

Pre-Launch Calibration of the Advanced Camera for Surveys

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Introduction

The fully integrated Advanced Camera for Surveys (ACS) (Ford et al. 1998, SPIE Vol. 3356, 234), successfully installed in the Hubble Space Telescope (HST) in early March 2002, underwent a series of ground calibration tests at Ball Aerospace and Technologies Corporation (BATC) and at the Goddard Space Flight Center (GSFC) to verify its performance and flight readiness (Hartig et al. 1998, SPIE Vol. 3356, 321). The flight build detectors were installed in late 2000 and the majority of the flight quality data were acquired in the following year. The activities revolved around several major campaigns designed to characterize the flight build detectors and the optical and ultraviolet channels of the instrument and to verify the contract-end-item specifications. In the following, we briefly describe the different ground-based activities.

1. Pre-Shipment Testing at BATC

At BATC, the Refractive Aberrated Simulator/Hubble Opto-Mechanical Simulator (RAS/HOMS) (Sullivan et al. 1993, SPIE Vol. 1996, 237), an HST simulator capable of delivering external monochromatic point-source and broad-band full-field illumination at $\lambda > 350$ nm, was used to verify several calibration items :

(a) image quality vs field position : The instrumental PSF was characterized at several locations in the field-of-view of each detector and the optimal focus and corrector adjustments were determined.

(b) external “white light” flat fields : RAS/HOMS was equipped with a Mylar flat field diffuser at the pupil mask location so that “white light” illumination from a quartz-tungsten-halogen (QTH) lamp approximately simulated the OTA beam angles over the entire field. Flat fields were acquired through all filter combinations, up to signal levels that reached the full well of the CCD detectors.

(c) external monochromatic flat fields : The QTH lamp was fed to a monochromator and flat fields were acquired at several wavelengths (2 nm resolution) across the broad-band filters for assessment of the optimal scheme for flat-fielding of the ACS ramp filter images and for numerical modeling of the fringe pattern in the CCDs at $\lambda > 700$ nm.

(d) wheel position vs ramp filter wavelength : The optimal filter wheel position for five separate wavelengths spanning the entire range of each linear ramp filter segment was determined by mapping the location of monochromatic patches on the detectors, resulting in a refinement of the component-level ramp calibration measurements.

(e) straylight evaluation (point source) : A bright point source was imaged at the field center, corners, and along the mask edges of the detectors to look for evidence of stray light and “ghosts”.

(f) geometric distortions : A Ronchi ruling was placed at the RAS focal plane and measurements were made through a broad-band (F625W) and polarizer filters. These will serve as first estimates of the instrumental distortions and will fill the reference tables of the STScI pipeline.

(g) coronagraph performance : A bright point source was translated over the two coronagraphic spots and the Fastie finger to evaluate their suppression capabilities and their sensitivity to decentration.

(h) shutter performance : The accuracy of the shutter and exposure non-uniformity “shading” effects were measured from the shortest allowed exposure times up to significantly longer exposures with external “white light” flat field exposures.

2. Post-Alignment Testing at GSFC

In the Spacecraft Systems Development and Integration Facility at GSFC, the light stimulus was delivered by the Calibration Delivery System (CDS) through the Reflective Aberrated Simulator for Calibration (RAS/Cal) (see Figs 1 and 2) and into ACS configured in the Thermal Balance Fixture (TBF). For a few items, RAS/Cal was not necessary and a simple light stimulus was customized. The principal activities that were covered in the Mar-Oct 2001 period are :

(a) grism (G800L) characterization : The 4 μm pinhole of the RAS/Cal filter wheel was illuminated with a multi-mode fiber which was alternately fed by a QTH lamp and an Ar emission-line source. A dispersed spectrum of the continuum QTH lamp and of the Ar line lamp were taken at 5-6 field points, as well as a direct image of the point source through a broad-band filter.

(b) prism (PR200L) characterization : Light from a Hg line lamp is focused on the RAS/Cal 4 μm pinhole by a MgF_2 lens. A narrow-band filter was inserted in the light path to isolate the Hg 546.1 nm emission line. Dispersed spectra and undispersed point sources were observed at six field locations of the HRC.

(c) HRC and SBC confocality : The correct focus position of the M1 mirror, shared by both the HRC and SBC light paths, was determined at a central field point with RAS/Cal and a D_2 lamp.

(d) absolute throughput of each filter : Monochromatic patches from the QTH and D_2 lamps coupled to the monochromator in the CDS were imaged at the central wavelength of each ACS WFC and HRC filter. The throughput without the filters was also measured. A RAS/Cal photodiode was inserted in the beam to calibrate the absolute fluxes.

(e) polarization efficiency and angle of the visible and UV polarizers : A Glan-Thompson CaF_2 prism polarizer was placed in the unpolarized QTH beam and the “extinction” curve was measured for the most popular combinations of broad-band and polarizer filters. The internal polarization from RAS/Cal+CDS was removed by imaging through the broad-band filter only.

