Technical Requirements

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JEO Pre-Project

EJSM Instrument Workshop
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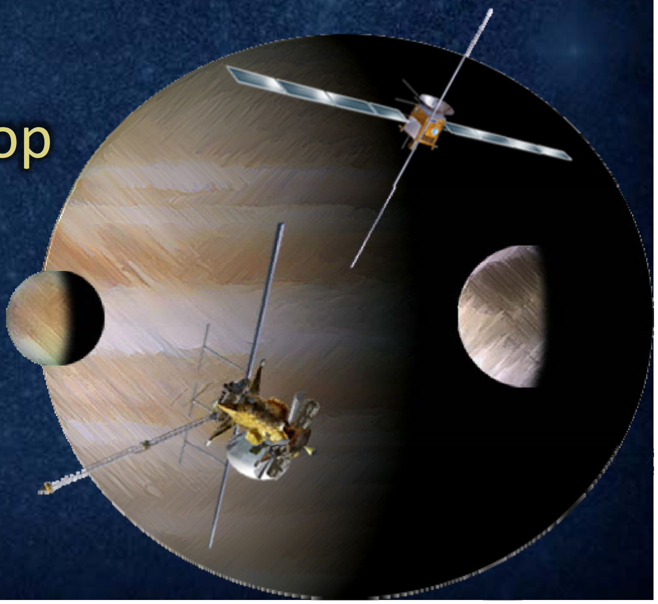
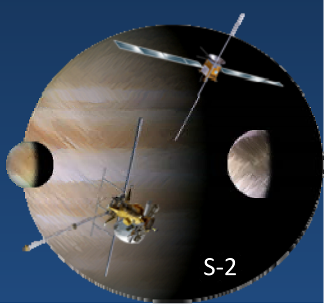


Environmental Requirements Topics

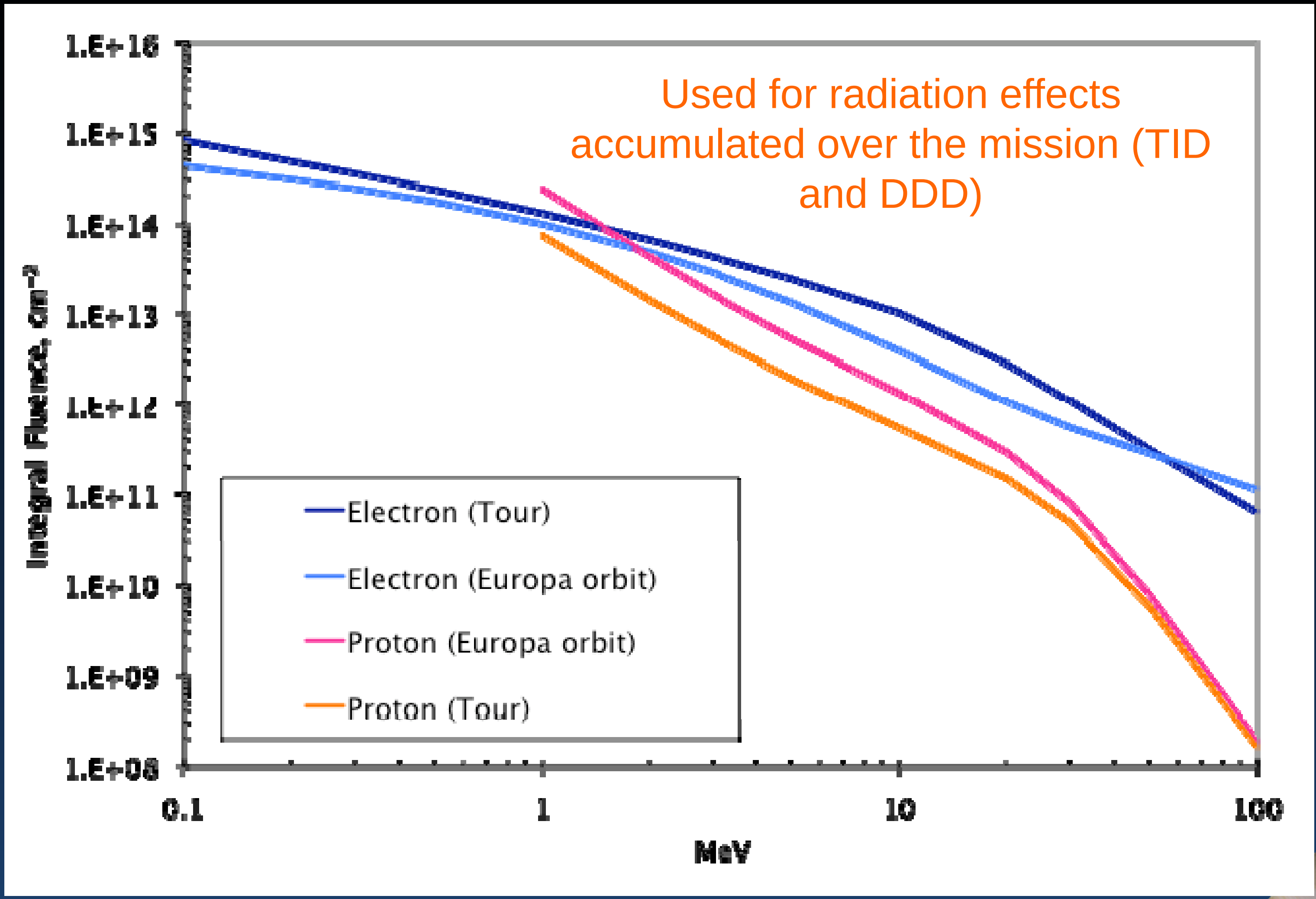
- Environmental Requirements Document
- Radiation
  - Unchanged since the 2008 study
- EMI/Magnetics/ESD
- Dynamics
- Thermal
- Other Environments Addressed in the ERD

