranicas et al., GRL (2007)



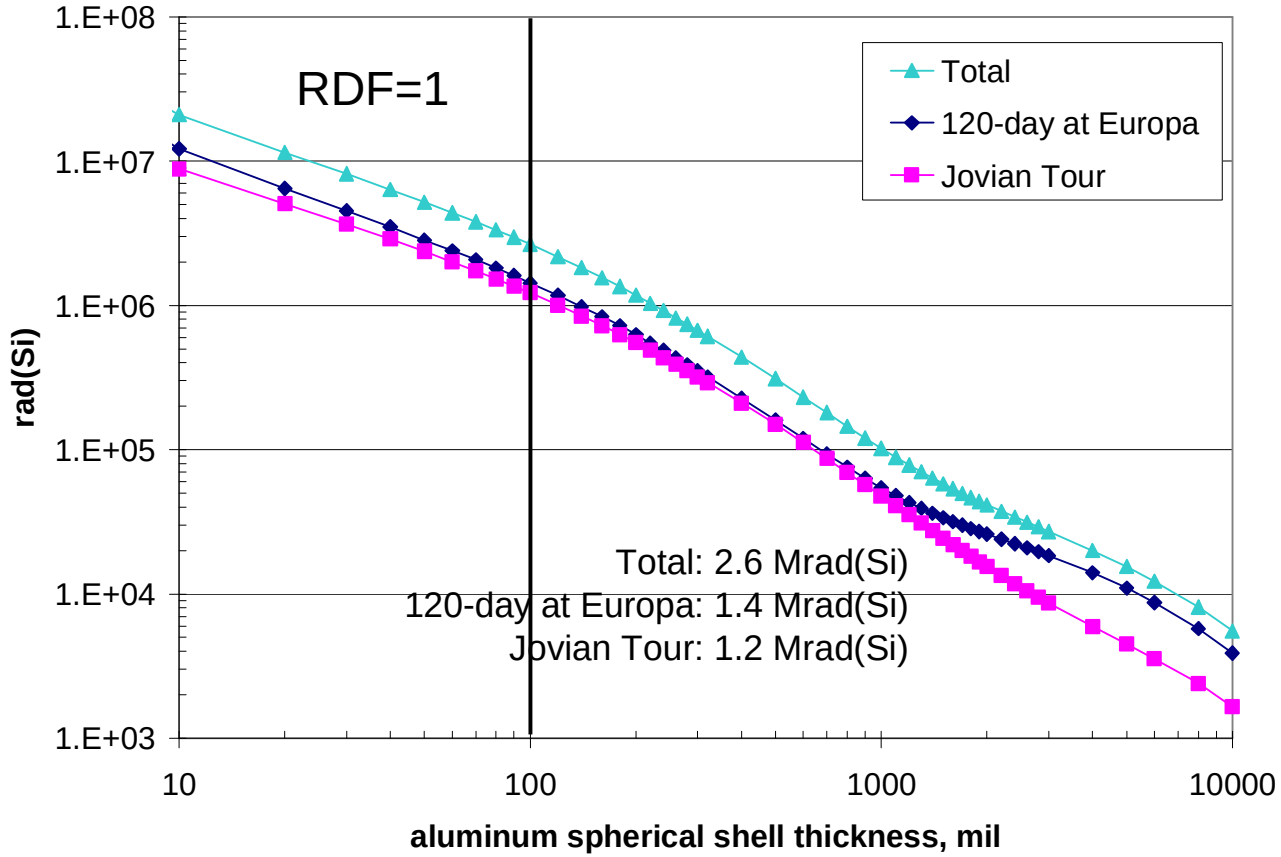


EE2007 Energy Spectra for 120-days at Europa



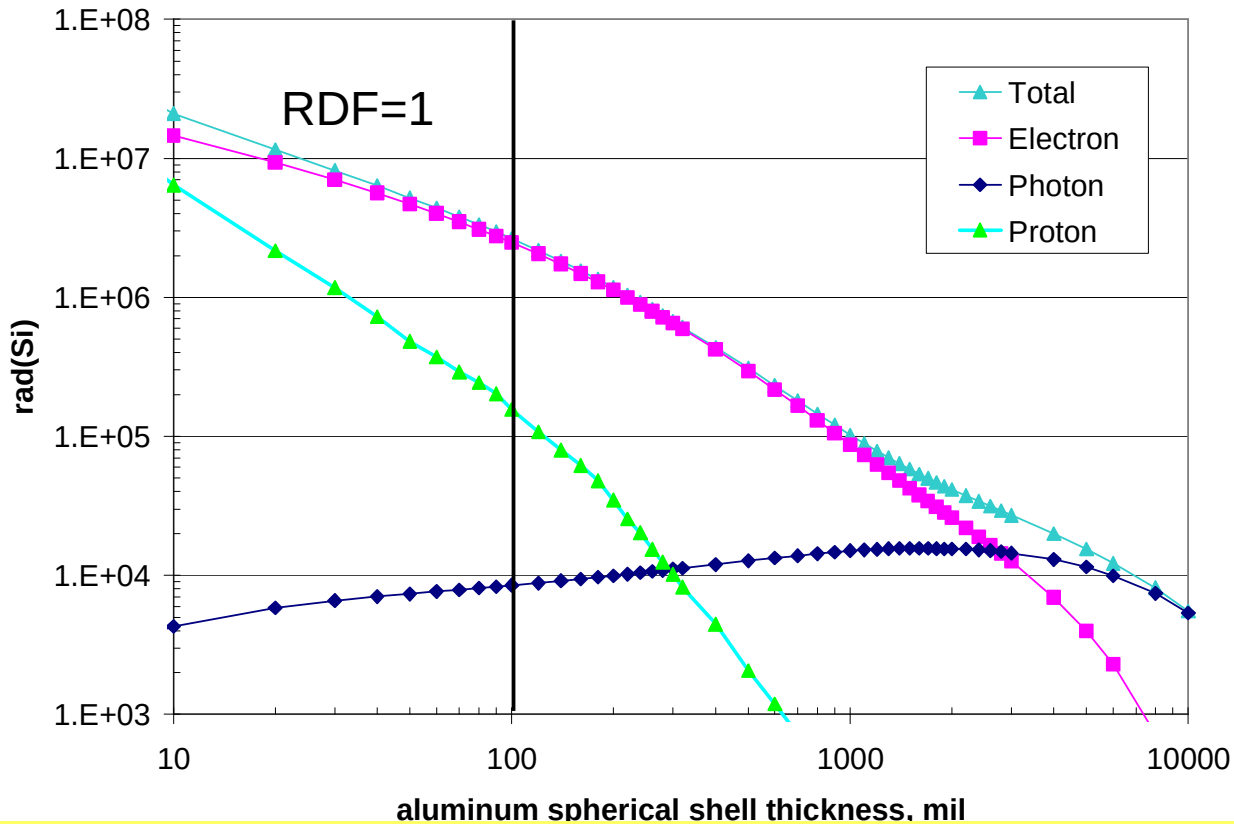
This figure shows the integral energy spectra of 120-day fluence at Europa

