The Scientific Rationale For HST Servicing Mission 4

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Assumptions About SM4

- 12/05 launch date assumed for planning purposes only
- Actual launch date depends entirely on safe Shuttle return to flight and demonstration that HST can be safely serviced
- Current SM4 payload manifest includes
  - Cosmic Origins Spectrograph (COS)
  - Wide Field Camera 3 (WFC3)
  - Six new gyros (three RSU packages)
  - Six new batteries
  - Replacement Fine Guidance Sensor (FGS)
  - Aft Shroud Cooling System (ASCS)
  - Data system cross-strapping kit
  - Multi-layer insulation (MLI) repair kits
  - Re-boost to higher orbit
- Final payload may differ, depending on new safety procedures or future HST maintenance needs

Statement of Principle

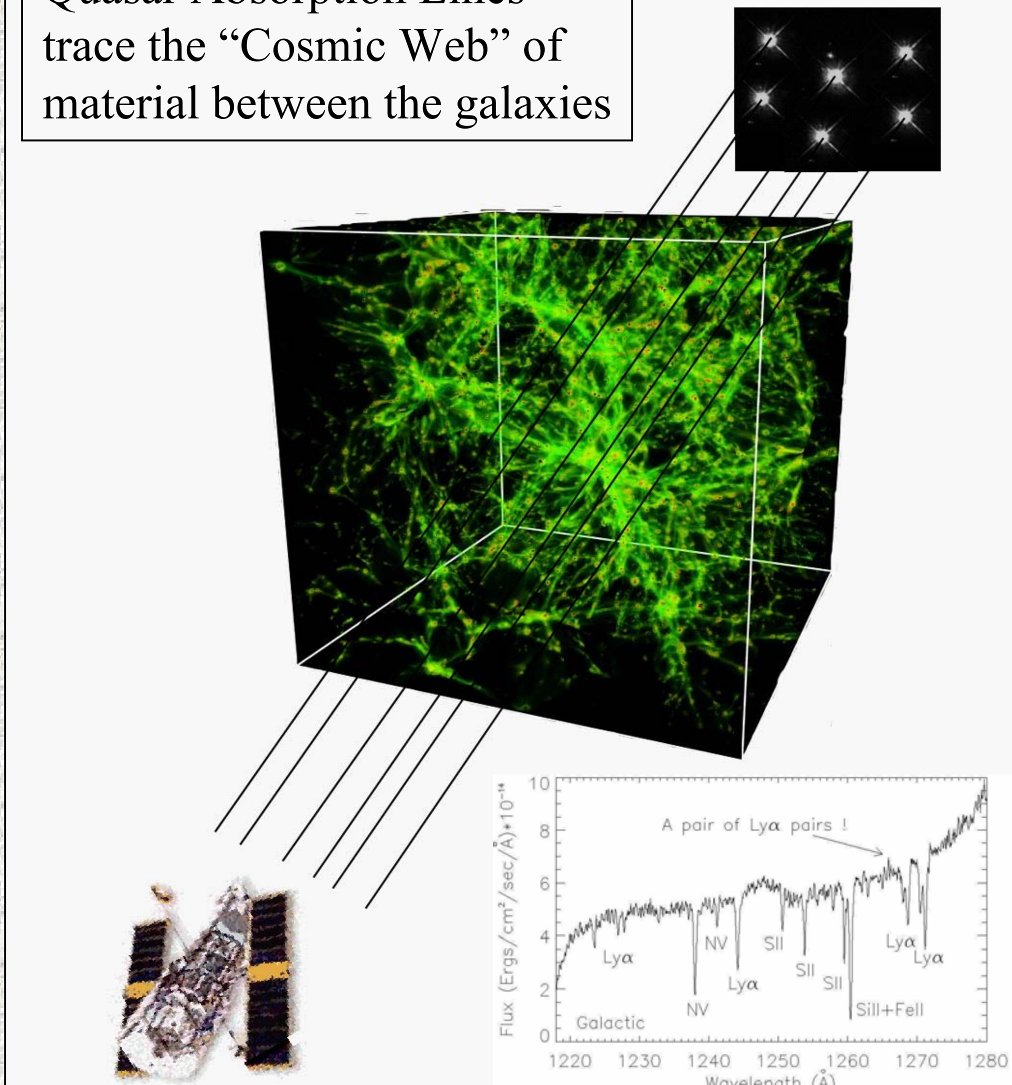
- No corners will be cut in the safe return of the Shuttle to flight, no time pressure will be applied for any reason.
- If we have to go into a period of scientific dormancy on Hubble to allow sufficient time for a safe return to flight, so be it.
- If Hubble fails irretrievably because it wasn't yet safe to go back to it for repair and maintenance, then we will accept that fate with equanimity.

