WFC3 Calibration & Data Processing

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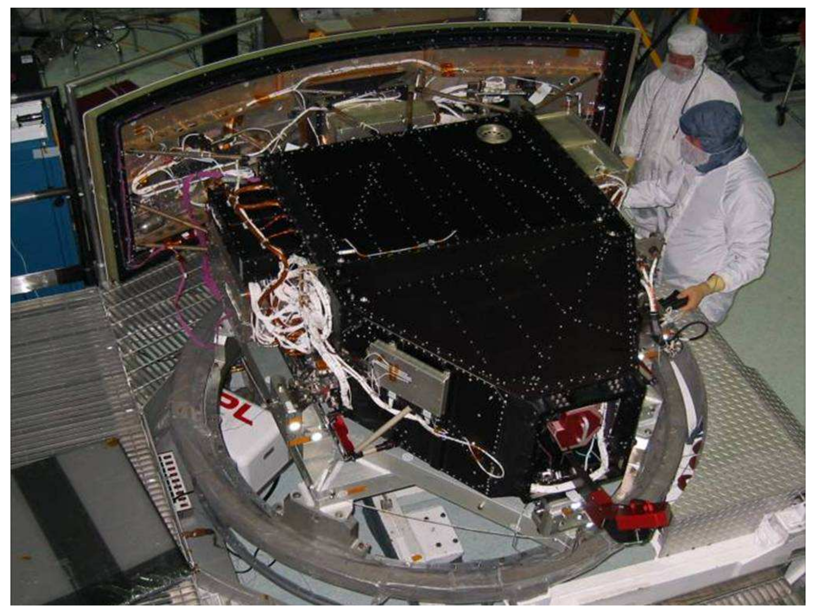
Introduction

Wide-Field Camera 3 (WFC3), a panchromatic imager being developed for the Hubble Space Telescope (HST), is now fully integrated and over the past year has completed first rounds of extensive ground testing at Goddard Space Flight Center (GSFC), in both ambient and thermal-vacuum test environments. This report summarizes the results of those tests and describes the pipeline processing methods that will be used to calibrate WFC3 data.

WFC3 is designed to ensure that the superb imaging performance of HST is maintained through the end of the mission and takes advantage of recent developments in detector technology to provide new and unique capabilities for HST. WFC3 contains ultraviolet/visible (UVIS) and near-infrared (IR) imaging channels, offering high sensitivity and wide field of view over the broadest wavelength range of any HST instrument. It is slated to replace the current Wide Field and Planetary Camera 2 during Servicing Mission 4.

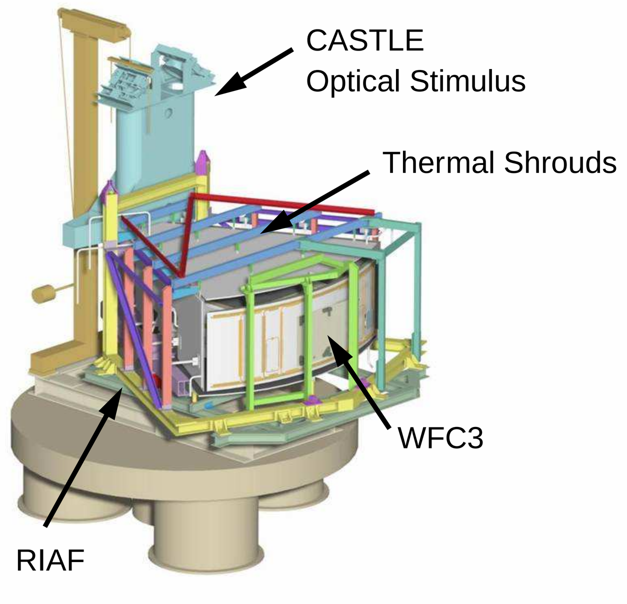


The WFC3 UVIS channel is based on elements from the Advanced Camera for Surveys (ACS) Wide Field Camera (WFC), with a 4096x4096 pixel Marconi CCD covering a 160x160 arcsecond field of view. The WFC3 UVIS channel is optimized for maximum sensitivity in the near-UV and contains a complement of 48 spectral filters and a grism. The WFC3 IR channel uses a 1024x1024 pixel HgCdTe Hawaii-1R detector array covering a 135x135 arcsecond field of view. The array sensitivity is optimized in the 0.8-1.7μm spectral range. The IR channel accomodates 15 filters and 2 grisms for slitless spectroscopy.

