Wide-Field Camera 3 for the Hubble Space Telescope

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ABSTRACT

In June 1997, NASA made the decision to extend the end of the Hubble Space Telescope (HST) mission from 2005 until 2010. As a result, the age of the instruments on board the HST became a consideration. After careful study, NASA decided to ensure the imaging capabilities of the HST by replacing the Wide Field Planetary Camera 2 (WFPC2) with a low-cost facility instrument, the Wide Field Camera 3 (WFC3). This paper provides an overview of the scientific goals and capabilities of the instrument.

Keywords: Hubble Space Telescope, HST, instrument, CCD, MCT

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1. INTRODUCTION

Since the meeting of HST's final 2002-Instrument Selection Team that selected the Cosmic Origins Spectrograph, NASA made the programmatic decision to continue operation of HST at least until 2010. The previous expectation was that the 2005 Servicing Mission would be the final, "deorbit" mission. The new plan deletes this 2005 Servicing Mission, replacing it with the last Servicing Mission for upgrading HST in 2003, and the deorbit mission sometime after 2010.

As a result of the decision to extend the HST mission, the Project initiated a number of studies to understand how to use available resources to maximize HST's scientific productivity and competitiveness until 2010. These studies address issues ranging from the optimal approach to replacing spacecraft parts, to the scientific strategy for HST in its second decade of operation.

A serious concern is that in the period 2002 to 2010, an adequate imaging capability on HST may not be assured. In 2010, HST's primary imager, the Advanced Camera for Surveys (ACS), will be 11 years old. The current imager, the Wide Field and Planetary Camera 2 (WFPC2) will be 17 years old. The Space Telescope Imaging Spectrograph (STIS), which has some limited imaging capability, will be 13 years old. The WFC3 Project was initiated to address these concerns. During the study phase for the instrument, it became apparent that the instrument can be tailored to address a number of new scientific questions.

2. SCIENTIFIC GOALS

A main theme for WFC3 science is the ability to do wide-field, panchromatic imaging. Its UV/visible UVIS channel extends large-format imaging to the near-UV. Its wide-field IR channel will explore the IR universe that has been revealed by the NICMOS deep field observations. With an appropriate set of narrow-band filters, both of these wide-field and low-noise channels are well tailored for probing the astrophysics of the interstellar medium.

These features can also be brought to bear to provide an unprecedented panchromatic view of galaxy evolution. It will allow for studying the controlling mechanisms of star formation in galaxies, and help interpret the flood of tantalizing data on very distant galaxies. These data are often observed in the restframe UV, and we require high quality UV-optical-IR imaging of nearby objects for which good correlative radio, infrared, and X-ray data are available.

WFC3 is uniquely capable of providing such imaging. The UV conveys the most information about the history of star formation over the past 500 Myr, and allows direct detection of massive stars responsible for most of the ionization, photodissociation, kinetic energy input, and element synthesis in galaxies. The IR traces the mature stellar population, most of the stellar mass, and probes dusty star forming regions. The panchromatic coverage of WFC3 from the near-UV at 200 nm to the near-IR at 1800 nm, with high resolution over a wide field, therefore offers powerful insights into galaxy evolution.

3. INSTRUMENT PERFORMANCE

Table 1 summarizes the key scientific specifications for the instrument. The field size is carefully optimized given the available detector technology and the maximum desirable pixel size, including the effectiveness of image reconstruction techniques like *drizzling*. Figure 1 shows the relative field sizes for the HST imaging instruments (and instruments with imaging modes).

The expected total instrument limiting flux as a function of wavelength is shown in Figure 2. The wide wavelength coverage at high efficiency is made possible by the dual-channel design using two detector technologies.

The optical purity of the instrument will support diffraction- limited imaging through 300 nm for the CCD channel, and 1000 nm for the IR channel. This allows the instrument to exploit another unique HST capability, that of a well-defined and uniform point-spread-function over the entire field-of-view.