Cosmic Origins Spectrograph
Hubble Space Telescope

COS will study:

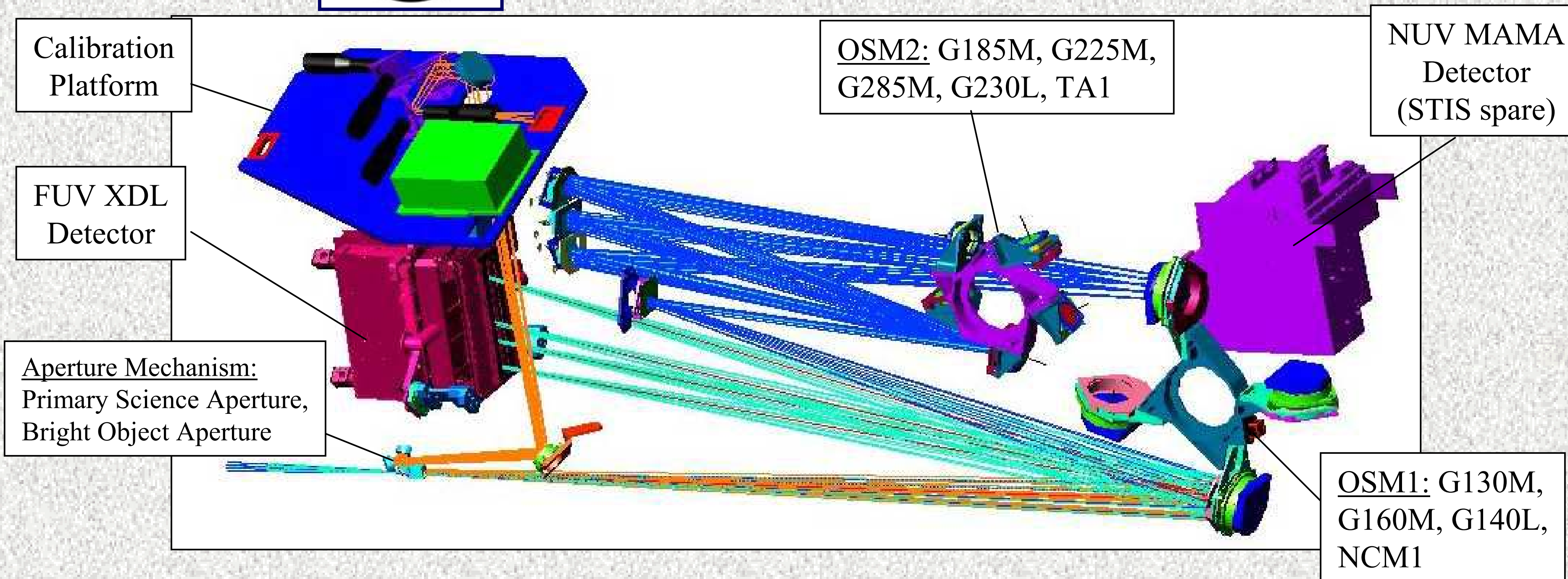
- Large-scale structure by tracing Hydrogen Lyman α absorptions
- Formation of galaxies
- Chemical evolution of galaxies and the intergalactic medium
- Hot stars and the interstellar medium of the Milky Way
- Supernovae, supernova remnants and the origin of the elements
- Young Stellar Objects and the formation of stars and planets
- Planetary atmospheres in the Solar System

Quasar Absorption Lines trace the "Cosmic Web" of material between the galaxies



- Visualization concept from Schiminovich & Martin
- Numerical simulation from Cen & Ostriker (1998)
- Songaila et al. (1995) Keck spectrum adapted by Lindler & Heap