Test Setup and Procedures

WFC3 is designed to have its UVIS and IR detectors cooled to flight temperatures of -83°C and -123°C, respectively, to minimize dark current and thermal background. The IR detector can only be cooled sufficiently close to this flight temperature when it is in a thermal-vacuum environment, while the UVIS detector can be tested in both ambient and thermal-vacuum conditions. To date, the WFC3 UVIS channel has undergone 2 episodes of ambient testing, in January and June-July 2004. The UVIS and IR channels have together undergone thermal-vacuum testing during September-October 2004.

In both environments, the WFC3 is mounted to the Radial Instrument Alignment Facility (RIAF), which provides a reference to the HST latch plane. An optical stimulus apparatus, known as "CASTLE", is also mounted to the RIAF and is used to provide external sources to WFC3 for testing. The CASTLE is capable of providing point and extended targets, as well as flat-field illumination, over the entire wavelength range of WFC3. Single- and double-mode monochromators in CASTLE can be used to control the bandwidth of all sources. The CASTLE also includes NIST-calibrated detectors to measure absolute flux levels of incident sources, which are used to measure the absolute throughput and sensitivity of WFC3.



During routine data taking episodes, WFC3 test exposures are commanded via an HST-style SMS run on the instrument. Complementary scripts are used to control the CASTLE optical stimulus, to provide the desired source for each exposure, resulting in a highly automated process. All exposures are processed, previewed, and archived locally, and are also automatically sent to the STScI pipeline (OPUS) system to be converted to FITS files and stored in the long-term HST archive.

Ground Tests Performed

The goals of the ground tests performed to date were to:

- Characterize the thermal performance of WFC3
- Demonstrate flight-like operations of the UVIS & IR channels
- Characterize the science capabilities of WFC3

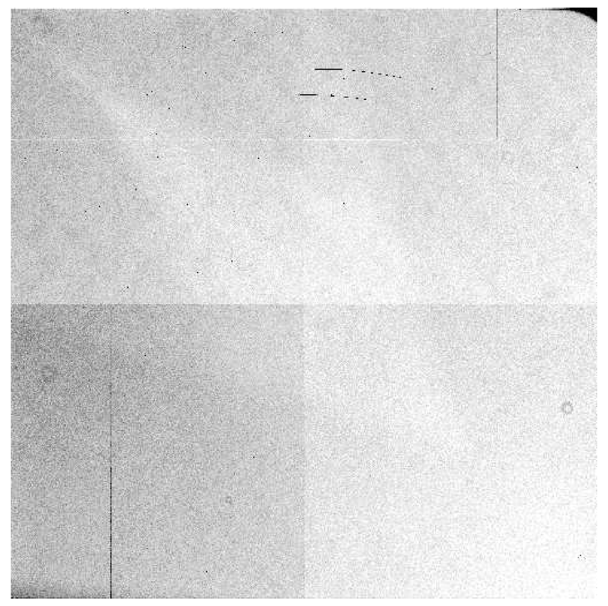
The following sets of tests have been performed during the ambient and thermal-vac testing campaigns:

- Detector Alignment
- Encircled Energy
- Read Noise
- Dark Current
- Flat Fields
- Detector Gain
- Detector Linearity
- Image Stability
- Detector Crosstalk
- Grism Dispersion
- Filter Ghost Checks
- Thermal Background (IR only)
- System and Filter Throughputs
- Internal Calibration System Checks

