HST - the HUBBLE SPACE TELESCOPE

1 Original Science Objectives of the FUSE Mission - March 1977

- The constitution, physical characteristics, and dynamics of celestial entities [Everything in space].
- The nature of processes which occur in the extreme physical conditions existing in and between astronomical objects [Black holes].
- The history and evolution of the universe [Past, present and future].
- Whether the laws of nature are universal in the space-time continuum [Physics].

2 A partial list of science accomplishments not anticipated

- Study extrasolar planets (e.g., transit of a planet with radius 1.35 ± 0.06 that of Jupiter in front of the star HD 209458).
- Study of substellar mass objects (brown dwarfs).
- Astrometry with the FGS (stellar masses and previously unknown companions).
- Acceleration of the expanding universe.
- Quasars at very large resdhift ($z > 6$).
- Deep surveys of objects in “empty fields”.
- Circumstellar matter around young stars.
- Large scale structure of the universe.

3 HST Spacecraft

Orbit: LEO requiring Shuttle reboosts every few years.

Optical Telescope Assembly = OTA: 2.4m primary and secondary mirrors. The primary mirror, built with spherical aberration, requires additional optics in the instruments or COSTAR to correct the image. COSTAR was designed by Merk Bottema at Ball Aerospace.

Pointing: Pointing stability to 0.007 arcseconds.

Fine Guidance Sensors = FGS: Used for guiding on stellar images and for excellent quality astrometry.

Operations: Science operations by the Space Telescope Science Institute in Baltimore MD.

Archive: The Multimission Archive at Space Telescope (MAST) includes data from many missions. Its website is http://archive.stsci.edu/.

4 HST Imaging Instruments

HSP = High Speed Photometer: An initial instrument on HST but removed in 12/93. HSP was designed to make very rapid photometric observations of astrophysical sources in a variety of filters and passbands from the near ultraviolet to the visible.

FOC = Faint Object Camera: An initial instrument on HST but removed in 3/02. Highest spatial resolution camera early in the HST mission.

WFPC1 = Wide Field Planetary Camera 1: An initial HST instrument and operated until 11/93 obtaining high resolution images of astronomical objects over a broad range of wavelengths (1150 to 11,000 Å) with a range of filters.

WFPC2 = Wide Field Planetary Camera 2: Installed in 12/93 and still operational. The WFPC2 is used to obtain high resolution images of astronomical objects over a wider field of view and a broad range of wavelengths (1150 to 11,000 Å) with a variety of filters. Decreasing charge transfer efficiency (CTE) in the CCDs is increasing the readout noise.

ACS = Advanced Camera for Surveys: Operational from 3/02 to the present. This is the best imager (widest field and low noise) now available on HST. There are 3 channels:

- A Wide Field Channel (WFC), with a field of view of 202x202 square arcsec covering the range from 3700 to 11000 Å and a plate-scale of 0.05 arcsec/pixel;
- A High Resolution Channel (HRC), with a field of view of 26x29 square arcsec covering the range from 2000 to 11000 Å and a plate-scale of 0.027 arcsec/pixel, fully samples the HST point spread function;
- A Solar Blind Channel (SBC), with a field of view of 31x35 square arcsec, spanning the range from 1150 to 1700 Å with a plate-scale of 0.032 arcsec/pixel.

WFC3 = Wide Field Camera 3: Built to be installed on SM4 in 2005. The near-UV/visible channel (UVIS) uses a large (4096 x 4096 pixel) format backside illuminated CCD. New coatings can provide greater than 50% quantum efficiency (QE) at 2000 Å. The near-IR channel (to 1.9μ) uses state-of-the-art IR focal plane arrays from Rockwell providing a factor of 16 increase in the number of pixels, and over a factor of 2 increase in quantum efficiency over NICMOS.

STIS = Space Telescope Imaging Spectrograph: Installed in 2/97 and fully operational. STIS has a solar blind UV imaging mode.

NICMOS = Near IR Camera and Multiobject Spectrometer: Installed 2/97, ran out of cryogen in 1/99, and rejuvenated with a new cooling system in 2/02. NICMOS provides imaging capabilities in broad, medium, and narrow band filters, broad-band imaging polarimetry, coronographic imaging, and slitless grism spectroscopy, in the wavelength range 0.8-2.5 microns. NICMOS has three adjacent but not contiguous cameras, designed to operate independently, each with a dedicated array at a different magnification scale.

5 HST Spectroscopic Instruments

FOS = Faint Object Spectrograph: Initial complement of instrument but removed in 2/97. Low resolution spectroscopy 1150–8000 Å.

GHRS = Goddard High Resolution Spectrograph: Initial complement of instruments but removed in 2/97. Spectroscopy from 1150–3200 Å with $\lambda/\Delta\lambda$ =100,000, 20,000, or 2,000. MAMA detectors are solar blind. Limited spectral coverage at one time since GHRS is not an echelle spectrograph.

