Total Dose Survivability of Hubble Electronic Components

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Acronyms

- AE-8 – Aerospace Electron Model-8
- AP-9 – Aerospace Proton Model-9
- CEASE – Compact Environmental Anomaly Sensor
- CMOS – Complementary Metal-Oxide-Semiconductor
- HST – Hubble Space Telescope
- IR - infrared
- JWST – James Webb Space Telescope
- NOVICE – Numerical Optimizations, Visualizations, and Integrations on CAD/CSG Edifices
- CAD – Computer Aided Design
- CSG – Constructive Solid Geometry
- PET – Proton Electron Telescope
- RAM – Random Access Memory
- ROM – Read Only Memory
- RPS – Relativistic Proton Spectrometer
- SAMPEX – Solar Anomalous and Magnetospheric Particle Explorer
- TID – Total Ionizing Dose
- TSX-5 – Tri-Service Experiments Mission 5
- 3-D – three-dimensional
Outline

• Introduction
• HST Lifetime Planning
• Total Dose Analysis and Results
• Summary

Credit: http://www.spacetelescope.org
Introduction

- Hubble Space Telescope (HST) deployed from Discovery April 25, 1990
  - Low Earth Orbit, 569 km altitude, 28.5° inclination
  - First telescope designed to be serviced in space
- Advantages in space:
  - No atmospheric distortions
  - Little background light
  - Portions of ultraviolet and infrared spectra seen, not observable with Earth-based telescopes

Credit: http://hubblesite.org/
The Universe, Looking Back in Time

Credit: http://hubblesite.org/
Service Mission 1
Corrective Optics for Spherical Aberration

Galaxy M100, Before  
Galaxy M100, After

Credit: http://hubblesite.org/
HST Lifetime Planning

- Fifth and final HST servicing mission occurred in May 2009
- James Webb Space Telescope (JWST), launches in October 2018
  - Will complement and extend HST discoveries with greater IR wavelength coverage and sensitivity
  - Desirable that HST and JWST operate simultaneously
- After more than 27 years in orbit, main radiation concern for HST is a hard failure due to total ionizing or non-ionizing dose.
  - Objective is to evaluate these possibilities out to the year 2020 for HST life extension initiatives and contingency planning
Total Dose Analysis
Van Allen Belts

- Dose comes mainly from trapped $p$, with smaller contribution from trapped $e$
- Must account for solar cycle dependence of fluxes
- Boeing Trapped Proton Model-1 used
  - AP9 used to extend energy range to 2 GeV (RPS instrument on Van Allen Probes)
  - Calculations showed good agreement with SAMPEX PET and TSX-5 CEASE data
- AE8 used for trapped electrons
  - Results insensitive to electron model

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Total Dose Analysis
Radiation Transport

- NOVICE code used for radiation transport
  - Interfaces with CAD models
  - Adjoint (reverse) Monte Carlo simulation greatly increases calculation efficiency
- Lockheed Martin spacecraft CAD model imported
- Extensive review of subsystem and instrument mechanical drawings
  - Implemented using correct dimensions, wall thicknesses, masses and placement
- TID exposure tracked accounting for servicing missions

HST NOVICE Radiation Model

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Expected Mission Doses by 2020
66 Subsystems / Instruments

5 krad(Si) parts
(Transponders)

Mission Part Requirements:
5 – 15 krad(Si)
Parts Discussion

• HST Parts and Control Plan specifies TID hardness of 5 - 15 krad(Si)
  – Many selected parts substantially exceed this

• Initial HST development occurred in 1980s
  – Bipolar technologies generally more total dose hard than CMOS
  – Literature and parts list reviews showed total dose concerns were primarily CMOS parts
  – Biggest concern is Hughes Aircraft CMOS parts in transponders - microprocessors, RAM and ROM
    ▪ Will be exposed to ~2X their total dose hardness by 2020

• Factors favoring part survivability:
  – Annealing of parts for many years in space not accurately accounted for with ground test protocol
  – Parts may operate satisfactorily outside specs
Summary

- HST has been through:
  - 27 years of mission operations
  - 5 servicing missions
  - 3 generations of scientific instruments
  - 14,000 electronic parts
    - Procured by 5 generations of parts engineers
    - Protected by 12,200 kg of spacecraft mass / shielding
- HST still operating satisfactorily

To Be Continued.....
Questions?

Credit: http://hubblesite.org/


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