Cosmic Origins Spectrograph
Hubble Space Telescope



<u>Optical bench</u> (not shown): re-use of GHRS bench

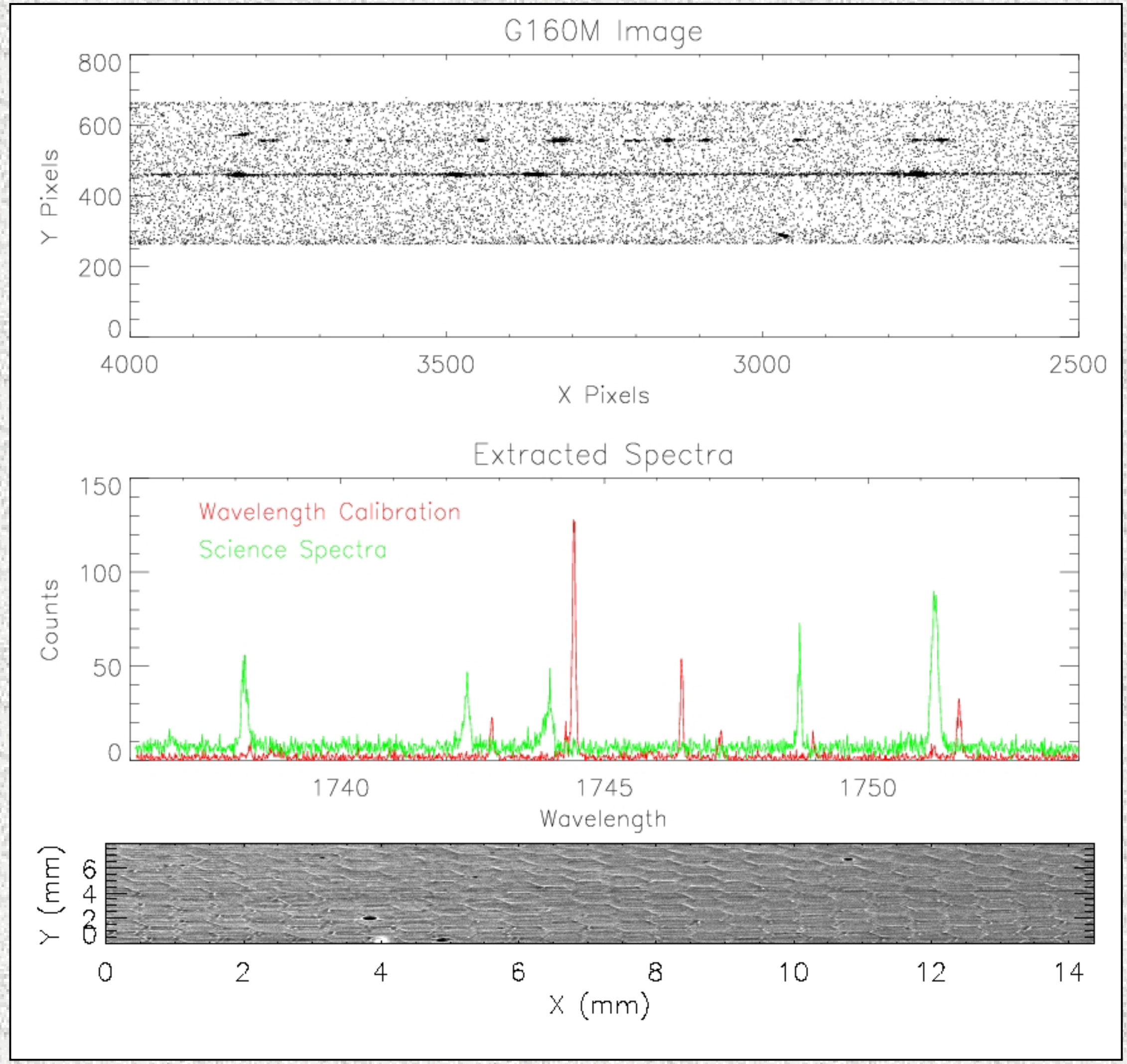
- COS has 2 channels to provide low and medium resolution UV spectroscopy
  - FUV: 1150-1775Å, NUV: 1700-3200Å
- FUV gratings: G130M, G160M, G140L
- NUV gratings: G185M, G225M, G285M, G230L
  - M gratings have spectral resolution of R ~ 20,000

COS PRIOR TO SHIPMENT TO GSFC

Cosmic Origins Spectrograph
Hubble Space Telescope

* N_2 purge data through FUV detector door window.

* Portion of FUV detector flat-field obtained during component-level testing.



COS vs. STIS in the Far Ultraviolet

Performance Metric	COS G130M/ STIS G140M	COS 130M/ STIS E140M	COS G160M/ STIS G140M	COS G160M/ STIS E140M
Effective Area	6	22	14	28
Eff. Area x Bandpass ("Discovery Efficiency")	32	11	72	14
Time to achieve same S/N	32^{-1}	~ 20^{-1}	72^{-1}	~ 28^{-1}

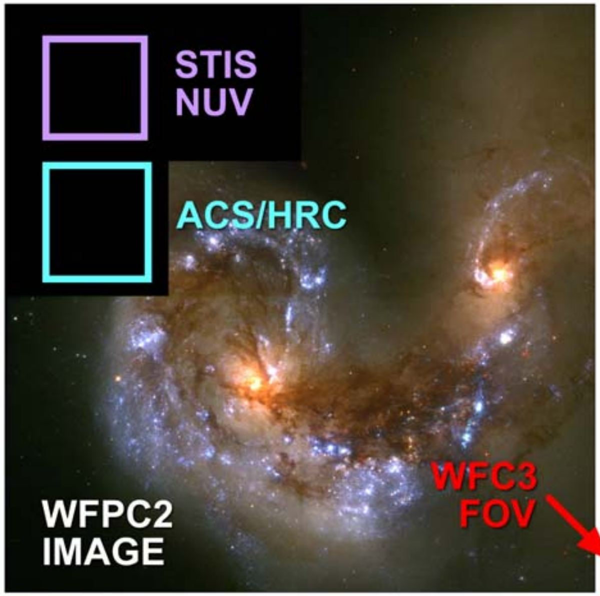
Wide Field Camera 3: UVIS Channel

Scientific Motivation for UVIS Channel

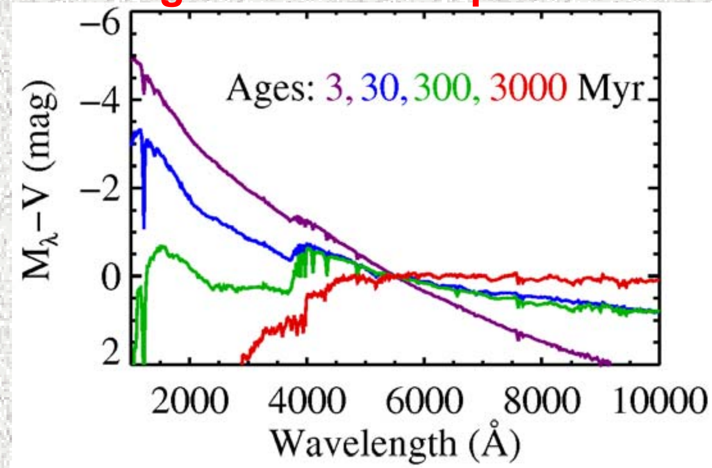
Complementary backup to ACS, with fresh, undamaged CCDs, improved CTI amelioration.