4. INSTRUMENT CONFIGURATION

The WFC3 is configured as a two channel instrument. The incoming beam from the HST is directed into the instrument using a pick-off mirror. It is then corrected for the spherical aberration (of the HST primary mirror) using a two element system to reimage and correct the pupil. The corrected beam is then sent to either a UV/visible UVIS channel or an IR channel.

Table 1. Key scientific specifications for the WFC3.

	UVIS Channel	IR Channel	Units
[2pt] Format	2 x 2K x 4K	1K x 1K	pixels
Field	160 x 160	135 x 135	arcsec
Pixel	39 x 39	130 x 130	milliarcsec
Spectral Range	200 to 1000	600 to 1800	nm
Dark Current	< 0.003	< 0.4	e^-/pixel/sec
Readout Noise	< 4	< 15	e^-/readout
Operating Temp	-90	-120	C
Filters	48	> 10	

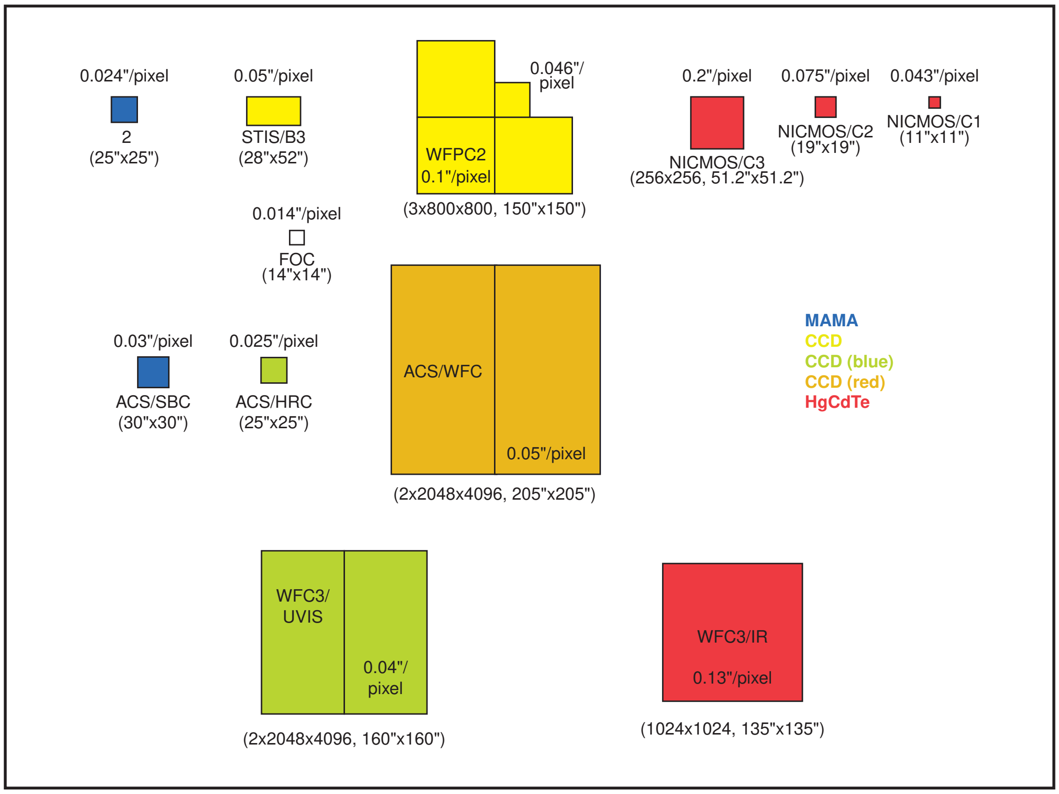

Figure 1. Imaging fields-of-view for HST instruments. The spectral range covered by the particular mode or channel is shown schematically by its horizontal location (far left is 100 nm UV, far right is 2500 nm IR).

5. NEW TECHNOLOGY

The WFC3 is a fourth-generation instrument for HST. It is built on a low-cost paradigm that maximizes the reuse of existing designs and parts. In order to improve its scientific productivity, we have incorporated new detector technologies wherever possible.