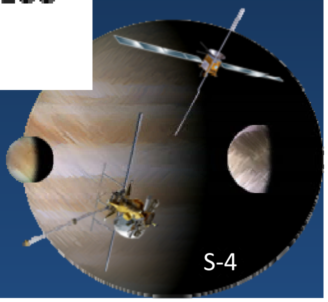


Environmental Requirements Document

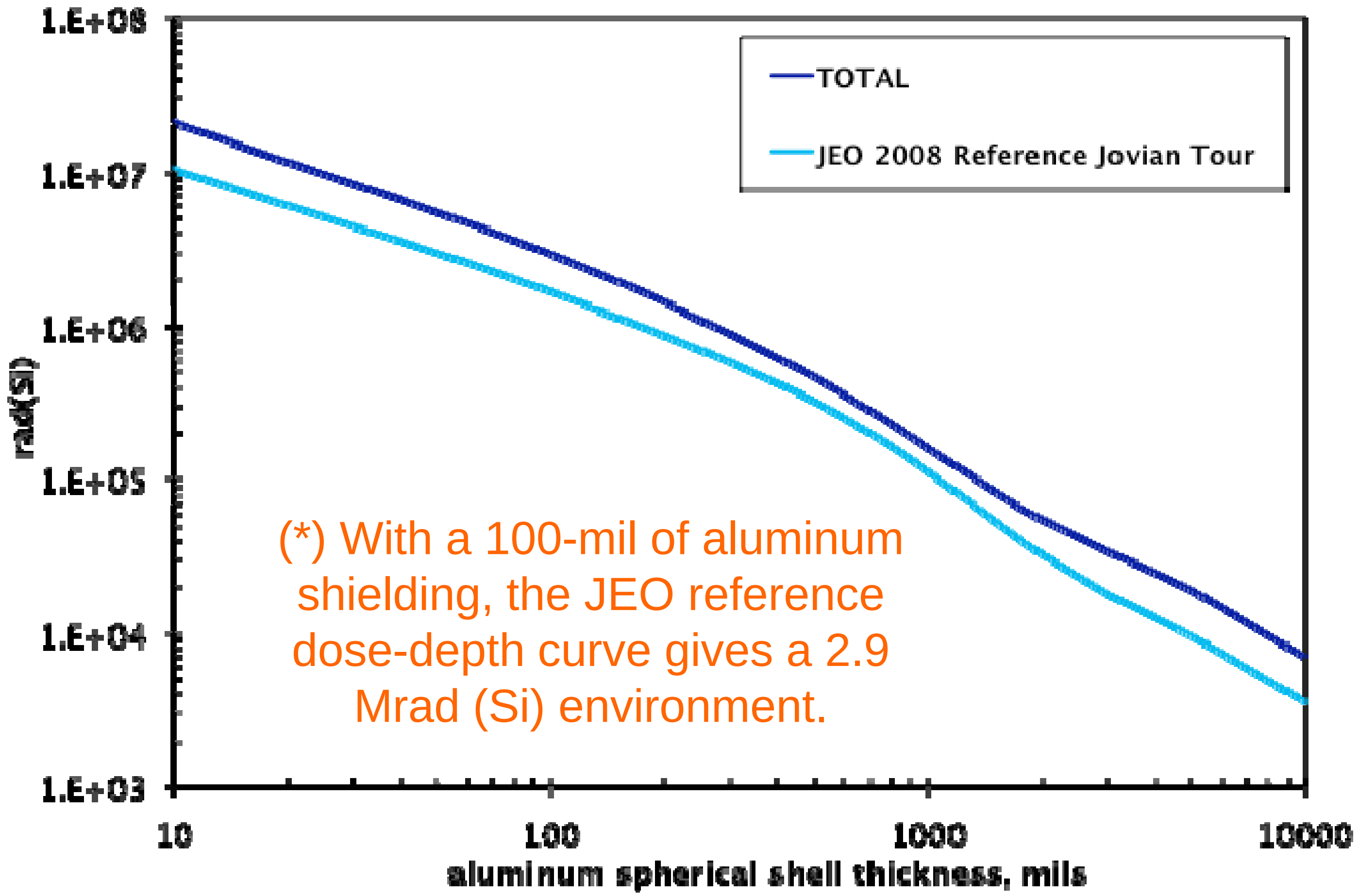
- All environmental requirements are specified in the Environmental Requirements Document (ERD)
- The ERD contains:
  - Environmental program approach
  - Environmental verification requirements
  - Environmental design requirements and verification levels
  - Environmental verification matrix (what needs to be done for each instrument/hardware)
- The ERD release schedule:
  - A preliminary version of the ERD will be available by the release of the AO
  - The ERD will be updated at major project milestones

Mission Fluence Energy Spectra



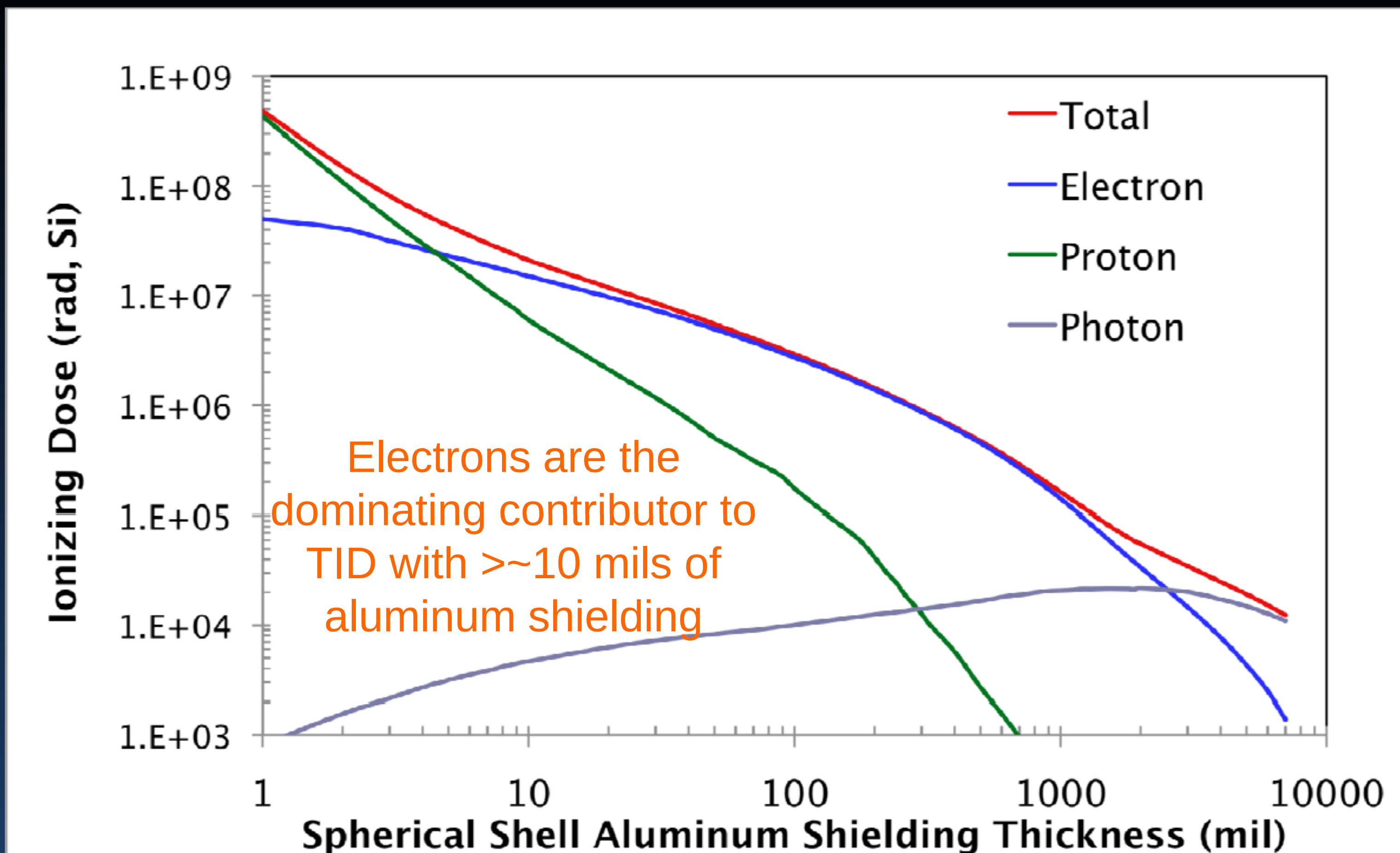


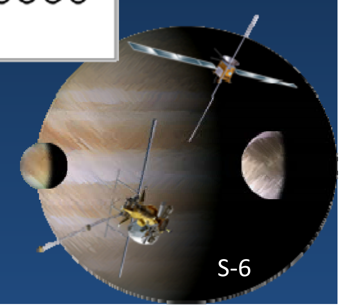
JEO Reference(*) Ionizing Dose-Depth Curve by Mission Segment