Uniquely capable in the NUV, unmatched by any other planned mission:

- Star formation history of galaxies
- Chemical enrichment history of galaxies
- Ly α dropouts at $z = 1 – 2$
- Probe one of the darkest spectral regions of the natural sky background (~200 nm)



NUV Observations Probe Age of Stellar Populations



Key Properties of UVIS Channel

- 200-1000 nm wavelength range
- 4K x 4K CCD mosaic (2 UV-optimized CCDs)
- 0.04” x 0.04” pixels, 160” x 160” field of view
- rich filter set, with 62 passbands, 1 grism
- ***~35 x FOV of current sensitive UV imagers***
- ***1-2+ magnitudes sensitivity advantage over WFPC2 in NUV, with better spatial sampling than PC, lower red leak in UV filters***

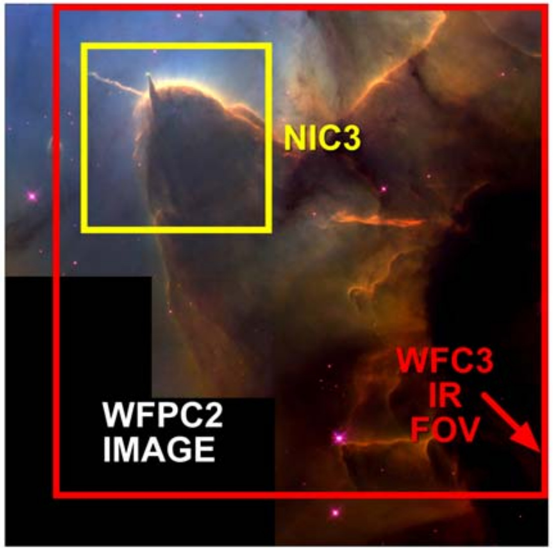
Wide Field Camera 3:
Near-Infrared Channel

Scientific Motivation for IR Channel

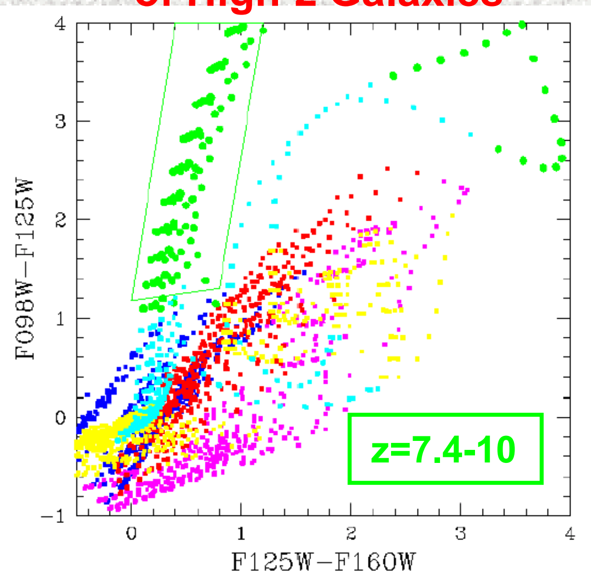
Advance IR observations over NICMOS with much larger field of view, greatly improved detectors.

Take advantage of dark IR sky in space:

- High-redshift galaxy formation (high-z dropouts)
- Sources of cosmic re-ionization
- Dust enshrouded star formation
- Water and ices in the solar system



IR Color-Color Identification of High-z Galaxies



Key Properties of IR Channel

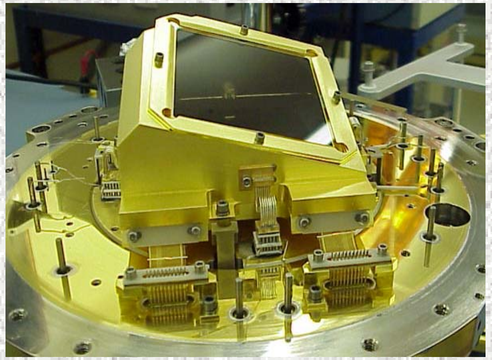
- 800-1700 nm wavelength range
- 1K x 1K HgCdTe array from Rockwell Scientific
- 0.13” x 0.13” pixels, 135” x 135” field of view
- 15 filters, 2 grisms
- zodi-limited sensitivity in broad band filters
- ***>10 x improvement in J+H band point source survey efficiency vs. NICMOS 3 + Cryocooler (>15 x vs. original NICMOS)***
- ***with better spatial sampling, photometric accuracy, stability, and cosmetics***