EE2007 Mission Dose-Depth Curve by Mission Segment



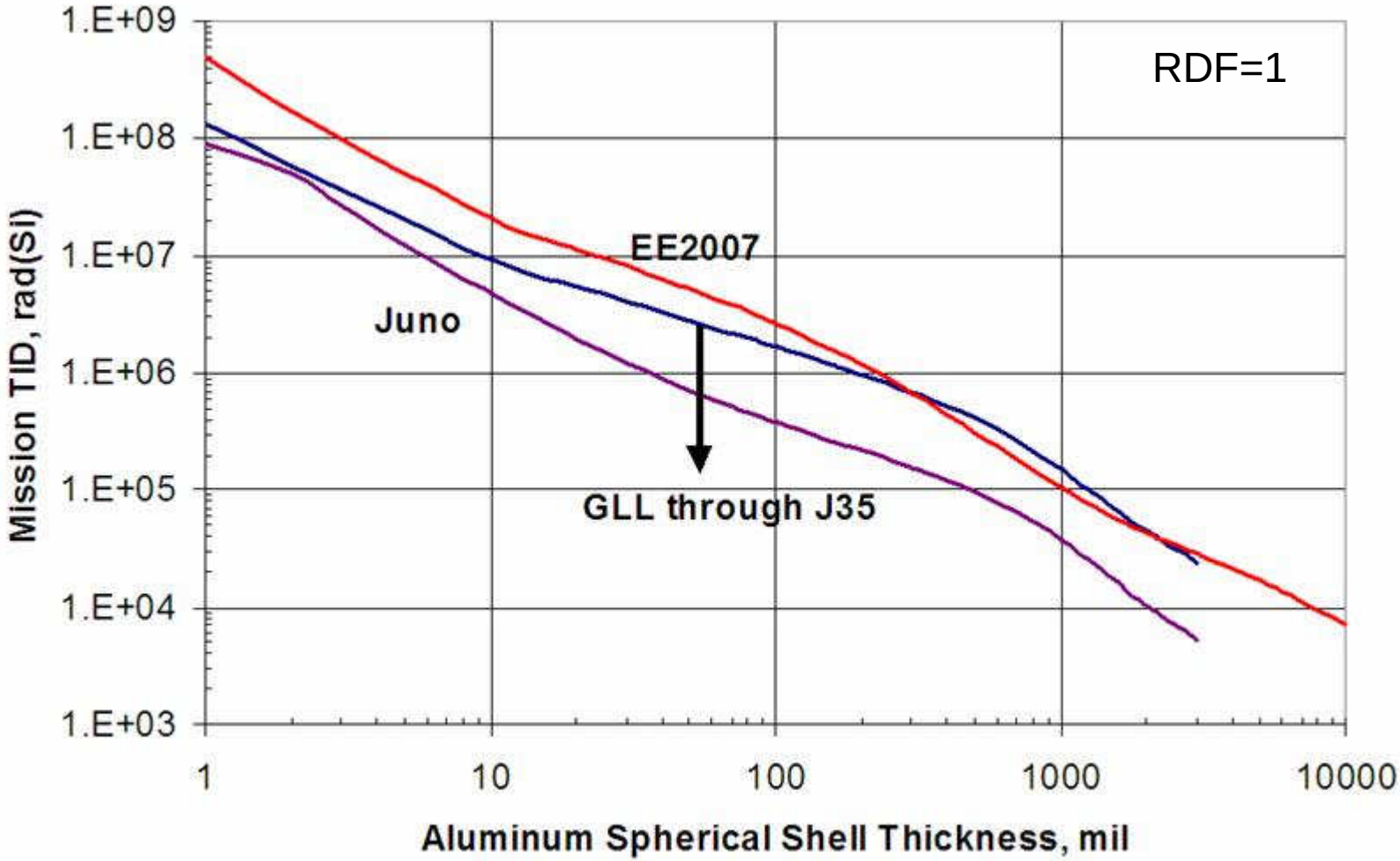
The external environments defined in the previous two charts are used to generate this spherical shell dose-depth curve, which provides the TID levels at the center of aluminum spherical shell spacecraft.

EE2007 Dose-Depth Curve by Particle Type



The same dose-depth curve, but this illustrates the contribution of different particle species to the TID. As shown, the electron contribution dominates to about 3-in of aluminum shielding, and then the bremsstrahlung contribution takes over.