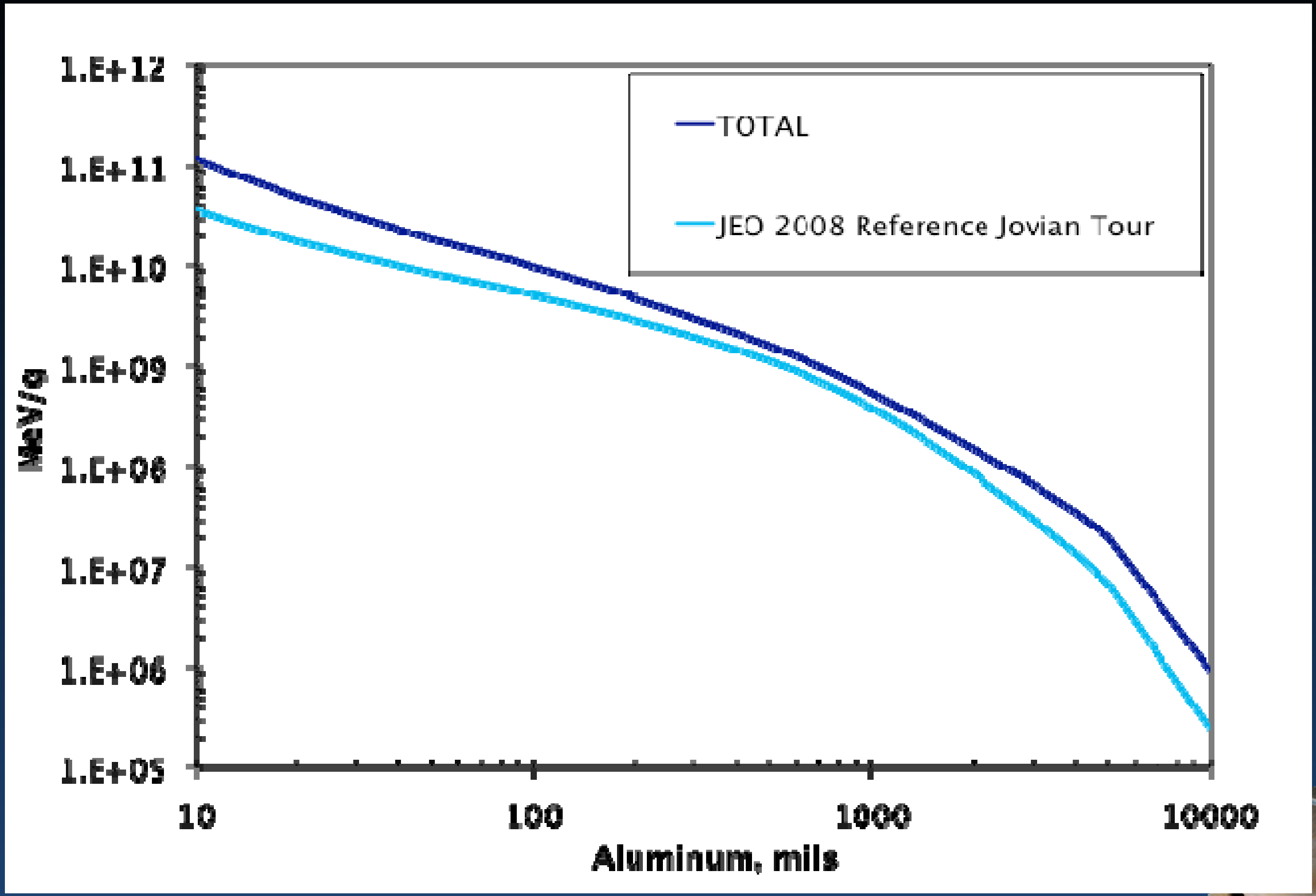
(*) With a 100-mil of aluminum shielding, the JEO reference dose-depth curve gives a 2.9 Mrad (Si) environment.

