How Long Can the Hubble Space Telescope Operate Reliably?

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

- Introduction
- Service Missions
- Total Dose Analysis and Results
- Other Potential Failure Mechanisms
- Summary

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

- **Hubble Space Telescope (HST)** deployed from Discovery April 25, 1990
  - Low Earth Orbit, 590 km altitude, 28° 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/](http://hubblesite.org/)
The Universe, Looking Back in Time

Credit: http://hubblesite.org/

To be presented by Michael A. Xapsos at the Institute of Electrical and Electronics Engineers (IEEE) Nuclear and Space Radiation Effects Conference (NSREC), Paris, France, July 14-18, 2014.
Service Mission 1
Corrective Optics

Galaxy M100, Before  

Galaxy M100, After

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

- Fifth and final HST servicing mission occurred in May 2009.
  - Planning has been for one mission every 4 – 5 years
- James Webb Space Telescope (JWST), the successor to HST, launches no sooner than 2018.
- Preferable that HST and JWST operate simultaneously for at least 1 – 2 years.
- Can HST continue reliable science operations until then?
- Main radiation concern is a hard failure due to total ionizing or non-ionizing dose.
  - HST in orbit for 24 years
Total Dose Analysis

• Used NOVICE code for 3-D ray trace and Monte Carlo radiation transport.
  – Lockheed Martin spacecraft CAD model imported
  – Extensive review and implementation of subsystem and instrument dimensions, mass and placement

• Used Boeing TPM-1 for trapped protons
  – True solar cycle dependence
  – Service missions add another level of complexity to analysis

• Used AE-8 for trapped electrons.
  – Results insensitive to electron model
Expected Mission Dose in 2020
62 Subsystems / Instruments

Requirement: 5 – 15 krad-Si
Other Potential Failure Mechanisms

- **Gyroscopes**
  - 5 currently functional; 3 required

- **Fine Guidance Sensors**
  - 3 currently functional (1 barely); 2 required

- **Batteries**
  - 6 battery system expected to last ~ 10 years
  - All 6 replaced during 2009 servicing mission

- **Avionics System Reliability**
  - Predictive model shows 50% failure possibility in 2018, but is known to be conservative

- **Loss of Science Instruments**
  - Designed for 5 years but typically last longer
  - 2 installed in 2009 with full redundancy
  - 2 repaired in 2009, but now lack full redundancy
Summary

- HST has been in orbit for about 24 years.
- A key goal is to keep science operations going for a year or two after JWST is launched.
- As a result of HST’s longevity, total dose failures are an important consideration for continuation of the mission.
  - Just as significant as the other major potential failure modes.
Acronyms

- HST – Hubble Space Telescope
- JWST – James Webb Space Telescope
- NOVICE – Numerical Optimizations, Visualizations, and Integrations on CAD/CSG Edifices
- CAD – Computer Aided Design
- CSG – Constructive Solid Geometry
- 3-D – three-dimensional
- TPM-1 – Trapped Proton Model-1
- AE-8 – Aerospace Electron Model-8