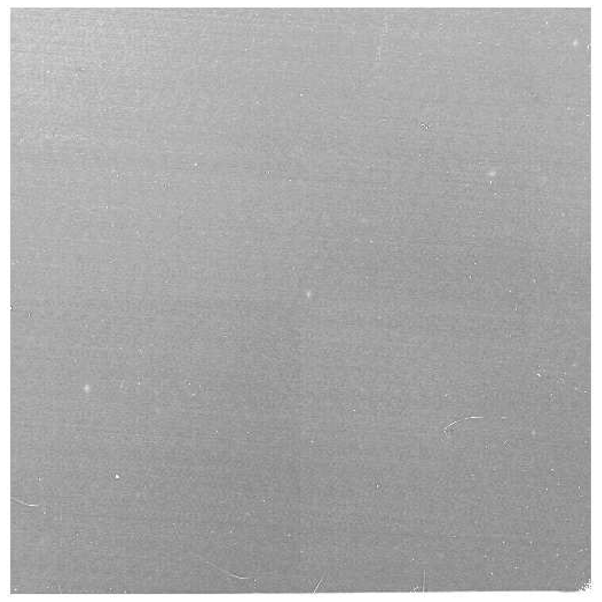
Detector Characteristics

UVIS:

Dark Current:	0.3 e^-/pix/hour	(spec: < 20 e^-/pix/hour)
Read Noise:	3.0 e^-/pix rms	(spec: < 4 e^-/pix rms)
Linearity:	5% deviation at ~67,000 e^-	(spec: < 5% up to 50,000 e^-)
Full-well:	~70,000 e^-/pix	(spec: > 50,000 e^-/pix)



UVIS CCD 555nm Flat Field Image



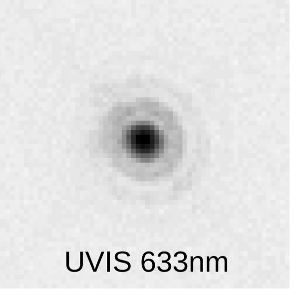
IR 1.6μm Flat Field Image

IR:

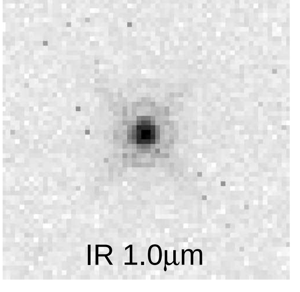
Dark Current:	0.15 e^-/pix/sec	(spec: < 0.4 e^-/pix/sec)
Read Noise:	22 e^-/pix rms (correlated double read)	(spec: < 15 e^-/pix rms)
Linearity:	5% deviation at ~93,000 e^-	(spec: < 5% up to 70,000 e^-)
Full-well:	~105,000 e^-/pix	(spec: > 100,000 e^-/pix)

Encircled Energy

UVIS: 250nm: ~72% total light in 0.20" radius
633nm: ~79% total light in 0.25" radius



UVIS 633nm



IR 1.0μm

IR: 1.0μm: ~60% in 0.25" radius; ~75% in 0.37" radius
1.6μm: ~46% in 0.25" radius; ~80% in 0.60" radius

High-Level Results

- Achieved first integrated operation of IR channel
- UVIS and IR detectors show same good performance seen in previous unit tests
- Routine science operations in flight-like conditions have been demonstrated
- Good margins on achievable UVIS and IR detector temperatures
- IR thermal background lower than expected from subsystem tests
- Optical performance is generally excellent, with UVIS and IR image quality at or near specifications