JEO Reference Ionizing Dose-Depth Curve by Particle Type

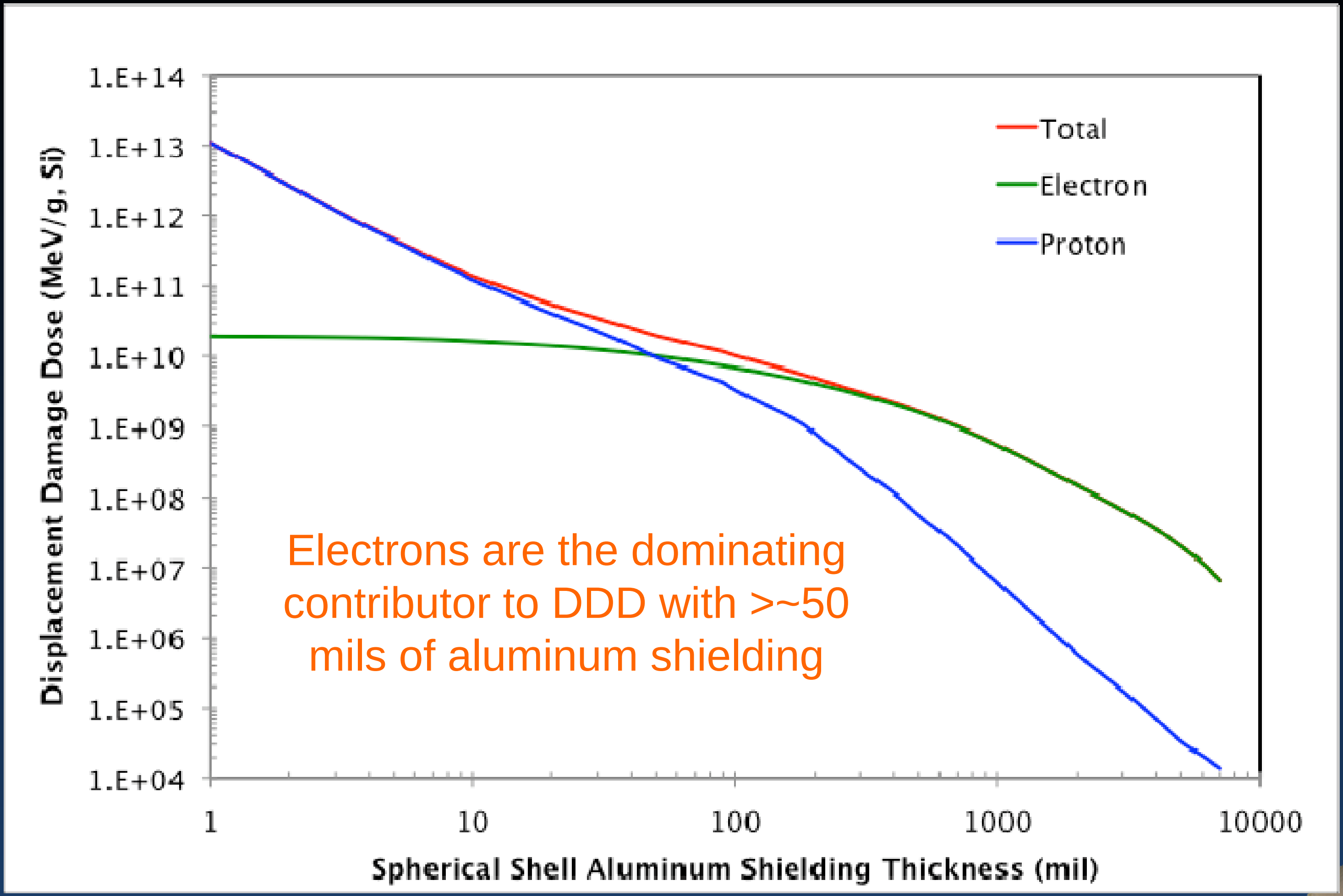


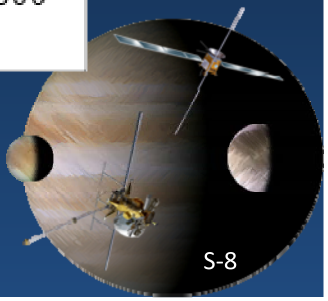


JEO Reference Displacement Damage Dose-Depth Curve by Mission Segment

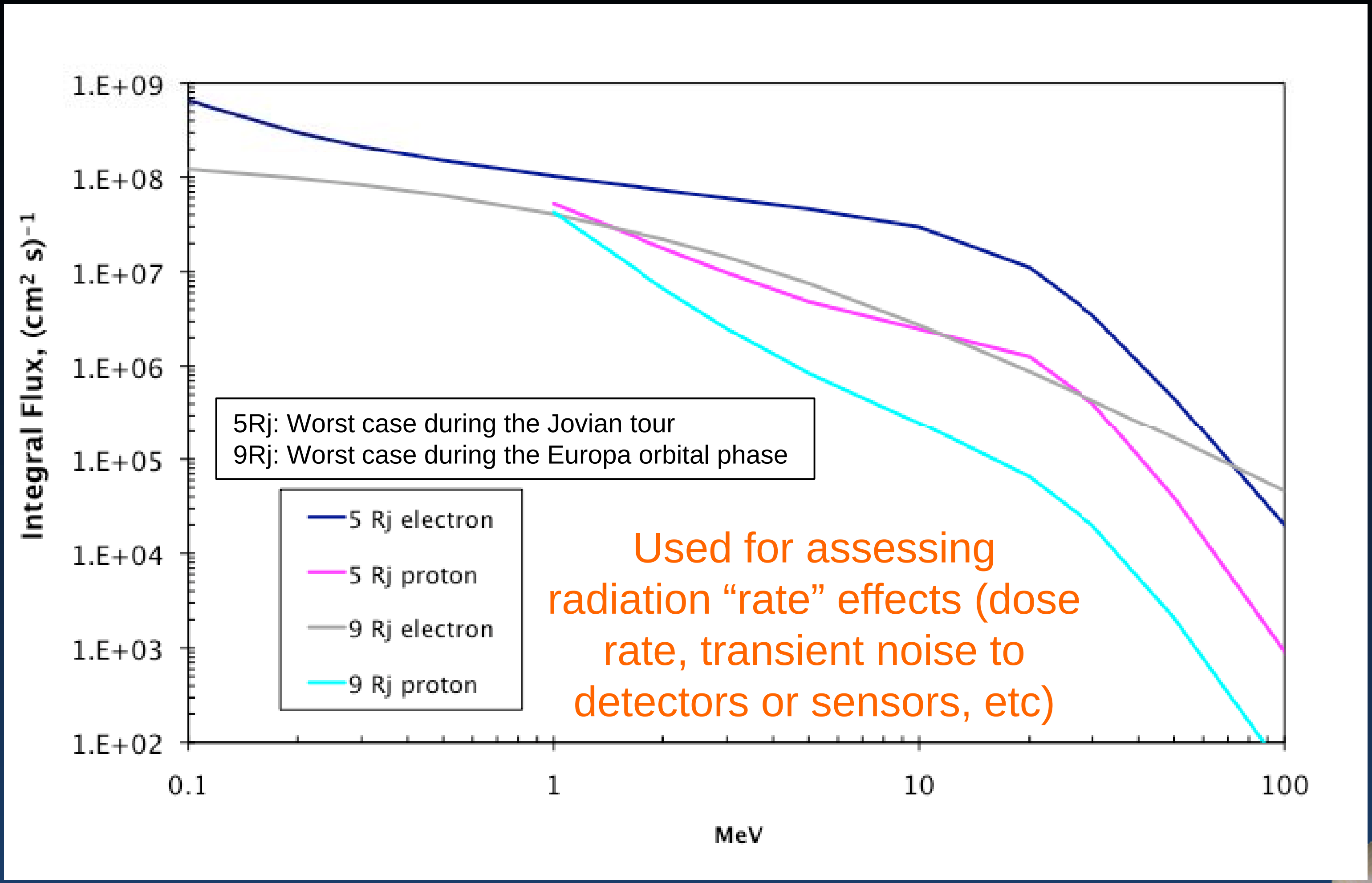


JEO Reference Displacement Damage Dose-Depth Curve by Species

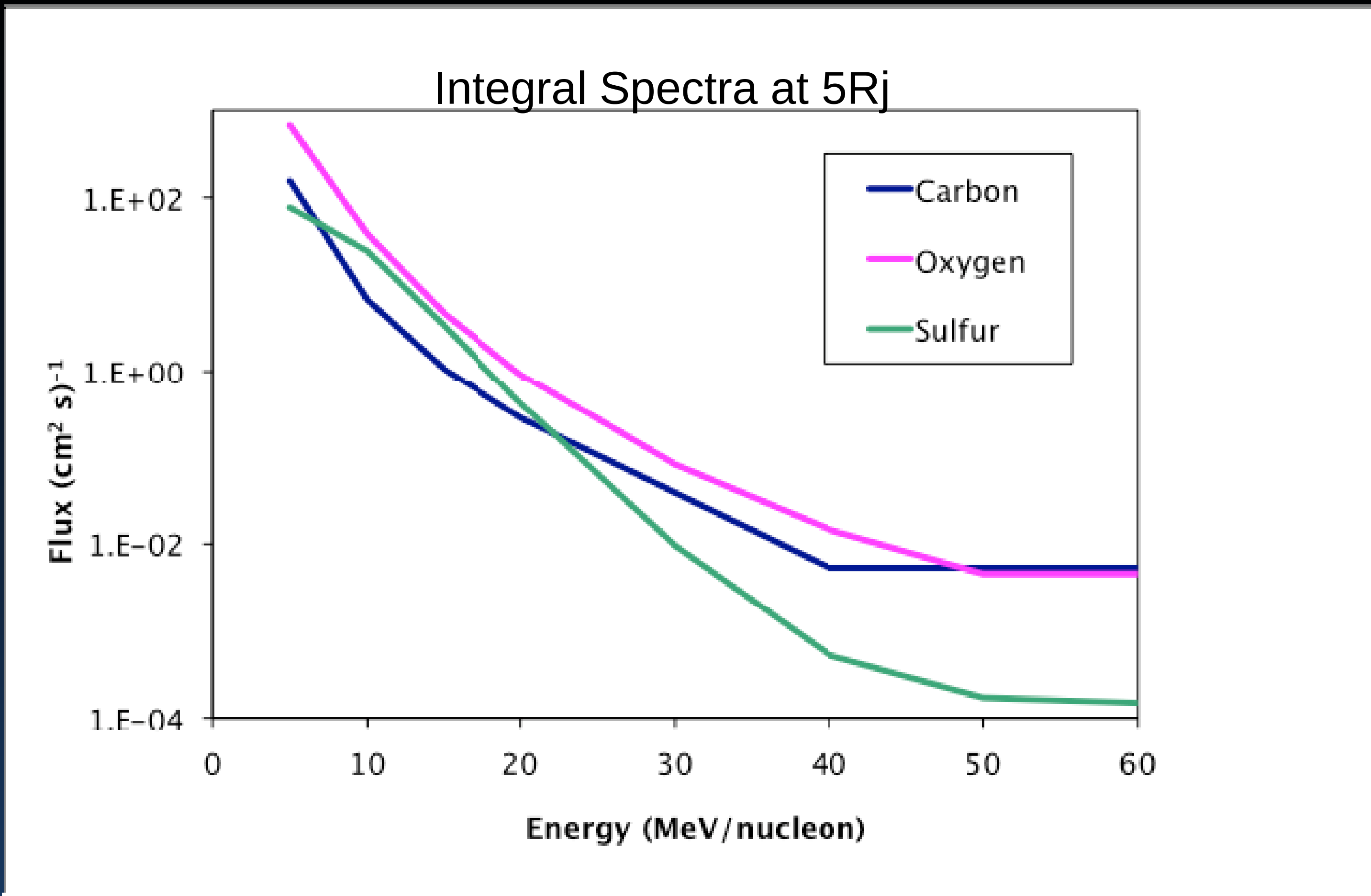




Flux Energy Spectra at 5Rj and 9Rj



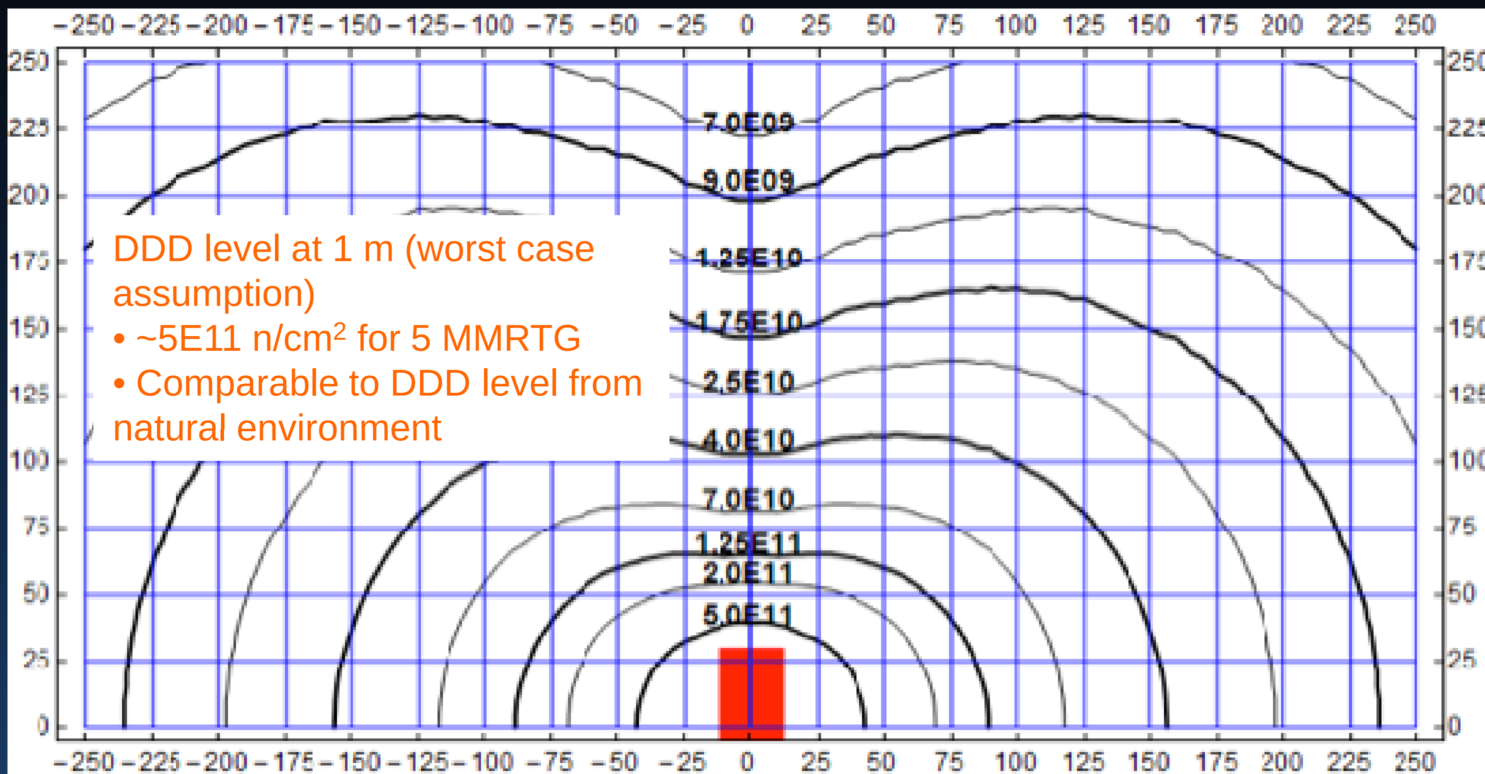
Jovian Trapped Heavy Ion Energy Spectra