The UVIS channel uses a large format, 2 x 2K x 4K CCD design. This is similar to the configuration used by the HST Advanced Camera for Surveys, scheduled for deployment in 2001. The additional time available for WFC3 permits using advanced coating technology for the backside-illuminated WFC3 CCDs. These coatings can provide

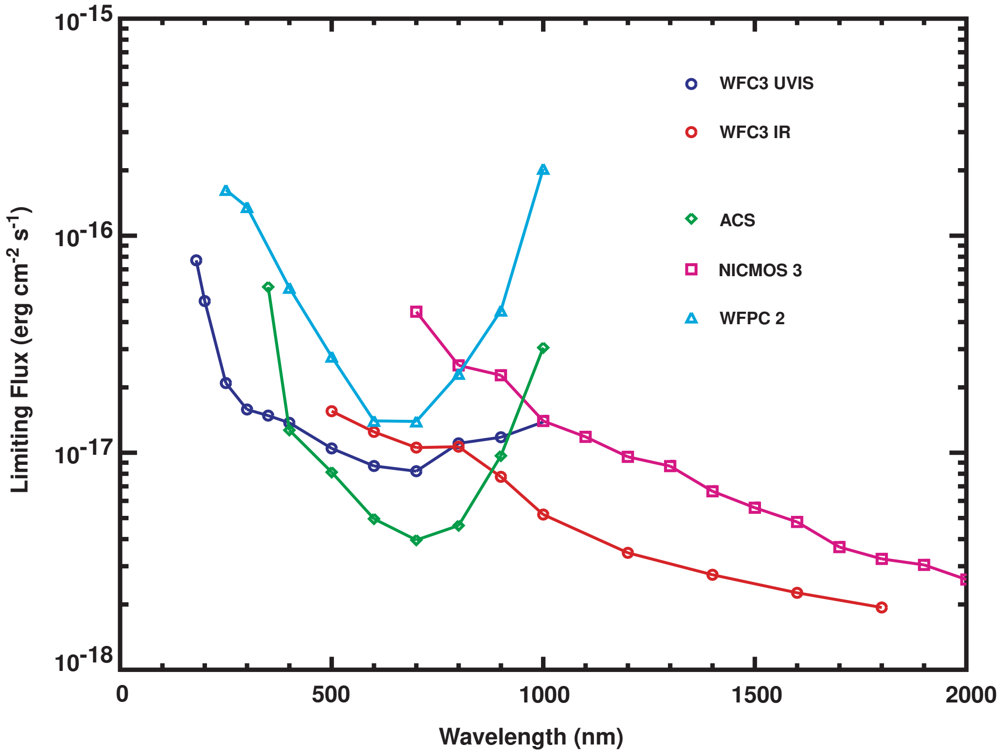

Figure 2. Expected limiting flux for WFC3 as a function of wavelength (S/N= 10, 1 hour exposure).

greater than 50% quantum efficiency (QE) at 250 nm to improve near-UV capabilities.

The near-IR channel uses a state-of-the-art Mercury-Cadmium Telluride (MCT) focal plane array from the Rockwell Science Center. This detector is a more advanced version of the ones in the HST Near-Infrared Camera and Multi-Object Spectrometer (NICMOS) instrument, providing a factor of 16 increase in the number of pixels, and over a factor of 2 increase in quantum efficiency. Another innovation in the MCT detectors is our tailoring the long-wavelength cutoff to a shorter wavelength than is usual. This cutoff (at 1.8 m) allows the detector to operate at relatively warm temperatures (-120C) with acceptable dark current. This feature simplifies the instrument, allowing the use of thermoelectric cooling systems instead of the cryogens or mechanical cryocoolers that are typical in other IR instruments.

6. SCIENTIFIC OVERSIGHT COMMITTEE

The WFC3 Scientific Oversight Committee (SOC) is chartered to provide broad scientific advice to the WFC3 project. Members of the SOC are listed in the third list of authors for this paper. The SOC defines the key scientific objectives achievable by the WFC3, within the instrument's main programmatic and technical constraints. The SOC works closely with the WFC3 Science Integrated Product Team (SIPT), which consists of scientists from GSFC, the STScI, and JPL. The SIPT provides daily scientific oversight for the Project.