Wide Field Camera 3: Hardware Status

***WFC3 hardware fabrication is nearly complete; Integration and Test program is well underway*.**

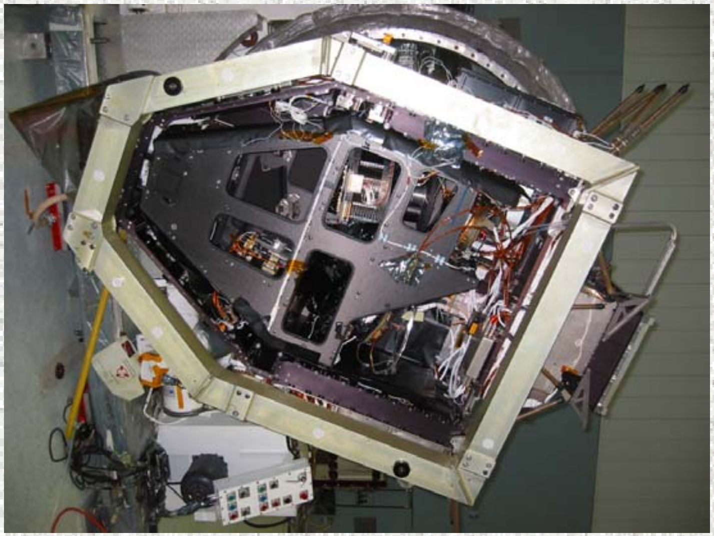
- All mechanisms, optics, electronics boxes, flight UVIS detector integrated into optical bench and enclosure.
- Optical performance exceeds specifications in both channels.
- ***Delivery of completed instrument to HST Project scheduled for July 2004.***

UVIS Flight Detector

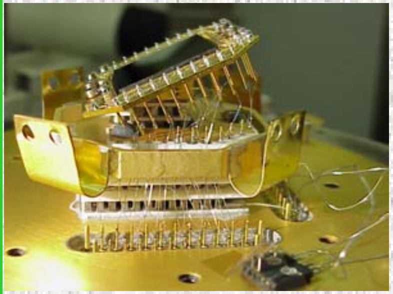


- Two superb 2K x 4K e2V CCDs
- 3 e rms read noise in all 4 channels
- Flight detector package is in instrument
- Flight spare is nearing completion

WFC3 in GSFC Clean Room



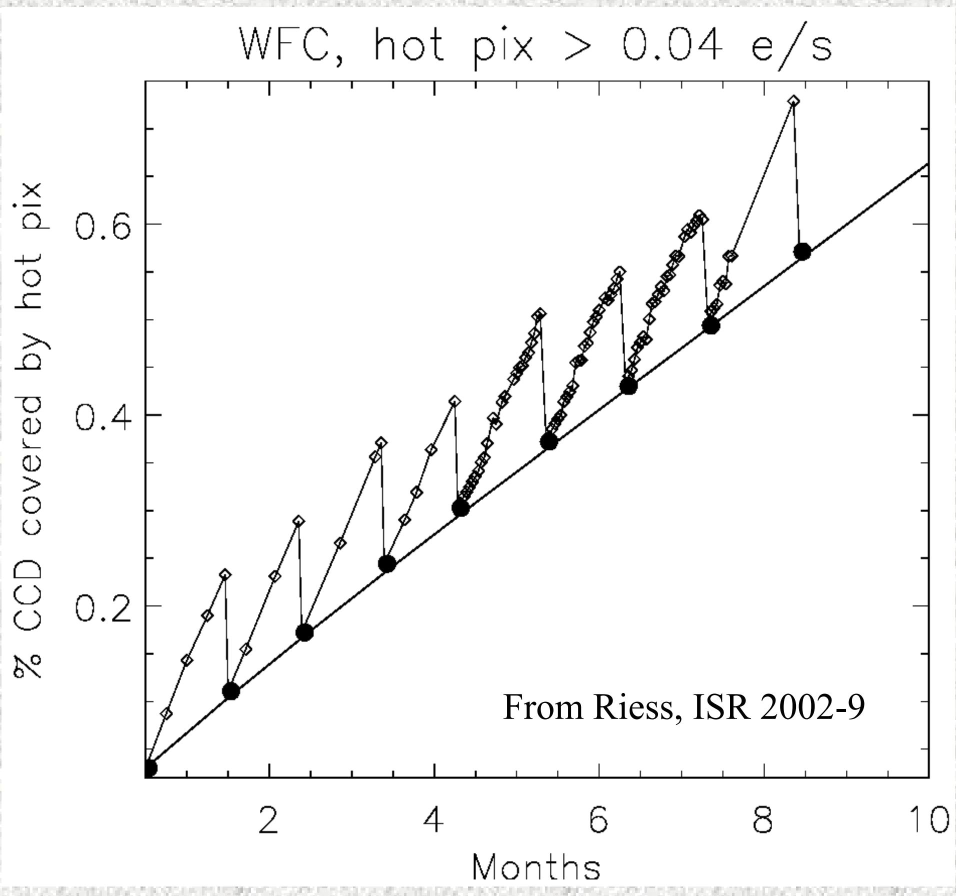
IR Flight Detector



- HgCdTe IR array with 1.7 μm cutoff yields low background/low dark current performance without cryogen or mechanical cooler
- ***Five flight quality IR arrays in hand***
- Packaging of prime flight array nearing completion at Ball
- IR qualification unit validated thermal and mechanical design of package

CR-Induced Hot Pixels in the ACS WFC

- A. Riess (ACS ISR 2002-09) finds that the anneal rate of hot pixels on the ACS WFC is ~60%-65%, significantly lower than the characteristic anneal rate of 80-85% seen for other CCD's flown on HST. "Approximately 2 years after launch the coverage by hot pixels is expected to exceed that by cosmic rays in a ~1000 sec exposure."