The trapped heavy ions at Jupiter are not important for single event effects on shielded electronics, but they may be important for surface materials

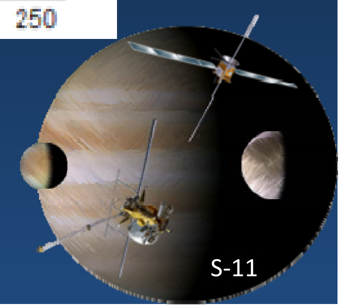
MMRTG 1 MeV Equivalent Neutron Fluence Level for 10 Years of Operation

10 Year Fluence, # of 1MeV neutron/cm²



Axial distance from the center of the MMRTG, (cm)

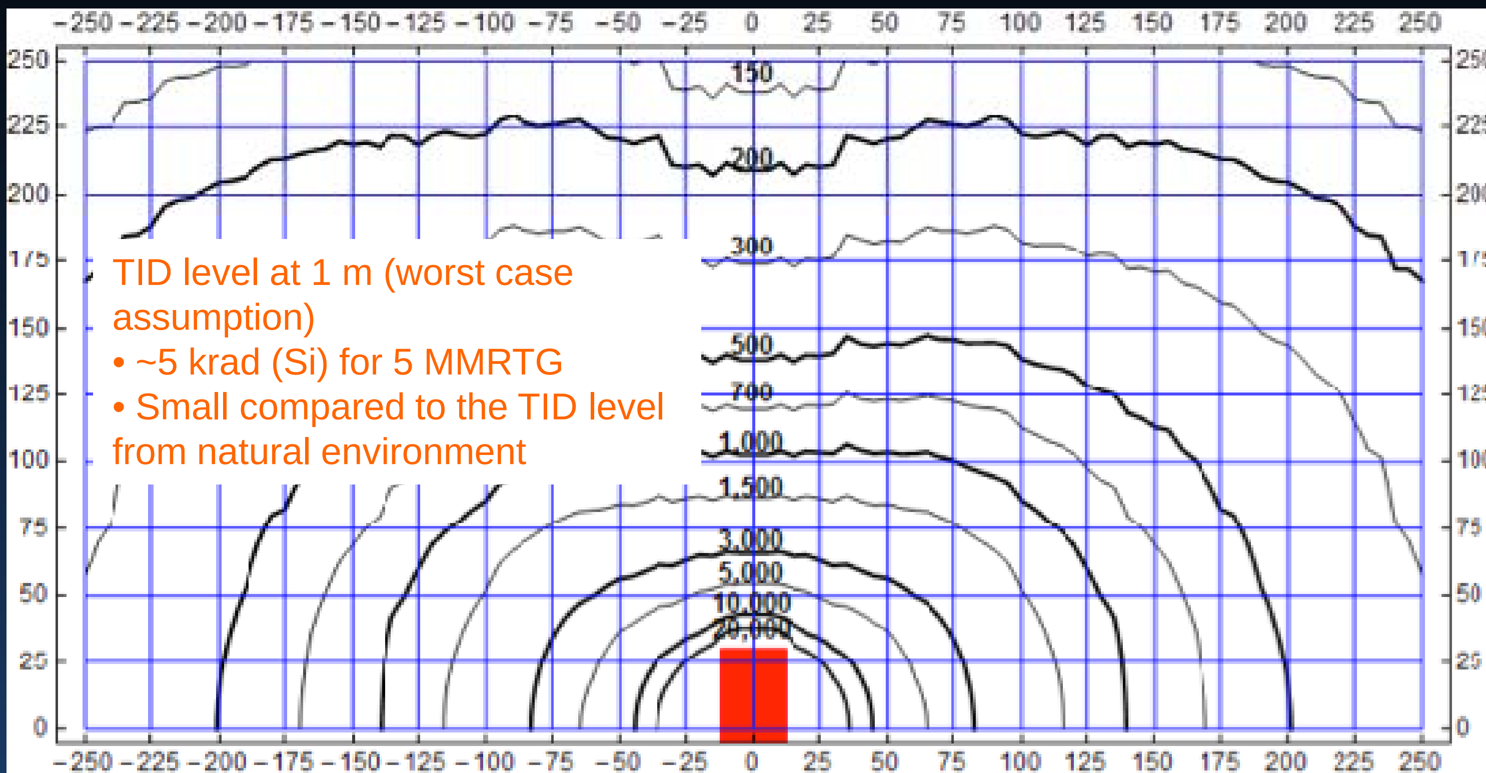
Radial distance from the center of the MMRTG, (cm)