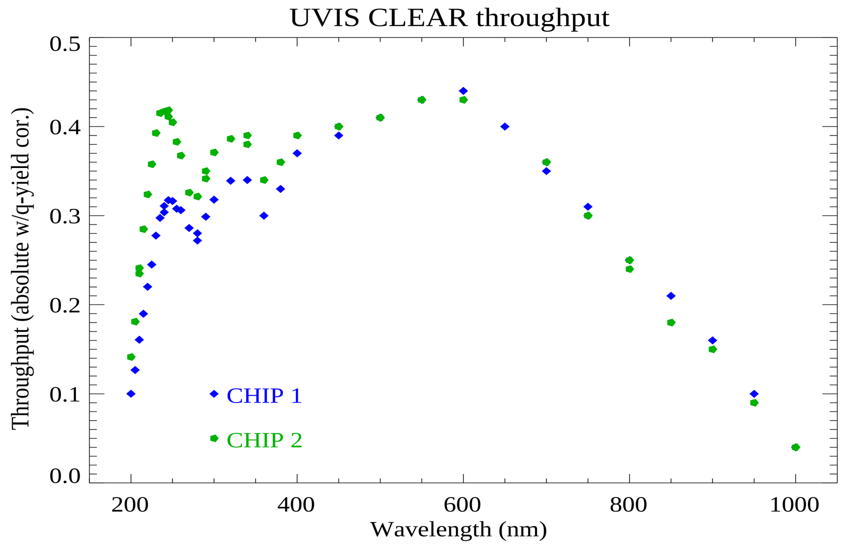
Instrument Science Reports

All data analysis results to date have been documented in a series of over 30 ISRs, which are available for downloading from the HST WFC3 web site at:

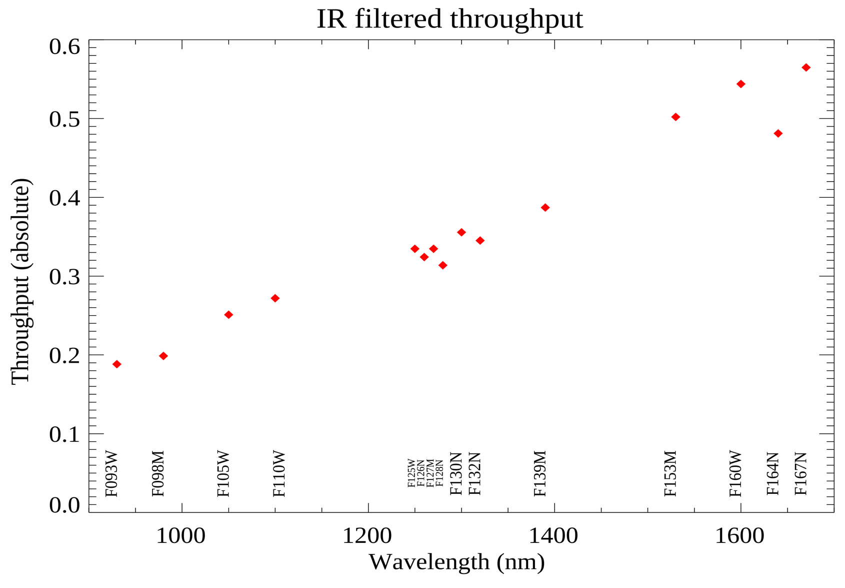
http://www.stsci.edu/hst/wfc3/documents/ISRs

Throughput

The blue-optimized CCD's of the WFC3 UVIS channel result in system throughputs that are below that of ACS/WFC at the red end of the optical range, yet far exceed that of WFPC2 at near-UV wavelengths. The plot below shows the througput of the UVIS channel (optics+detector) without filters in place.



WFC3 IR channel throughputs are 50% or more higher than that of the HST NICMOS cameras over the 0.9-1.7μm wavelength range. The plot below shows the throughput of the entire IR channel as seen through each IR filter.



Pipeline Processing

The calwf3 pipeline that will be used in the STScI OPUS system to calibrate WFC3 data will be very similar to the calacs pipeline in high-level structure. There will be two main branches: one for UVIS channel images and another for IR images. The steps applied on the UVIS branch will be the same as what's used for ACS/WFC images and the IR steps will be similar to NICMOS processing.

Basic calibration will include the usual necessary steps such as bias and dark subtraction, flat fielding, and saturation and bad pixel flagging. UVIS images will also have shutter shading and post-flash corrections, as necessary. IR exposures will receive a non-linearity correction and "up the ramp" fitting, which includes CR rejection.

The ground system will allow observers to obtain multiple exposures on a target, in either CR-SPLIT or REPEAT-OBS modes. These multiple images will be associated and combined during calwf3 processing. Both UVIS and IR calibrated images will receive drizzle processing, either as individual images or as associated sets (e.g. for dithered patterns). Drizzle processing is necessary, even for individual images, in order to remove geometric distortions and to correct for distortion-induced photometric errors.