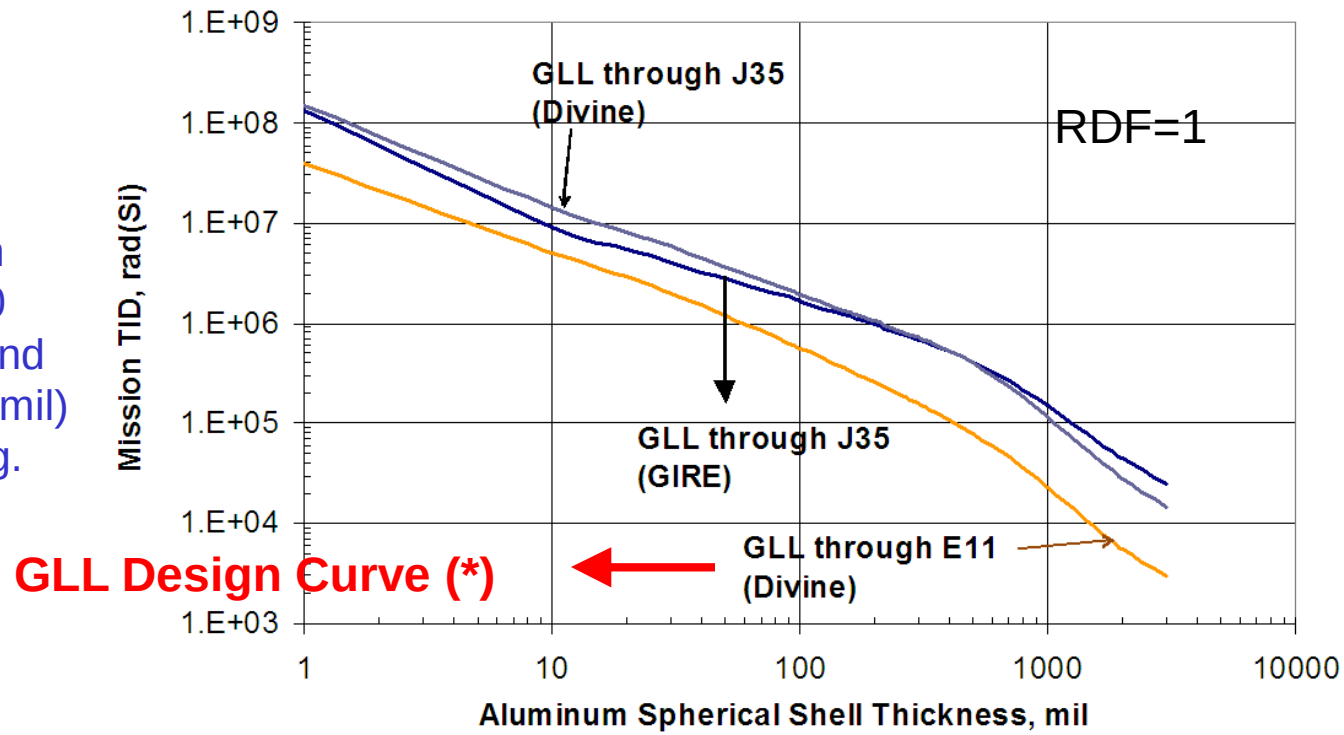
Dose-Depth Curve Comparison (1)



The EE2007 radiation environment is comparable to the GLL radiation environment.