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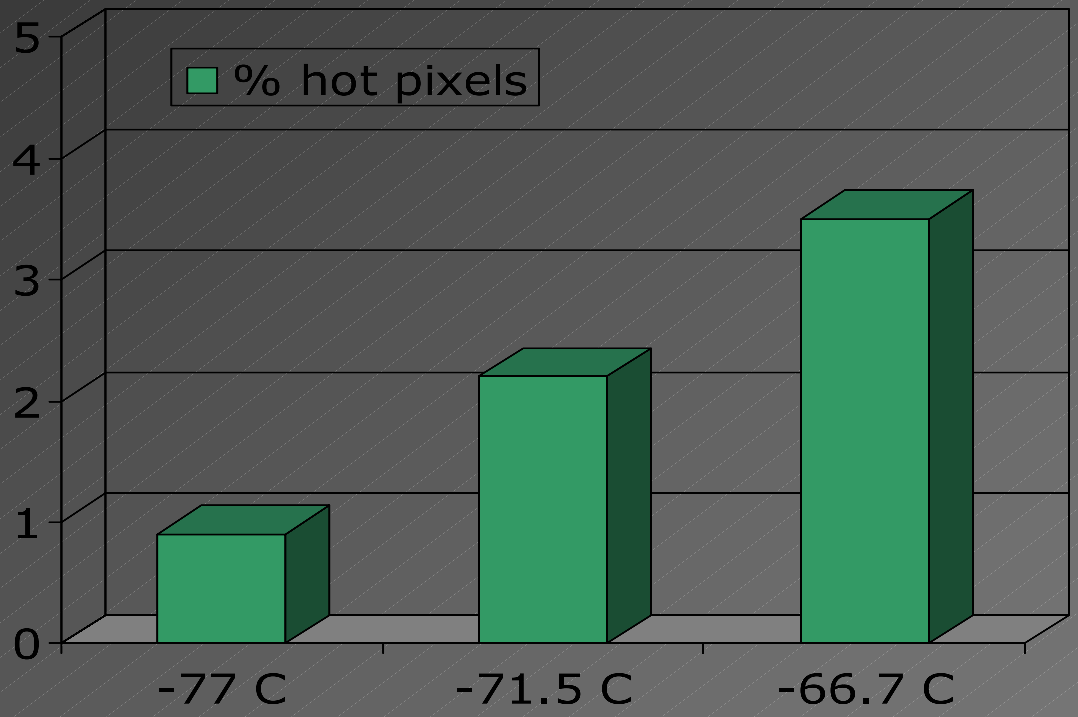
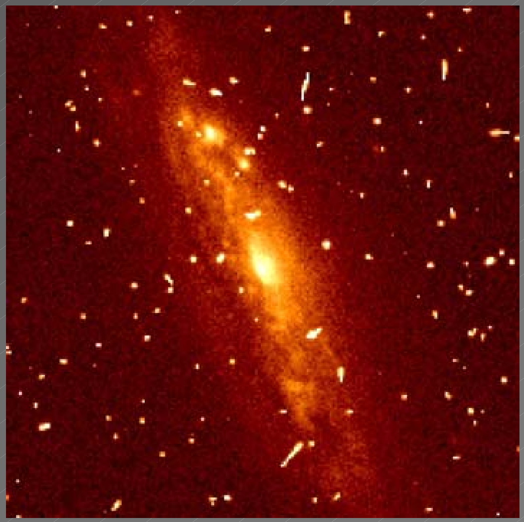
ACS Hot Pixel Test

