This briefing will provide an overview of the present condition of the Hubble observatory and describe the upcoming servicing mission.

Ambitious mission with three major objectives:
- Enhance Hubble’s science capabilities
- Restore existing capabilities on the telescope
- Strengthen its ability to last through 2013

New instruments are a new camera and a new spectrograph, capabilities will be described.

Briefing is being led by Dr Chris Blades, STScI

Bio: Chris Blades was born in Birkenhead, England, and studied at the University of St Andrews (B.Sc.) and University College, London (Ph.D.). Following his Ph.D. studies, he worked at the 150-inch Anglo-Australian Telescope as a Research Fellow and then joined Rutherford Appleton Laboratory to work on the International Ultraviolet Explorer in Spain. In 1983, he moved to the Space Telescope Science Institute in Baltimore, Maryland to work for the European Space Agency on the Faint Object Camera, and then transferred to AURA as a tenured Astronomer a few years later. He has published over 125 research papers, mainly in the field of absorption line spectroscopy. Currently, he is working as Project Scientist for SM4 at STScI.

Contact: blades@stsci.edu
Servicing Mission 4

THE GOOD NEWS

- “One final House Call”: says NASA Administrator Griffin on October 31, 2006: SM4 scheduled for 11 September 2008

- Flight will be on Atlantis - last flight of this shuttle
  - Contingency flight: Discovery on pad in case of need

- Fifth and final servicing mission to Hubble

- Atlantis will carry ~ 22,000 lbs of hardware
  - Heaviest servicing mission so far
  - Envisaged as an 11 day mission with rendezvous on the 3rd day.

- Five EVAs, with three major goals
  - Enhance; Restore; Upgrade
The astronauts selected for the final shuttle mission to perform work on the Hubble Space Telescope pose for a group photo. From left to right are astronauts Megan McArthur, Michael Good, Gregory C. Johnson, Scott Atman, John Grunsfeld, Michael Massimino, and Andrew Feustel.
Trivia - Did You know?

- That Space Shuttle Atlantis is named after the Woods’ Hole Oceanographic skip - the Atlantis?
Hubble Science Operations

- Although we have an active and oversubscribed observatory - we need this mission !!!
  - Since SM3B in 2002, we have lost our prime spectrograph, STIS, and our prime camera, ACS
    - Using venerable WFPC2 and repaired NICMOS for essentially all science
  - Conserving Gyros, so observing in 2-gyro mode
    - Imaging quality is fine, but some restrictions on pointing
    - We have 6, but several have failed
  - Hence this final servicing mission IS critical
    - Originally planned for 2004
    - Cancelled after the Columbia accident
    - Re-instated after a long public & political campaign
  - This final mission will be, without doubt, the most complicated and challenging that NASA has ever mounted.
Only one of four axial instruments is in use (NICMOS).

STIS failed in Aug 2002
ACS failed in Jan 2007
COSTAR not used
Objectives for SM4

Three Major Goals for SM4

1. **Enhance** Hubble’s scientific capabilities with a new camera and new spectrograph
   - WFC3, a panchromatic camera, replacing WFPC2
   - COS, a very efficient spectrograph, replacing COSTAR

2. **Restore** existing Hubble capability through in-situ repair
   - STIS: repair failed electronics
   - ACS: repair failed electronics

3. **Upgrade** Hubble to last to beyond 2013
   - Install refurbished Fine Guidance Sensor
   - Install 6 new gyros
   - Install 6 new batteries
   - Install thermal protection covers
   - Install Capture Mechanism for de-orbit mission

*If successful, HST will be at the height of its power, with 6 working, complementary, science instruments*
Early EVA Schedule

HST SM4 EVA Timelines

- **EVA 1** (0:45)
  - Initial Setup (00:35)
  - RSU (-V3) (02:55)
  - Battery (-V3) (01:55)

- **EVA 2** (0:50)
  - Setup
  - COS (-V2) (03:25)
  - Battery (-V3) (01:55)

- **EVA 3** (0:10)
  - NOBL 7 & 8 (00:50)
  - NOBL 5 (00:30)
  - Close Out (00:30)

- **EVA 4** (0:25)
  - WFC III (-V3) (2:55)
  - STIS (+V2) (03:55)
  - STIKER (+V2) (01:15)

- **EVA 5** (0:30)
  - FGS 3 (+V2) (03:15)
  - OVP (00:45)
  - OCE-UK (00:35)
  - Final Close Out (01:30)
Cosmic Origins Spectrograph

- Spectroscopy is a fundamental astrophysical tool.
- Especially true for Hubble, which can observe the ultraviolet-optical-near IR regions unencumbered by atmospheric absorption.
  - Unique attribute for Hubble.
  - The ultraviolet spectral region is so important; many of the cosmically abundant elements are found in the UV.
- Spectroscopy allows us to establish the masses of objects, their motions, temperatures, cosmic abundance, and atomic & molecular compositions.
- This is why the new spectrograph, COS, is so very important.
- Proposed in 1997 by Dr James Green of University of Colorado
  - High-throughput spectrograph, based on many features already proven with FUSE - so it was attractive for these reasons, required little technological development, and affordable.
- Status today
  - Completed, fully tested, and ready to fly
Cosmic Origins Spectrograph

- COS equipped with state-of-the-art UV detectors and optics and optimized for maximum FUV throughput. Provides moderate and low resolution spectroscopy throughout the HST-accessible satellite ultraviolet.