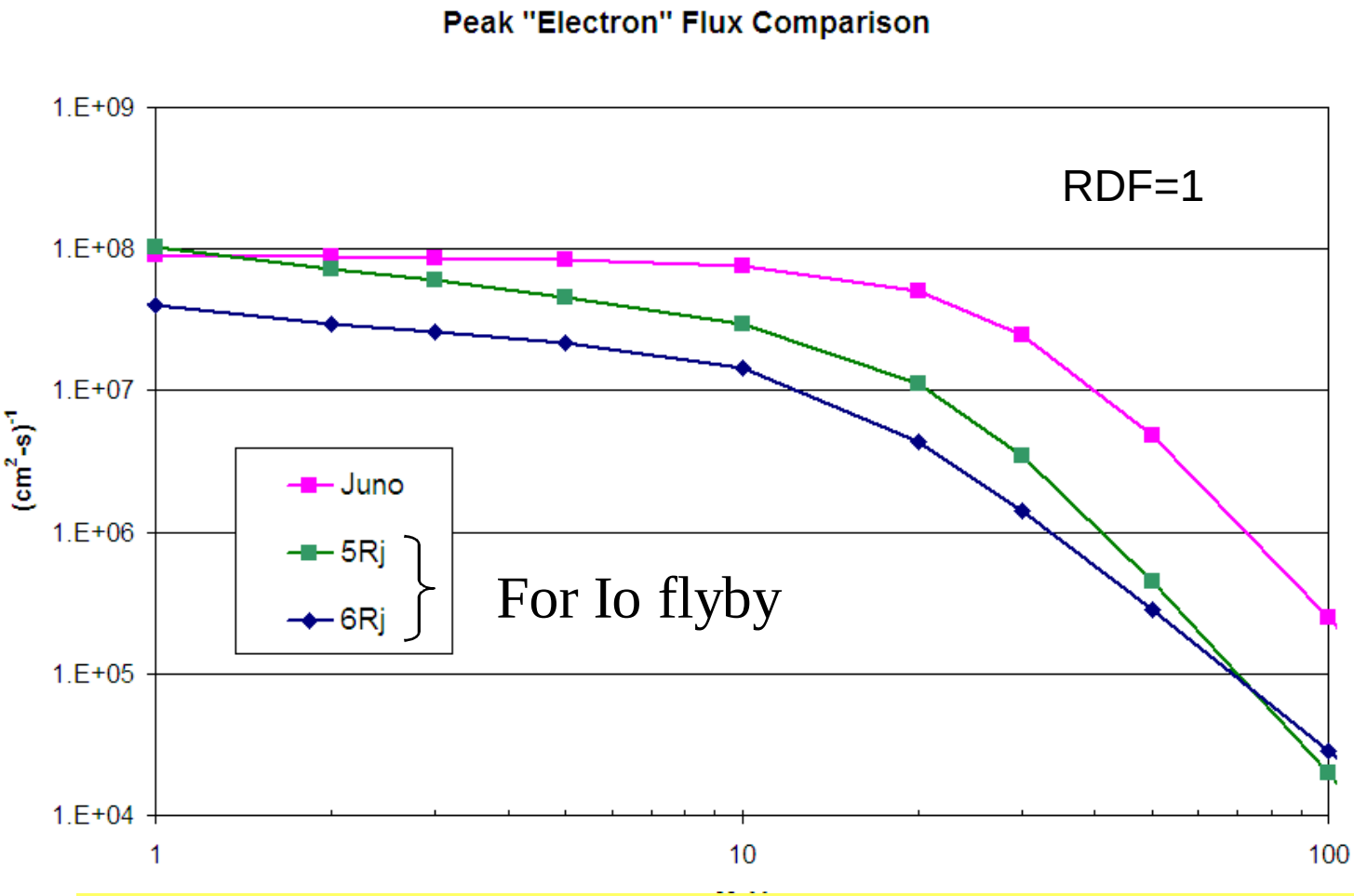
Dose-Depth Curve Comparison (2)

(*) The GLL design environment is 150 krad (RDF=1) behind 2.2 g/cm^2 (= ~320-mil) aluminum shielding.