STIS = Space Telescope Imaging Spectrograph: Installed in 2/97 and fully operational. Spectroscopy 1150–9100 Å with $\lambda/\Delta\lambda$ =100,000, 40,000, 20,000, 2,000, or very low resolution. MAMA detectors for UV are solar blind. CCD for visible and near-IR. Wide spectral coverage at one time for the echelle modes. Newest version of the CALSTIS user's manual at http://hires.gsfc.nasa.gov/stis/software/doc_manuals.html

COS = Cosmic origins Spectrograph: Built to be installed in 2005 on SM4. Far-UV channels 1150–1800 Å and $\lambda/\Delta\lambda$ =20,000 or 2,000 with 15 times the throughput of STIS. Near-UV channels 1800–3200 Å and $\lambda/\Delta\lambda$ =20,000 or 2,000 with sensitivity similar to STIS. CASA built COS on the CU campus. Final calibration at Ball Aerospace Sept 18 to Oct 12, 2003.

6 HST Timeline

Initial push: Beginning in the late 1940s Lyman Spitzer, John Bahcall, and colleagues began to call for a "Large Space Telescope".

First call for instrument proposals: March 1977

Proposed launch date: End of 1983

Actual launch date: April 25, 1990

First suite of instruments: FOS, FOC, GHRS, HSP, and WFPC1.

Servicing Mission 1: In Dec 1993 installed WFPC2 and COSTAR. Removed HSP and WFPC1.

Servicing Mission 2: In Feb 1997 removed FOS and GHRS and installed STIS and NICMOS.

Servicing Mission 3: In Mar 2002 installed ACS and the new cooling system for NICMOS. Removed FOC.

Servicing Mission 4: In 2005? to install COS and WFPC3.

Present status: Operational with 3 good gyros and one flaky gyro. HST requires 3 good gyros for pointing and will go into safemode if there are fewer than 3 operational gyros.

Next call for proposals: Announcement in October 2003 for Cycle 13 proposals with a probable due date in January 2004.

Types of proposals: General observer (regular, large, and long term), Snapshot, Archival Research, Theory, Joint with other observatories, Legacy, Treasury, etc. See the HST webpage.

End of HST scenarios: NASA has said that it will operate HST until 2010 (unless it dies earlier), but a recent review panel (John Bahcall, Chair) has recommended that operations continue and that new instruments be considered.

7 More Information

- HST PR website: http://hubble.stsci.edu/.
- Main website of the Space Telescope Science Institute (http://www.stsci.edu/resources/) contains catalogs and surveys, meetings, publications, software, pretty pictures, etc.
- Main website for HST (http://www.stsci.edu/hst/) contains more than you even want to know about the HST instruments, software, approved observing programs for Cycles 1–12, schedules, data archive, data analysis tools, proposal planning tools, etc.

	UV Spectral Range (1150–3200 Å)	
IUE	International Ultraviolet Explorer	1978–1996
HST/GHRS	Goddard High Resolution Spectrograph	1990–1997
HST/FOS	Faint Object Spectrograph	1990–1997
HST/STIS	Space Telescope Imaging Spectrograph	1997 $\Longrightarrow$
HST/COS	Cosmic Origins Spectrograph	???
	FUV Spectral Range (900–1200 Å)	
OAO-3	Copernicus	1972–1981
UVS	UV Spectrographs on Voyager 1 and 2	1977 $\Longrightarrow$
HUT	Hopkins Ultraviolet Telescope	1990, 1995
ORFEUS	Orbiting and Retrievable Far and Extreme UV Spectr.	1993, 1996
IMAPS	Interstellar Medium Absorption Profile Spectrograph	1993, 1996
FUSE	Far Ultraviolet Spectrograph Explorer	1998 $\Longrightarrow$
	EUV Spectral Range (100–900 Å)	
HUT	Hopkins Ultraviolet Telescope	1990, 1995
EUVE	Extreme Ultraviolet Explorer	1992 $\Longrightarrow$
ORFEUS	Orbiting and Retrievable Far and Extreme UV Spectr.	1993, 1996
CHANDRA	Chandra X-ray Observatory	1998 $\Longrightarrow$
XMM-NEWTON	XMM-Newton	1998 $\Longrightarrow$

Instrument	Spectral Range (Å)	$\Delta\lambda$ one time (Å)	Resolution ($10^3\lambda/\Delta\lambda$)	Peak A_{eff} (cm^2)	Flux (S/N=10) in 10^4 s
IUE (SWP-HI)	1160–2000	840	10		
STIS (G140L)	1150–1736	586	0.9–1.4	500	
STIS (E140M)	1150–1735	585	46	80	
STIS (E140H)	1150–1700	210	114	80	
COS (HDC1)	1150–1775	625	20–24	1750	1.3×10^{-15}
COS (HSC)	1230–2000	770	2.5–3.5	1830	1.9×10^{-16}
Copernicus (U1)	900–3150	0.05	20		1×10^{-9}
HUT (first order)	825–1850	1025	0.28–0.62	24	2.5×10^{-15}
ORFEUS	390–1218	300	3	8.9	
IMAPS	920–1120	200	100	4.5	2×10^{-10}
FUSE	900–1187	287	24–30	70	5×10^{-14}
HUT (second order)	420–925	510			
EUVE	70–760	200	0.3	2	
AXAF (LETG)	$\Longrightarrow$160	100	1–2	10	
XMM (RGS)	$\Longrightarrow$80	60	0.1–0.8	200	