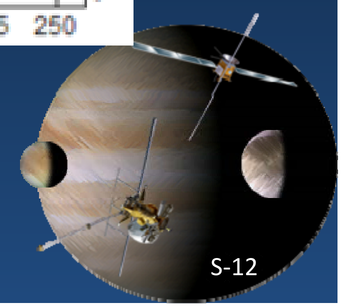
MMRTG Ionizing Dose Level for 10 Years of Operation

Rad (Si) for 10 year, Gamma Dose in Silicon

Axial distance from the center of the MMRTG, (cm)

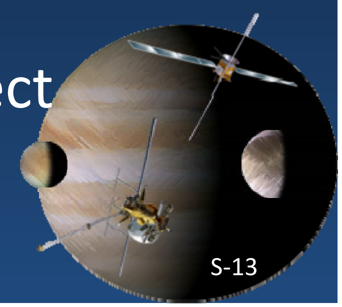


Radial distance from the center of the MMRTG. (cm)



General JEO EMC/MAG/ESD Characteristics

- JEO EMC/MAG/ESD program
  - The EMC/MAG/ESD design and test requirements are similar to previous outer planet missions (Voyager, GLL, Cassini, and Juno)
  - The program base is a tailored MIL-STD-461 with special requirements based on spacecraft, Jovian environment, and payload-based needs
    - Payload-based requirements based on present model payload
    - Plasma wave instrument not included in model payload
    - Payload changes may impact EMC/MAG requirements
  - Electrical requirements very much like Cassini
  - Payload power converters may be provided by project



EMC Key Requirements

- Spacecraft interface:
  - Users need to operate on resistive/referenced spacecraft power bus
  - Users need to be immune to full bus voltage power jumps
  - Subsystem interface isolation requirements
    - No deliberate current flow in chassis for power, signal, command, data, and telemetry
  - Power converter input requires isolation from chassis differing from past
    - Min 20 megohms, max 100 megohms from input leads to chassis
  - Subsystem Radiated Susceptibility
    - RS03 extends to ~ kHz or lower to simulate Jupiter decametric radiation fields
    - Other RS03 for general, launch, and SC telecom
- Subsystem payload accommodations:
  - Need for EMI quiet is emphasized (more stringent) than MIL-STD-461
  - If ground-penetrating radar is selected, will add lower frequency higher amplitude Radiated Susceptibility (RS03) levels and more stringent RE02 limits

MAG Key Requirements

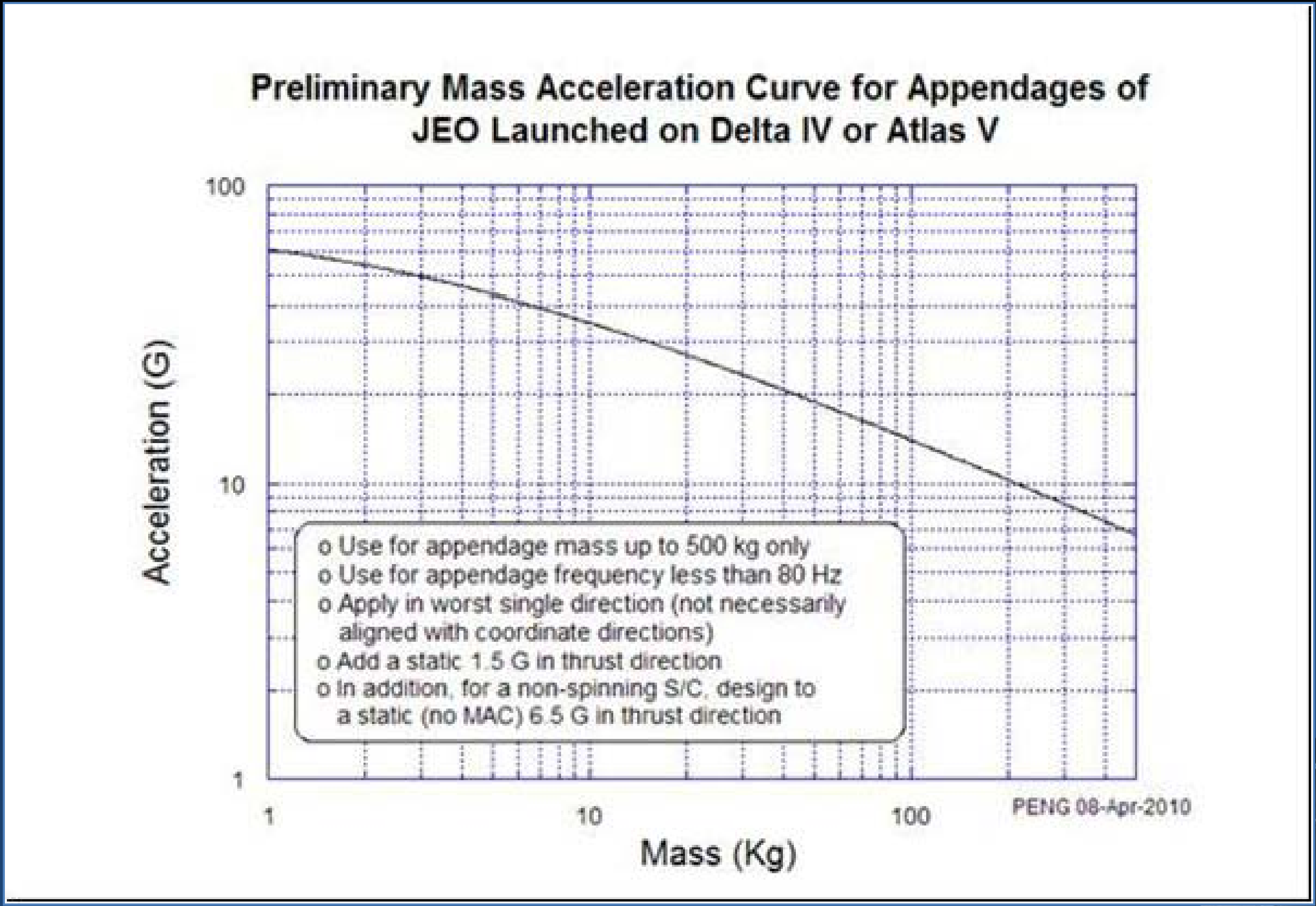
- Magnetic field at 5 Rj is 0.09 gauss vs. 0.3 at Earth (not significant)
- Significant magnetic fields used for degaussing (like prior SC)
  - 50 gauss is standard and has been used without incident in the past
- Required magnetic cleanliness
  - 0.1 nT stability at 10 m sensor,
  - < 2 nT total field from spacecraft for frequencies < 64 Hz
  - Spacecraft moment < 3 A-m2
  - Non-operating moment limits (low magnetic fields from hardware)
  - Operating moment limits (low magnetic fields due to current flows)
- Design and test requirements will be established by a project magnetic control plan that will be created once the payloads are selected

ESD Key Requirements

- JEO will fly through high energy plasma region
  - Charging of spacecraft surfaces and internal regions must be controlled
  - This is a new environment compared to typical missions; it is normal for Jupiter and certain Earth orbits, although Earth is less severe than Jupiter
- Key Requirement:
  - All exterior surfaces shall be conductive and grounded
  - All conductive materials, both external and internal, shall be grounded or ground-referenced
  - All electronics shall be designed against internal charging threat
  - All cabling external shall be designed against internal charging threat
  - All interface circuitry attached to cabling from non-protected regions shall meet certain ESD noise immunity requirements
- ESD design implementation requires coordination from the Project ESD organization
- Test verification is not possible at the subsystem level and also not at the system level - Design verification by analysis is required of all subsystems
- References for implementation: NASA TP-2361 (surface charging guidance) and NASA-HDBK -4002 (internal charging guidance)