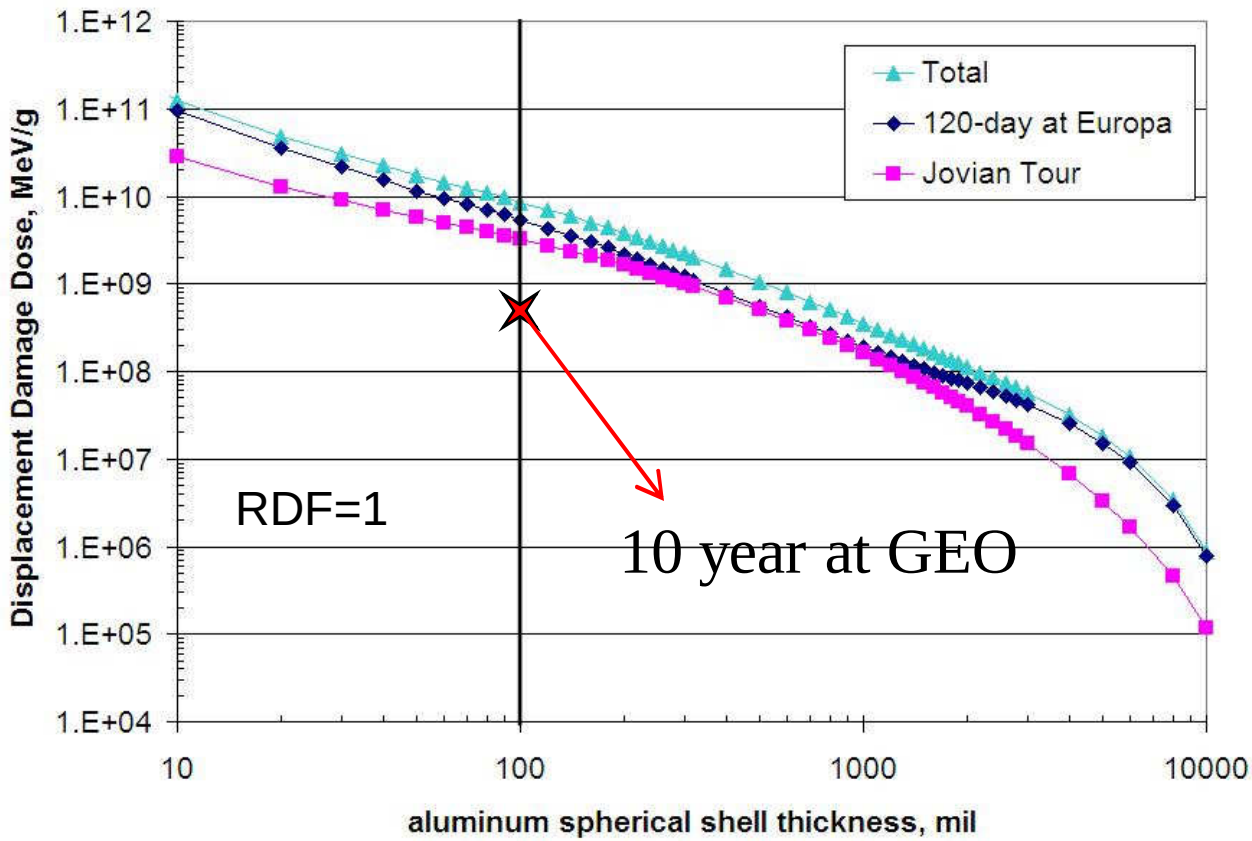
This clearly demonstrates the inherent conservatism in the GLL design. The radiation environment GLL actually experienced exceeds the design environment.

