

# How Long Can the Hubble Space Telescope Operate Reliably?

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# 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

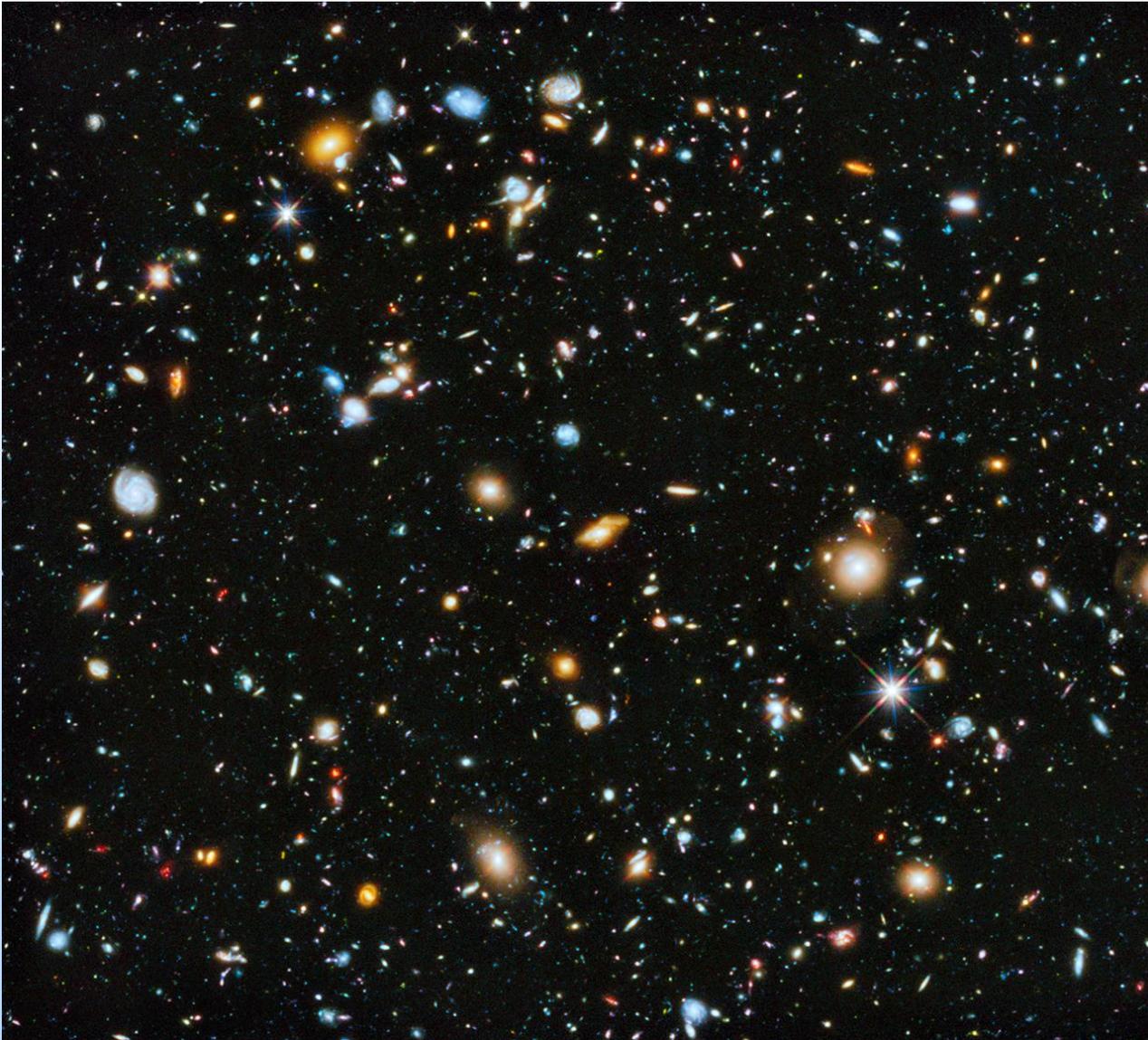
2.4 meter diameter primary mirror



Credit: <http://hubblesite.org/>



# The Universe, Looking Back in Time



Credit: <http://hubblesite.org/>