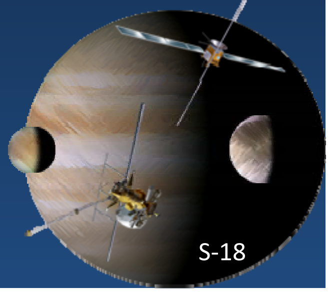
Mass Acceleration Curve (MAC)

For most conservative and earliest available structural design loads



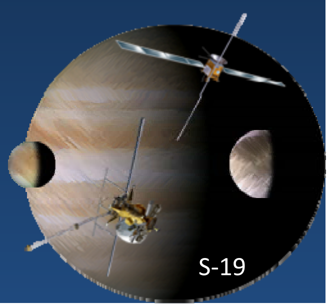
Thermal Margins Requirement

- Electronics hardware
  - Operating cold: (AFT cold - 15°C) or -35°C (whichever is colder)
  - Operating hot: (AFT hot + 20°C) or +70°C (whichever is warmer)
- Other hardware (mechanisms, sensors, detectors structure-like assemblies, and other unique flight hardware)
  - Operating cold: (AFT cold - 15°C)
  - Operating hot: (AFT hot + 20°C)
- Allowable Flight Temperatures (AFTs) are determined by the Project Thermal Control Engineer and the instrument/hardware provider
- Planetary protection implementation will put additional thermal requirements on the hardware



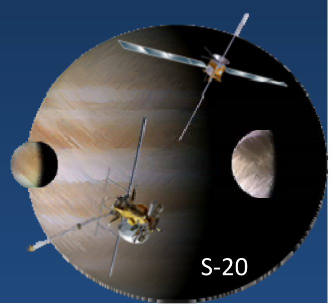
Other Environments Addressed in the ERD

- Acoustics – levels defined for an envelope of both Delta IV & Atlas V candidate launch vehicles at the PAF interface
- Random Vibration: TBD in ERD
  - Expect to be significantly higher than the Minimum Workmanship Random Vibration Level (6.8 grms)
- Pyroshock: TBD in ERD
  - Shock levels dependent upon shock source, and distance and type/number of structural joints from the hardware
- Microphonics: TBD in ERD
  - Heavily dependent on placement and type of components (e.g., ASRG vs. MMRTG)
- Plumes from Io flyby: TBD in ERD
  - Probably not a driver for JEO



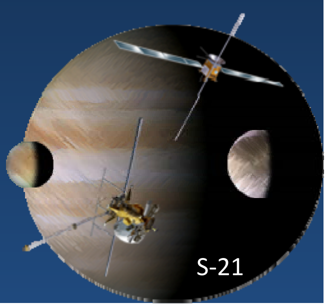
Other Environments Addressed in the ERD

- Plasma: TBD in ERD
  - Important charging effect. Will be mitigated with proper design implementation
- Meteoroid: TBD in ERD
  - Important for externally-mounted instruments and hardware
- Atomic Oxygen: TBD in ERD
  - Probably not a driver for JEO
- Solar electromagnetic Irradiance: ERD has a solar electromagnetic Irradiance Spectrum
- Once the final payload is selected, there may be additional requirements in the ERD



Planetary Protection Topics

- Mission Level Planetary Protection Recap/Modifications
- Instrument Specific Requirements and Constraints
- Planetary Protection Technologies
- Planetary Protection Implementation Approaches and Guidelines
- Ongoing/Future Trade Studies



Planetary Protection Recap

- Preliminary planetary protection categorization for JEO is category III
  - Formal planetary protection requirements have not been set for the baseline JEO mission
- Relevant NASA Planetary Protection documents
  - NPD 8020.7G, Biological Contamination Control for Outbound and Inbound Planetary Spacecraft
  - NPR 8020.12C, Planetary Protection Provisions for Robotic Extraterrestrial Missions
  - NHB 5340.1B, NASA Standard Procedures for the Microbial Examination of Space Hardware (To be superseded by NASA-HDBK-6022 Handbook for the Microbial Examination of Space Hardware)
- Categorizations are determined on a mission-by-mission basis:
  - Most current scientific information
  - Advice from the Planetary Protection Subcommittee of the NASA Advisory Council
  - Recommendations made by the Space Studies Board of the National Research Council

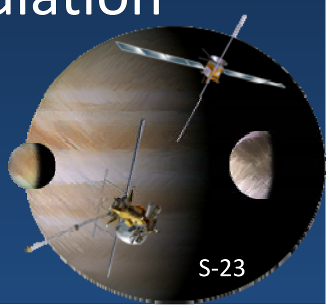
Planetary Protection Recap

- In the baseline approach, JEO proposes to meet the planetary protection requirement by sterilizing some hardware by either performing Dry Heat Microbial Reduction (DHMR) or another approved technique before launch and allowing the Jovian radiation environment to sterilize other hardware

Key paradigm: Penetrating sterilizing process must be used

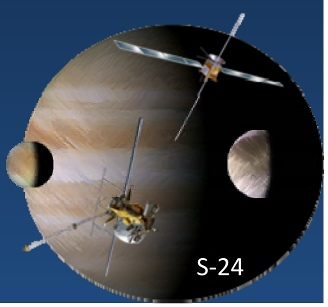
- High level guidelines:
  - Hardware sees more than 7Mrad: sterilized en route
  - Hardware sees less than 7Mrad: must be dry heat processed (T>110°C) or otherwise sterilized before launch

- Recontamination may be managed through surface sterilization technologies, including chemical sterilants and UV irradiation



Planetary Protection Recap

- Introduce into hardware design early
  - Confer with planetary protection leads
  - Incorporate an *approach* to planetary protection compliance into design
  - Preferred sterilization technologies:
    - *Penetrating*: DHMR, Irradiation
    - *Surface only*: Vapor Hydrogen Peroxide, others
  - Implementation methods and required activities may impact other assemblies and subsystems



Considerations for Planetary Protection

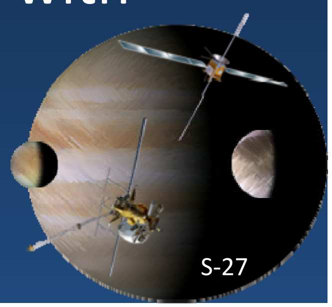
- In planning for sterilization processing of instruments, providers need to determine:
  - Which components/assemblies of the instrument are expected to be sterilized by the Jovian environment and which will require pre-launch sterilization processing
  - The sterilization process method and facility location options for components/ assemblies
  - Details for an instrument-level planetary protection plan
  - How initial estimates of spore bioburden on free surfaces, mated surfaces, and encapsulated volumes can be made according to standard methods
  - Options for protection against pre-launch recontamination
  - How compliance (surface bioburden) assays will be accommodated according to standard accepted practice
  - Estimating cost for all these activities

PP technologies descriptions - DHMR

- Baseline Pre-launch Sterilization Process
  - NASA Standard: 1 decimal reduction of bioburden at 125˚C takes 5hrs for embedded bioburden.
  - Expose at 110-125˚C for 35-50hrs (JPL typical flight hardware practice)
  - Performed under controlled humidity (partial vacuum or dry nitrogen)
  - Often combined with contamination control bake-out for schedule and cost reasons.
  - APML parts likely already qualified to more rigorous time/temperature regime
  - Qualification and acceptance processing parameters may be more stringent e.g. based on a revision of the Viking process, allowing for margin and rework
  - Exact JEO processes still to be defined in discussion with the project team