3. Internal Calibration System

When the schedule permitted, ACS underwent a series of tests to verify its internal calibration system in ambient or vacuum environments. The activities included bias and dark current measurements, SBC flat fields, tungsten and deuterium lamp count rates, internal flat field monitoring and stability, flash illumination, charge-transfer-efficiency (CTE) measurements, and filter wheel mapping.

Conclusion

The instrument was delivered to the Kennedy Space Center in late Nov 2001 and short functional tests were executed with the internal calibration system to verify its integrity. The ground calibration provided a comprehensive assessment of ACS and verified that the instrument is in general compliance with its specifications and ready to extend HST’s discovery efficiency by an order of magnitude. ACS was launched on 1 Mar 2002 on the orbiter Columbia (STS-109) for the HST Servicing Mission 3B and was installed on 7 Mar. It successfully passed its aliveness and functional tests.

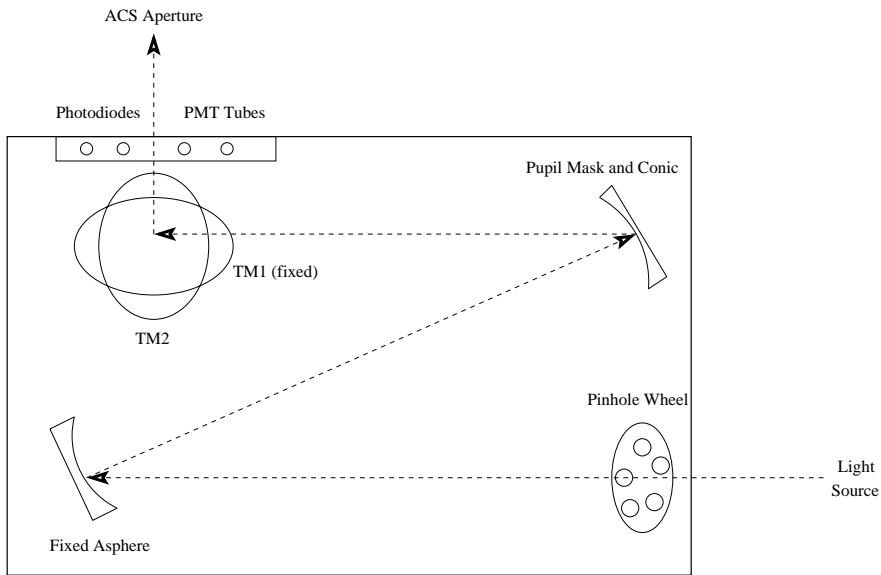


Figure 1: RAS/Cal at GSFC. The incoming stimulus passes through one of five apertures and is then reflected off a fixed asphere followed by a pupil mask + conic. Turning mirror 1 (TM1) is fixed but the tip, tilt, and angle of TM2 are set to their correct values for each selected field point. To move to a specified field point, RAS/Cal is mounted on RAMP, and by computer control, is translated along the X, Y, and Z (focus) axes.

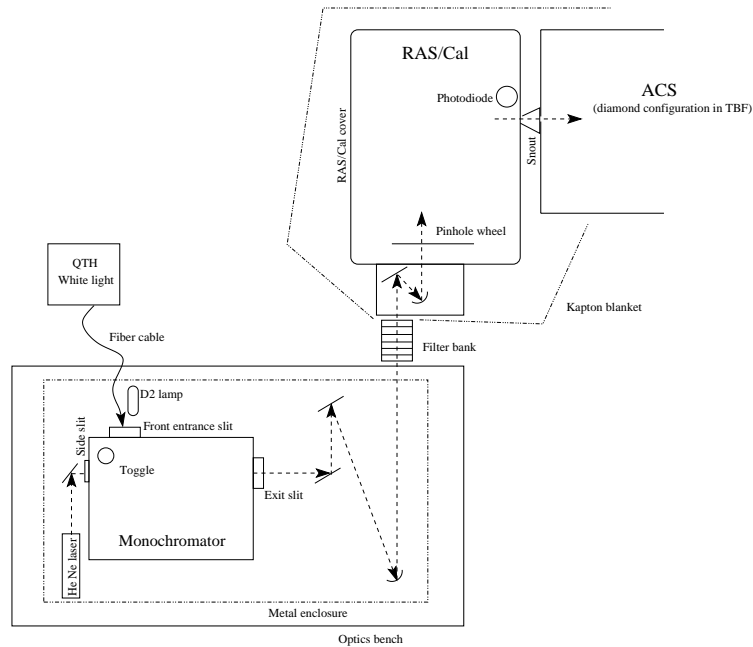


Figure 2: The Calibration Delivery System (CDS) at GSFC. A choice of HeNe laser, Quartz-Tungsten-Halogen (QTH) lamp, or deuterium (D₂) lamp ($\lambda < 350$ nm) feed the monochromator. The entrance and exit slit widths are typically set for a bandpass of 1-2 nm. The monochromator includes two gratings for “blue” (VIS : < 510 nm) and red (IR) wavelengths. The light intensity can be adjusted with a suite of neutral density (ND) filters. RAS/Cal is covered with lumalloy and Kapton blankets to minimize stray light from the clean room.