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/>



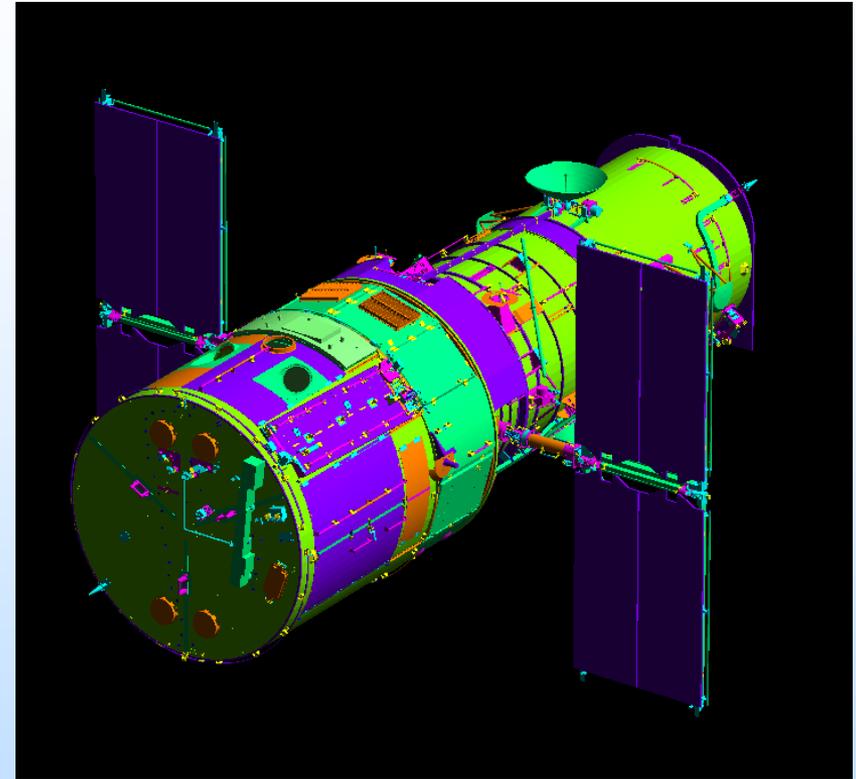
# Desired HST Lifetime

- **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

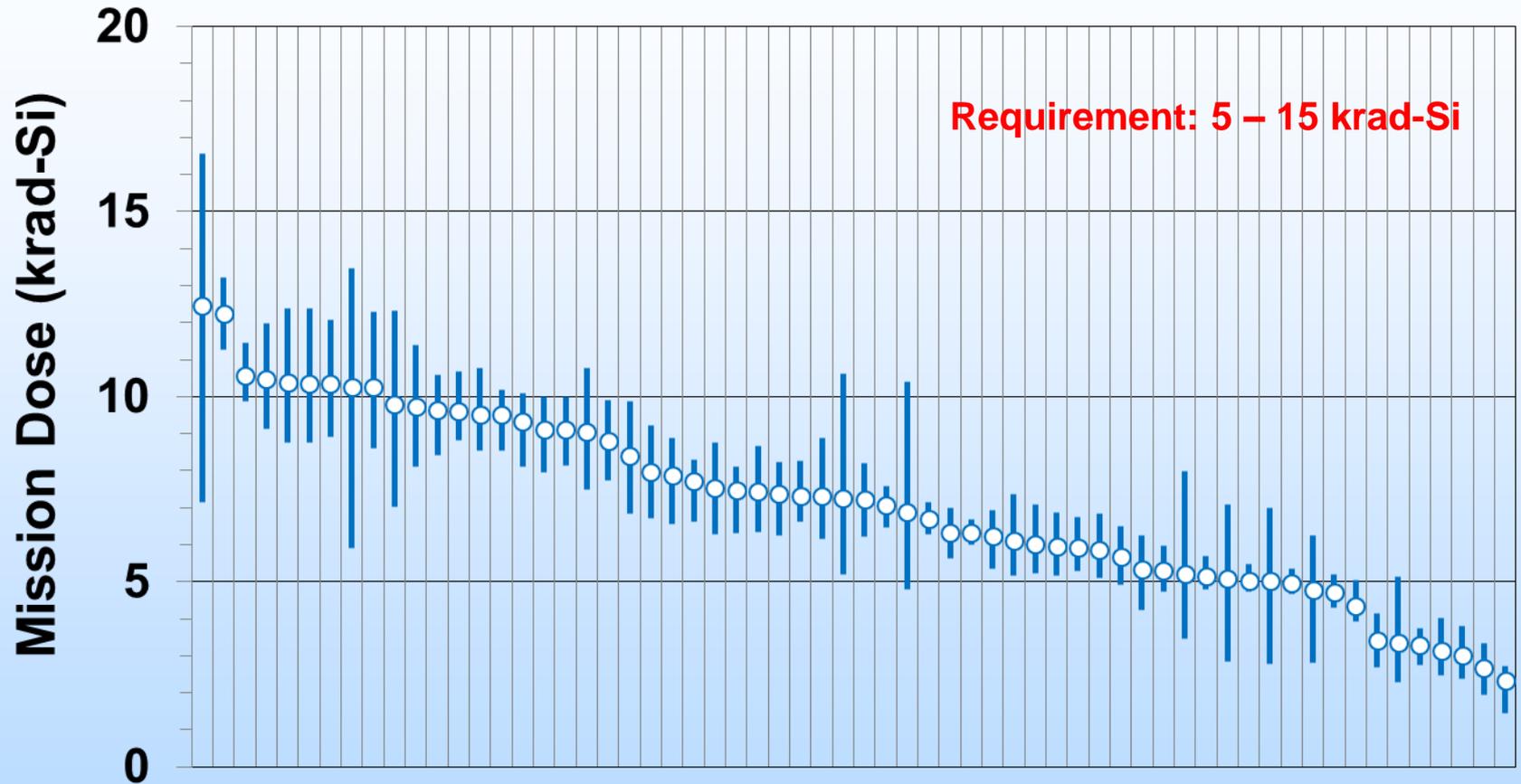


HST NOVICE Radiation Model



# Expected Mission Dose in 2020

## 62 Subsystems / Instruments





# 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**