Peak Flux Comparison



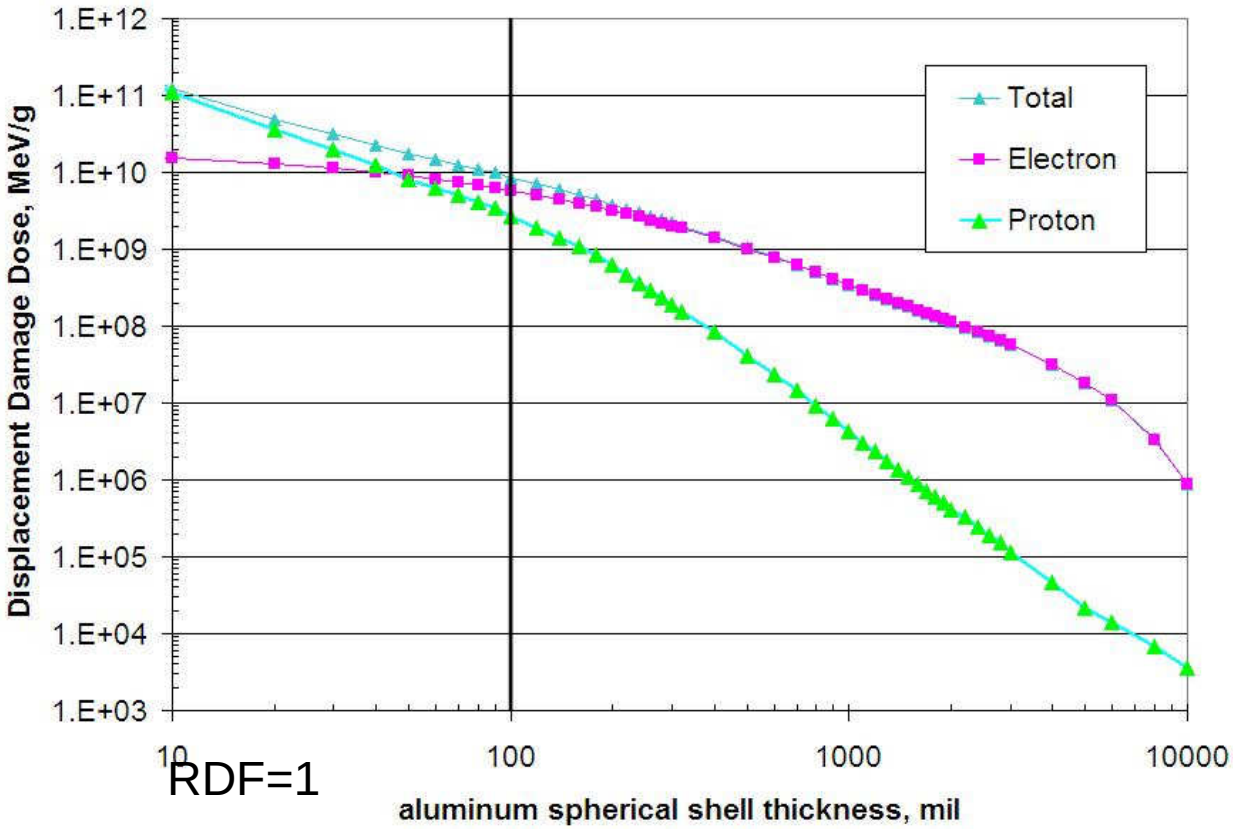
The peak flux (dose-rate) environment expected for EE is lower than the Juno peak flux environment.