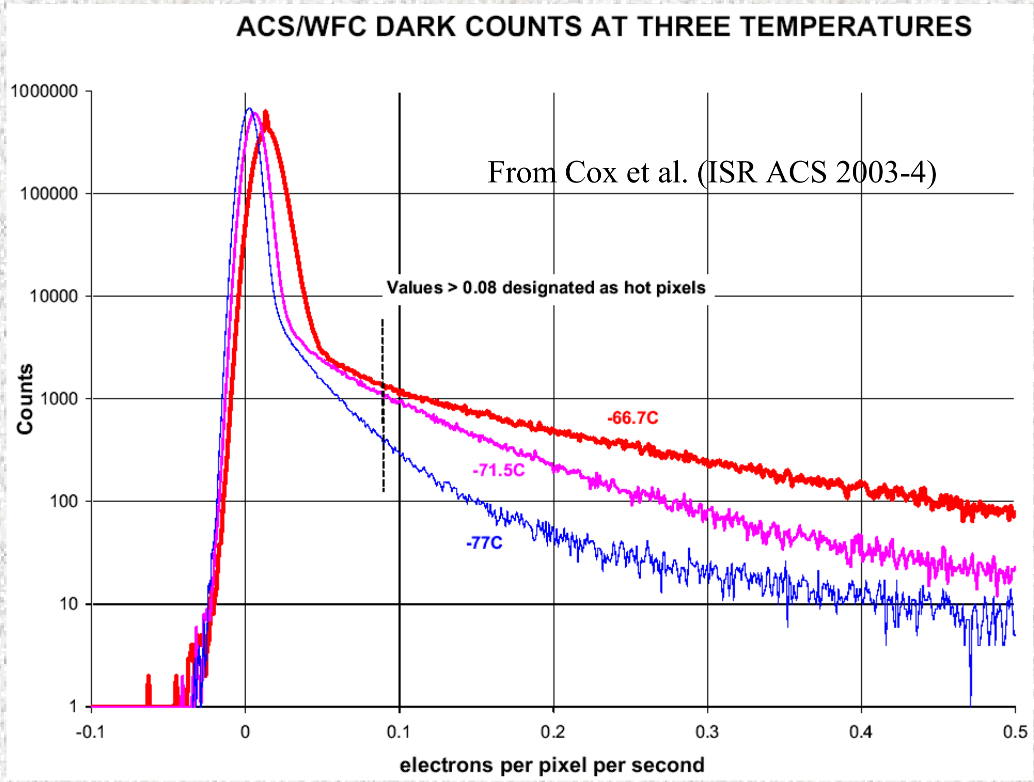




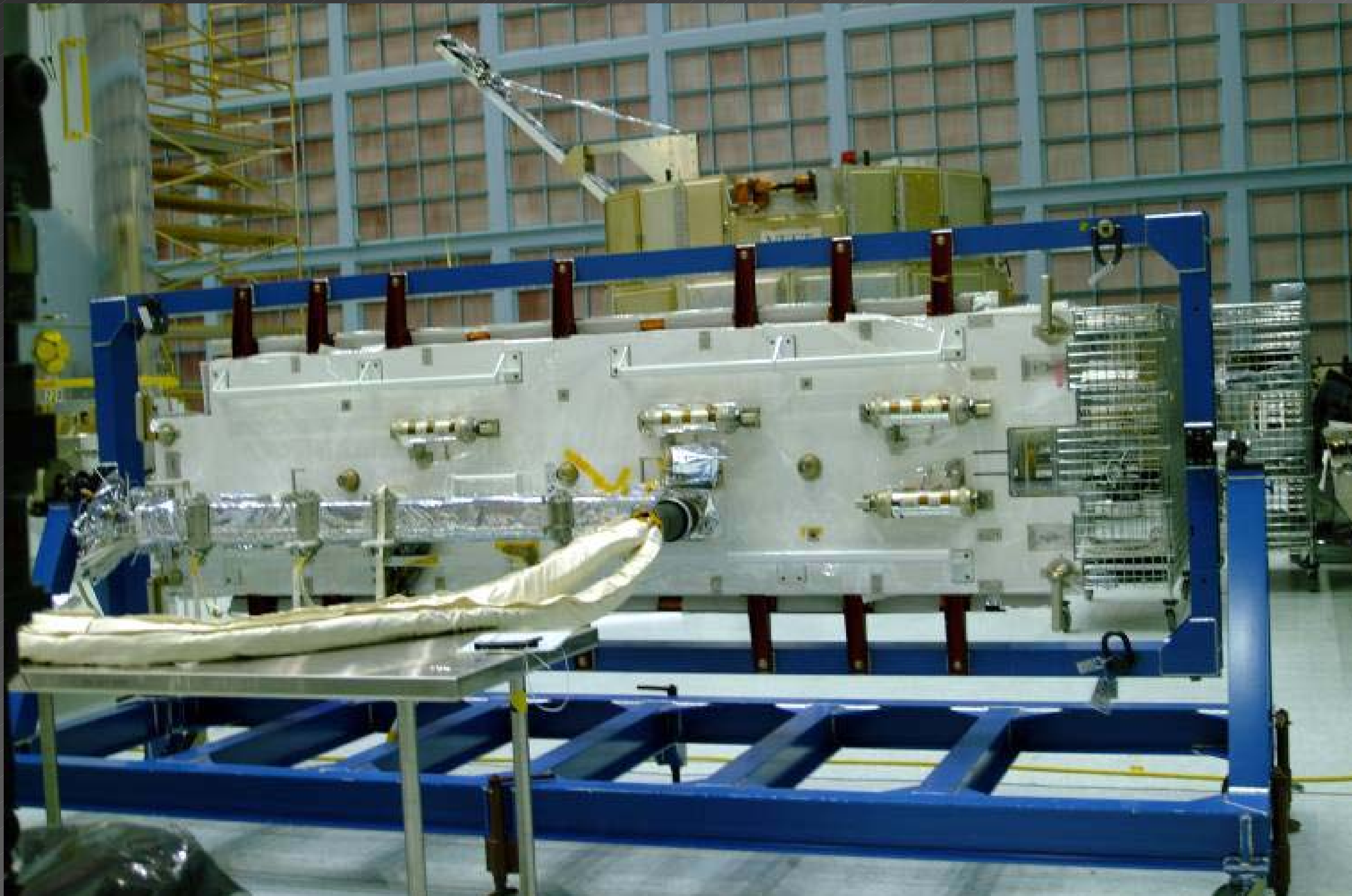
Hot Pixels: tests were done at higher than normal operating temperatures. The dark count rate in individual pixels increases. This pushes more pixels over the boundary (0.04 e/s) that flags them as hot pixels. Indicates that cooler operation with ASCS can mitigate the hot pixel coverage on WFC.