PP technologies descriptions - VHP

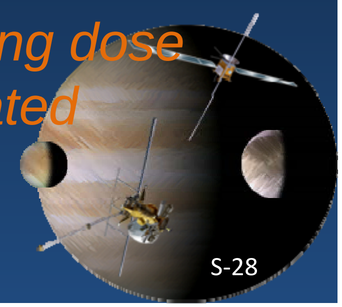
- Vapor Hydrogen Peroxide Processing – May be needed for recontamination management
  - NASA Standard (proposed): 1 decimal reduction of bioburden at Ct (Concentration x time) 100(mg/L)secs for surface bioburden
  - Expose at ~35˚C for 800(mg/L)secs (JPL planned practice)
  - Can be performed under ambient or partial vacuum conditions
  - Can be scaled to be performed in a small chamber or a large room
  - Qualification and acceptance processing parameters may be more stringent, allowing for margin and rework
  - Exact JEO processes still to be defined in discussion with the project team



JEO radiation environment

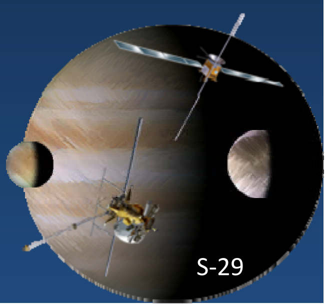
- Worst case (<u>3-sigma LOW</u>) radiation dose used for bioburden reduction estimates
  - Configuration dependent, based on Jovian radiation environment and tour models
- Planetary protection design point is EOI, with <u>mean</u> radiation dose for the 2008 reference tour estimated at:
  - ~ 1.65Mrad$_{SI}$/100mils aluminum
  - ~ 7Mrad$_{SI}$/18mils aluminum
  - ~136Mrad$_{SI}$/1mil aluminum
- 7Mrad needed to meet requirement for sterility

Elements “outside” the spacecraft will probably receive a sterilizing dose
Electronics cannot see a sterilizing dose, so must be DHMR treated



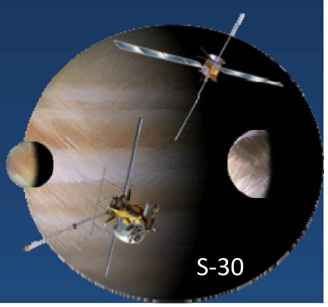
Considerations for Instruments

- JEO planetary protection lead will manage bioburden for the whole system, including each instrument, based on the bioburden nomenclature of the NRC Preventing the Forward Contamination of Europa (2000) report
- Aim for tolerance of DHMR process (e.g. heat at 110-125°C)
- Use Class S/MIL specification parts (from APML)
- Allow margin – for gradients and for repeat (rework/hierarchical) processing



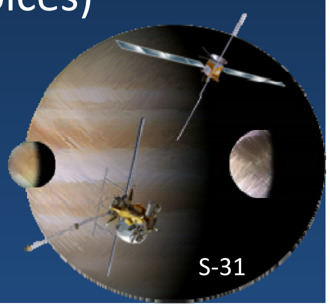
Considerations for Instruments

- Instruments as systems:
  - Instrument providers should identify DHMR/other sterilization technology venue and capability
    - Instrument providers should only implement alternative sterilization methods following negotiation and agreement with the JEO planetary protection lead
  - Biological contamination control
    - Clean benches, handling controls, cleaning
  - Bacterial burden accounting
    - Materials and accessibility issues
  - Microbial reduction
    - Design for tolerance of process
  - Recontamination prevention
    - Design covers, bagging, and proper storage
    - Consider testing, calibration and I&T
  - Record keeping
    - Assay results, process data, hardware treatment history, surface areas, organics list, etc.



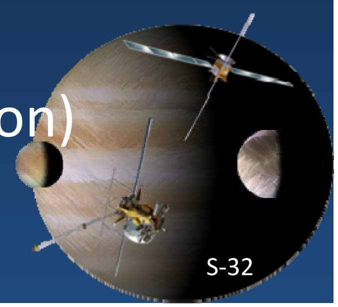
Considerations for Instruments

- Design for Cleanability
  - Current approach assumes capability to maintain post-sterilization recontaminant spore density at 300/m^2
  - System approach still requires capability to maintain pre-sterilization recontaminant spore density at low level
  - Design features need to be driven by sterilization process effect
  - Typical features:
    - Smooth surfaces
    - Robust surface finish
    - Accessibility before closeout
  - Material selection choices
    - Surface finishes (e.g. anodizing vs. coatings, different coating choices)
- Design for Integration and Test flow/schedule



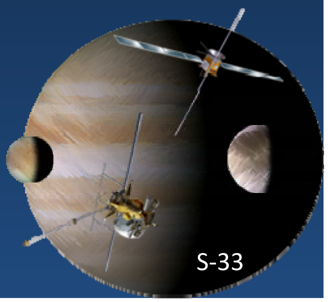
Considerations for Instruments

- Mechanical/Structure
  - Material selection choices
    - Dimensional stability/Coefficient Thermal Expansion mismatch issues
    - Effects of DHMR on performance of adhesives and lubricants
  - Configuration
    - Covers, Flight biobarriers needed
      - E.g. Phoenix needed to protect sampling arm from pre-launch/ launch/cruise/landing recontamination
      - Similar strategies may be required for JEO instruments with open apertures
    - Use of HEPA filters on enclosures sized for launch environment
    - Closed at closeout (no gaps to allow recontamination)



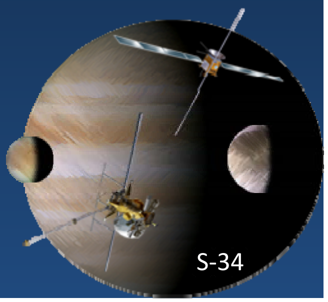
Considerations for Instruments

- Electrical/Electronic
  - Consider split assembly options for heat sensitive parts of the instrument
    - Capability to use different sterilization processes
- Thermal
  - Coating stability to DHMR, swabbing, color change
  - Access/sterility maintenance e.g. underneath blankets
- Other issues specific to individual instruments e.g. sensors, optics, will need to be addressed on a case-by-case basis
  - The project team is expecting this…



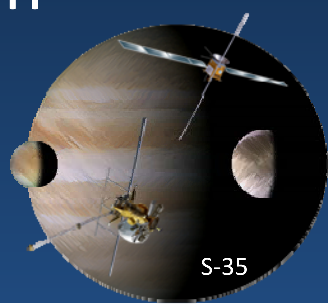
Design for I&T Flow/Schedule

- Understand end-to-end interfaces including integration/testing sequences and implications for recontamination
- Consider rework issues and develop mitigation strategies
- Integrate calibration sequences with integration/testing and sterilization activities
- Integrate instrument model philosophy into spacecraft schedule
- Baseline early testing (impact on model philosophy)



Assembly Level vs System Sterilization

- The Pre-project team is considering the option to perform a "system level" DHMR sterilization of the entire flight element in lieu of performing it at the various assembly levels
  - Occur at JPL or the launch site
  - All hardware would need see the high temperatures
  - Post DHMR sterilization instrument calibration?
  - Instruments would need to verify in advance that the instrument would be within spec post DHMR
- Other factors such as sterilization effect of Jovian radiation environment are common to both approaches



Assembly Level vs System Sterilization

PP Implementation Approach	100% DHMR Compatibility Required	Sterilization Process Responsibility	Aseptic Assembly Capability Required	ATLO Recontamination Risk	System Sterilization Capability	Launch Vehicle Recontami-nation	Biobarrier/ Capsule	Jovian environment Resterilization
Current Baseline: Box-level bulk sterilization	No	Instrument Provider	Yes	Significant – address by box-level surface resterilization	Not Required	Needs to be worked	Not Required	Required
System-level bulk sterilization w/o biobarrier	Yes	Project	No	Reduced	Required	Needs to be worked	Not Required	Required

Input from the instrument community are desired on both "Box-level" and "System" sterilization options