Total Dose Survivability of Hubble Electronic Components

M.A. Xapsos\textsuperscript{1}, C. Stauffer\textsuperscript{2}, T. Jordan\textsuperscript{3}, C. Poivey\textsuperscript{4}, D.N. Haskins\textsuperscript{1}, G. Lum\textsuperscript{5}, A.M. Pergosky\textsuperscript{6}, D.C. Smith\textsuperscript{5} and K.A. LaBel\textsuperscript{1}

\textsuperscript{1}NASA Goddard Space Flight Center, Greenbelt, MD, USA
\textsuperscript{2}AS&D, Inc., Greenbelt, MD, USA
\textsuperscript{3}EMP Consultants, Gaithersburg, MD, USA
\textsuperscript{4}ESA-ESTEC, Noordwijk, The Netherlands
\textsuperscript{5}Lockheed Martin, USA
\textsuperscript{6}SAIC, USA

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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

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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.....