ACS Hot Pixel Amelioration by the ASCS

- Cox et al. (ISR ACS 2003-004) find that there is a 20% increase in the hot pixel dark rate for every degree of temperature elevation.
- Cooling from –77° C to –85° C with the ASCS will reduce the amplitude of the hot pixels by ≥ 4. Cooling to –90° C will reduce the amplitude of the hot pixels by ~ 13.
- Cooling with the ASCS will improve the WFC's steadily declining CTE.



AFT SHROUD COOLING SYSTEM FLIGHT RADIATOR



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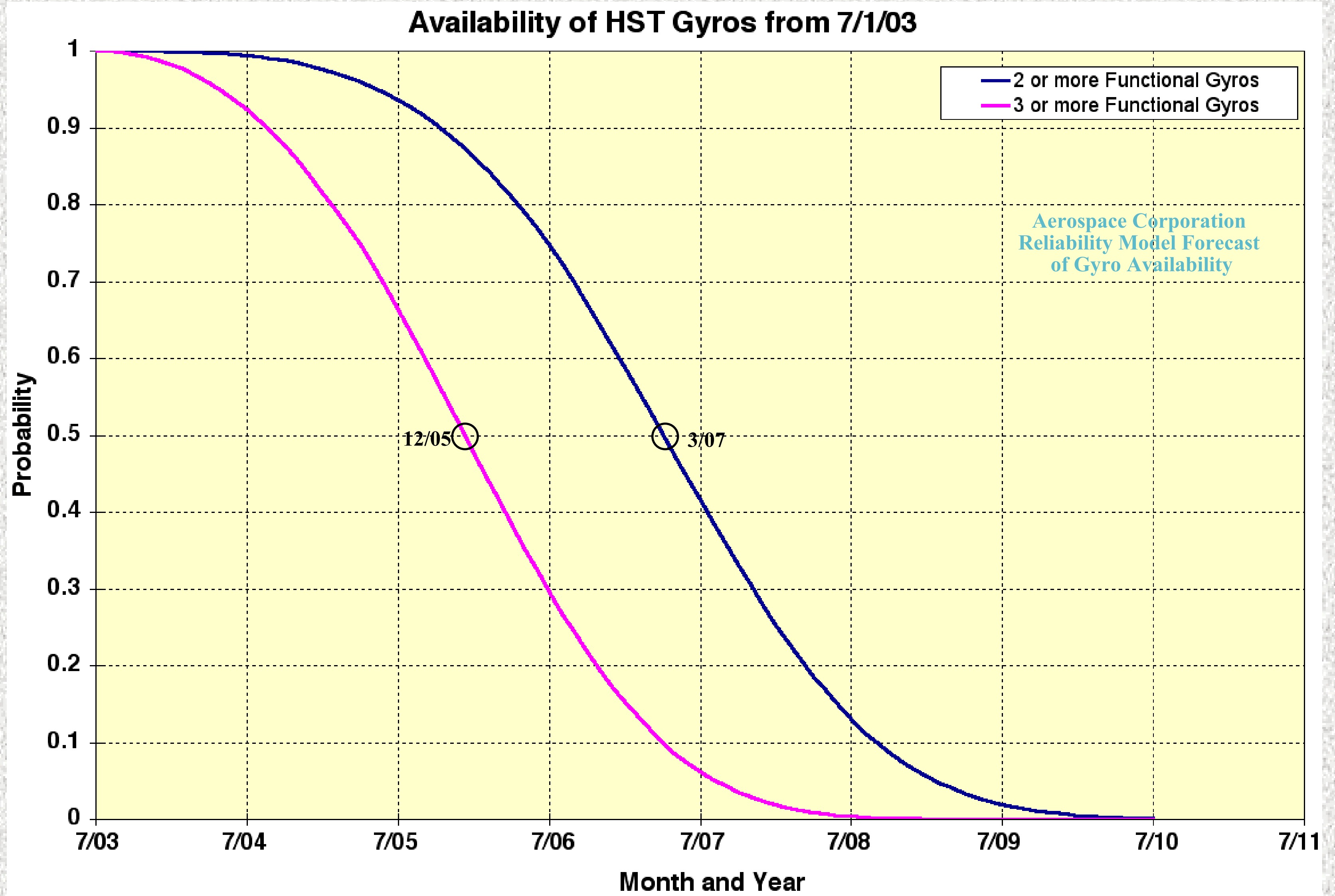
Probability vs. Time of Three-Gyro and Two-Gyro Science Operations



On average, TGS Mode enables a 15-month extension of science operations

Science Implications of Batteries and FGS

- Batteries
  - Average capacity loss, based on tests of 3 batteries = 6.3AHr/yr
    - Average was ~2AHr/yr between 1998 and 2002
    - Present full charge is ~320 AHr
    - Safemode limits are set at 235-180 AHr
  - Cells exceed expected discharge cycle lifetimes in early 2005
  - Aggregate loss of capacity may require power management sometime in 2005
    - NICMOS Cooling System will be turned off – loss of IR science
    - Block scheduling of science instruments may be needed
- Fine Guidance Sensor
  - FGS3 is final FGS planned to be replaced due to bearing wear
  - FGS2 (inserted in SM3A) is behaving anomalously, may fail
  - Two operational FGS's allow normal science operations but with reduced guide star availability – affects ~10% of targets
  - One operational FGS requires completion of FGS-FHST pointing control with major constraints on ability to point to targets