- COS has two distinct wavelength channels
  - **Far Ultraviolet Channel**
    - 1-reflection, aberration-corrected along dispersion
    - 2 side-by-side 16k by 1k pixel detector (FUSE design)
    - Records arrival time of every detected photon
    - 3 gratings; 300 or 800 (nm) spectral range
    - Resolving power ~3000, ~20,000 [115 to 205 nm]
  - **Near Ultraviolet Channel**
    - Fully corrected optical design
    - 1k by 1k pixel detector (STIS design)
    - Records arrival time of every detected photon
    - 4 gratings
    - 10 to 80 nanometers spectral ranges
    - Resolving power ~2000, ~20,000 [170 to 320 nm]
Cosmic Origins Spectrograph

- Calibration Platform
  - 4 lamps, 3 beam splitters

- Aperture Mechanism
  - 2 Apertures
  - 2 degrees of freedom (x & y translation)

- FUV Detector Head

- NCM2
  - Collimating mirror

- NCM3a, 3b, 3c
  - Focusing mirrors

- NUV Detector
  - (MAMA)

- OSM1
  - 4 optics
  - 2 degrees of freedom (rotation, focus)

- OSM2
  - 5 optics
  - 1 degree of freedom (rotation)

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COS FUV Spectrum

- The figure below shows the typical spectral format for one half (one segment) of the FUV detector. The upper spectrum is the internal Platinum-Neon wavelength calibration lamp, and the lower is an external source. Typically both the target and the cal lamp will be exposed simultaneously.

FUV MCP (1 of 2 segments)
COS Cabling
COS FUV performance compared to STIS

Limiting Flux for S/N=10 in 3600 sec (R~10,000 (0.15 Å) binning)

-13.0
-13.5
-14.0
-14.5
-15.0
-15.5

Wavelength (Å)

-12.5
-13.0
-13.5
-14.0
-14.5
-15.0
-15.5

log Flux (erg cm⁻² sec⁻¹ Å⁻¹)

STIS E140M
R=45,000

STIS G140M
R~11,000-17,000

COS G160M
R~20,000-24,000

COS G130M
R~20,000-24,000

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• Wide Field Camera 3
**Wide Field Camera 3**

- WFC3 has two wide field cameras
  - A UV-optical camera for near UV and optical imaging
  - An infrared camera for the near-IR
- Will make use of a large number of narrow-band and broad-band filters
- WFC3 will be the first truly panchromatic camera on-board Hubble
- Designed to study formation and evolution of galaxies, and star forming rates. Distant Universe - Observational cosmology
- Continue study of Dark Energy thru High-Redshift Supernovae
- Pathfinder for JWST - both technology and science
- Does not duplicate ACS & NICMOS
  - UVIS channel >30x discovery power of ACS/WFPC2
  - IR channel 15 to 20x discovery power NICMOS
Performance Comparison of Hubble’s Cameras

Point Source Limiting Magnitude

- WFC3/UVIS
- ACS/WFC
- WFC3/IR
- ACS/HRC
- NICMOS/NIC3
- WFPC2

ABMAG

Wavelength (nm)

10 hour exposure optimal extraction

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Hubble Upgrades

- Six new gyros, allow us to return to 3-gyro operations
- Six new batteries, current ones are 11 years beyond design lifetime
- New thermal covers, as HST is heating up, these will be needed in the out-years
- Soft capture mechanism to aid in Hubble’s eventual de-orbit
- The improvements of SM4 are expected to keep Hubble operational until at least 2013, and maybe beyond to the JWST era.
Hubble Repairs

- Attempts will be made to repair both STIS and ACS in-situ.
- Both have had electronic failures associated with voltage supplies.
- Access to electronics boxes will be required
  - For STIS 111 fasteners will be removed to allow access to the electronics, then circuit board will be removed and replaced with new one from warm pouch.
  - FOR ACS, a shearing tool is needed to cut through a grill. Three boards will be removed and replaced with a single one and a new power supply will be clamped to the casing.
- New astronaut tools are being prepared to help with these delicate tasks
- Very careful planning is going on with high fidelity mock-ups to ensure access to panels is OK.
- Go ahead for either repair has not yet been given by management.
Building a “month in the life” of Hubble, a post SM4 DRM
- will consist of real-life observing program using all Cycle 17 instruments (WFC3, COS, STIS, ACS, NICMOS and FGS) in 3-Gyro mode.
- Done earlier to prepare for 2-gyro mode, where it helped the implementation.
- Work has started now, use Astronomer Proposal Tools built for WFC3 and COS, plus all existing documentation to build Phase 2 proposals with these new instruments.
- “Observations” with new instruments will be combined with calibration and science observations of existing instruments

Develop a month-long schedule to see how instruments interact
- Make it as realistic as possible, include SNAPS, Parallels
- How do the instruments interact? Problems?
- What can we do to make them more efficient
- Fully test all of our new ground system software
Hubble’s Focal Plane
Over the Years

1990 Deployment
1993 SM1
1997 SM2
1999 SM3A
2002 SM3B
2008 SM4