EE2007 Displacement Damage Dose (1)



This is the displacement damage dose depth curve, which provides the damage dose levels at the center of aluminum spherical shell spacecraft.

EE2007 Displacement Damage Dose (2)



This shows the contribution of different particle species to the damage dose. As shown, the electron is the dominant contributor to the damage dose.

Radiation Mitigation Plan for Europa Orbiter

PRE-DECISIONAL DRAFT— For planning and discussion purposes only

Addressing the Radiation Risk

- Individual items were identified and understood.
- The phasing of tasks under the plan is driven by the following tentative milestones:
  - Mission Concept Review
  - Instrument Announcement of Opportunity (AO)
  - Preliminary Mission and System Review (PMSR)
  - Preliminary Design Review (PDR)
- Priorities are set:
  - Instrument AO and preparation material
  - System Engineering leading to PMSR
  - Engineering Design leading up to PDR
- Activities are planned to continue into FY09

#	***Radiation Task***
1	System Reliability Model
	Parts & Circuit Models & Validation
	Systems Element Models & Validation
2	Environment and Shielding Models
	Environment & Shielding Model
3	Radiation Design & Analysis Methods
	Tutorials & Guidelines - Environment, Shielding, Parts, Materials, Circuits and Subsystems
4	Sensors and Detectors
	Science detectors: assessment and testing
	Engr detectors: assessment and testing
5	Parts Evaluation & Testing
	Testing strategy including TID, ELDRs
	Juno parts testing exetension
	Part/Device testing
6	Approved Parts and Materials
	EEE Parts & Materials List

Radiation Design Challenges and Mitigation Plan for Science Instruments

- Radiation Induced Noises in Detectors/Sensors
  - Detector Working Group.
  - Simulation of radiation induced noise to better define the magnitude of issue and inform test plan.
- Electronic Parts and Materials
  - Approved Parts and Materials List (APML).
  - Extensive radiation testing (TID/DDD/SEE/Dose rates/Material/Charging).
- Shielding and Charging Mitigation Designs
  - Shielding Design Guideline and Charging Mitigation Design Guideline are planned for release later this year.
- Also, we will have an engineering Radiation Monitoring Subsystem to provide the real-time environmental conditions.
- Information will be made available to instrument community.
  - ITAR restrictions may apply to some of this information.

Today is the first of several workshops that we will have for potential instrument providers.