ENGINEERING CHANGE ORDER

Center for Astrophysics & Space Astronomy
University of Colorado, Boulder

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Date	November 21, 2002
Sheet	1 of 7

Drawing/Document Title	Drwg/Doc No.	Revision Letter Current	Revision Letter New	Special Distribution
OP-01	COS-01-0001	18	19	
				Stop Production Now ❑ Yes ❑ No

Description of Change:

1. Page 2 (Rev. 18), Sec. 1.2: Replace the entire sub-section with the following modified text.

The HST servicing missions of 1993, 1997, 1999, and 2001 (SM1, SM2, SM3a, and SM3b) met with great success. New instruments (WFPC2, STIS, NICMOS, ACS) have replaced first generation instruments (WF/PC, FOS, GHRS, FOC); the wavelength domain covered by HST has been extended into the near-IR; and several other improvements such as new solar arrays, gyros, FGS units, and a Solid State Recorder that has dramatically increased the data storage capacity of HST, have been implemented.

The final planned HST servicing mission (SM4) is currently scheduled for 2005, when COS and the Wide Field Camera 3 (WFC3) will be installed. COS will be placed into the axial bay currently occupied by COSTAR, which, after SM3b, will no longer be in use. WFC3 will replace WFPC2 in a radial bay, and will provide a back-up imaging capability to ACS as well as unique narrow-band and near-UV imaging science. WFC3's near-IR channel will also provide a unique imaging capability in the *J* and *H* bands. From SM4 until 2010 (the projected end of the HST mission), the HST focal plane will include the following instruments for imaging and spectroscopic studies of the universe: ACS, WFC3, NICMOS, STIS, and COS.

STIS provides a powerful spectroscopic capability for investigating point-like and extended objects over UV and visible wavelengths. At this time, STIS is functioning as expected (better than expected in some areas), except for the following items: (1) the opto-isolator relays suffer resets due to cosmic ray hits (the same is true for the relays on NICMOS; these relays will be fixed on COS in the same manner as they were fixed for ACS); and (2) the near-UV (NUV) MAMA detector has a higher than expected background rate,

Reason for Change:	Disposition/Effectivity				
Updates to COS operations in OP-01.	To Comply With ECO				
	Use As Is				
	Rework To ECO				
	Scrap And Rebuild				
	Record change Only				
	Other (See Above)				

Prepared By:	Jon Morse	Date	21 Nov 2002	CCB Required ❑Yes ❑No	❑Approved ❑NotApproved
Approved By:		Date		❑Class I ❑Class II	Immediate Incorporation ❑Yes ❑No
Approved By:		Date			
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Approved By:		Date		Completion	
Project Mgr:		Date		Date	

due to phosphorescence of impurities in the detector window in the on-orbit radiation environment. (The back-up STIS NUV MAMA flight unit will be used in COS as the NUV detector. This Band 2 MAMA is expected to have a background count rate ~ 1/4 of the STIS NUV MAMA.) COS will provide some redundancy to STIS spectroscopic modes, and will restore scientific capability that may be compromised by the high background rate of the STIS NUV MAMA. But mostly COS will represent the frontier instrument aboard HST for UV spectroscopy of faint sources in the most distant reaches of the Universe.

2. **Page 12 (Rev. 18), Sec. 1.3.3: In Table 1.3-2, change the 2nd order wavelength range for G230L stripe C in the bottom row from 1979-2178 Å to 2164-2361Å.**

3. **Page 134 (Rev. 18), Sec. 5.3.5: Replace the text and figures for the entire subsection with the following:**

5.3.5 Detector Lifetime Adjustments

"Detector lifetime adjustments" may be necessary to maintain the performance of the microchannel plate-based COS detectors. After considerable charge extraction at particular locations on the MCP detectors has occurred, the quantum efficiency will drop. This degradation is localized, so moving the locations where science spectra are projected onto the detectors will recover the QE performance. Resiliency to QE degradation is a function of the quality of the flight MCPs. The baseline aperture plate design allows flat-fielding with the internal calibration lamps over the central ~ ± 1.75 mm of the FUV detector. Figure 1.3-8 shows the locations of 5 potential FUV lifetime adjustment positions of the PSA. (Recall that the aberration corrected image projected onto the detector is much smaller than the size of the aperture, hence the overlapping aperture positions in Fig. 1.3-8 deliver point source spectra to distinct detector regions.)

The specification on the FUV detector is that the rate of gain degradation be < 100%/C/cm^2. This requirement translates to a 1% loss in detection quantum efficiency with 6.1 x 10^9 photons across the spectrum or 1.3 x 10^6 photons/resol. Such a loss would not compromise COS's ability to achieve its science goals, and yet the COS Design Reference Mission indicates that only a few × 10^9 events will be observed *over the entire COS (~7 yr) mission through each channel*. Including events received for flat-field and flux calibration, we may conservatively estimate 10^{10} events observed through each channel during the COS mission. Spreading the predicted 10^{10} events uniformly among the ~4800 total FUV resols results in each resol observing ~2 × 10^6 events.

On the FUV detector, there are ~2400 independent spectral resolution elements (resols) per segment (R = 20,000 modes), with each resol occupying ~40×200 microns (≈ 7×10 pixels ≈ 0.008 mm^2/resol). As stated above, each resol will be capable of supporting 1.3x10^6 events/resol with only a 1% loss in detection quantum efficiency. Even if some regions (e.g., rest Ly α) receive 10 times more events, only a few fresh detector regions are necessary to maintain the COS FUV performance. We suggest making FUV detector lifetime adjustments as necessary, when noticeable QE loss or gain drop has occurred or as observed in periodic gain maps. Section 5.3.5.1 discusses the physical mechanism responsible for loss in DQE, the diagnostics for monitoring the DQE, recommendations on when to adjust the spectrum location, and strategies for mitigating impacts to instrument operations.

The image at the NUV MAMA quickly degrades as a function of radius from the best focus aperture position. Hence, no detector lifetime adjustments are possible that will retain the full spectral resolution. However, spectra received from each grating will shift position on the MAMA as the gratings are scanned in wavelength. In addition, each grating is expected to be slightly mis-aligned with the other gratings and will use its own detector rows in the dispersion direction. Thus, lifetime adjustments for the NUV detector are not viewed as necessary. Limiting the number of detector lifetime adjustments for the FUV detector minimizes the number of times the new detector regions need to be re-calibrated (in terms of flat-fielding and flux calibration), resulting in a substantial savings in calibration orbits over the mission duration. Indeed, calibration – using bright external sources and internal lamps – may be one of the principal causes of detector performance degradation.

5.3.5.1 Microchannel Plate Gain Diagnostics & Spectral Adjustment Strategies

This section pertains to the repositioning of the spectrum on the FUV detector to compensate for fluence induced gain depression that eventually will lead to a loss of detection quantum efficiency. The purpose of this section is to provide practical guidance in determining when the FUV spectrum should be moved in the cross-dispersion direction on the detector.

It is important to understand the mechanism that results in the loss of detection quantum efficiency to appreciate the diagnostic tools. For each detected event a certain amount of charge is extracted from the microchannel plates. The amount of charge is characterized by the modal gain, A_{e-}, and is $\approx 1X10^7$ e^-/event for the FUV01 detector. This gain will decrease over time with total extracted charge due to physical and chemical reactions in the microchannel walls. For new microchannel plates, the gain decreases rapidly with extracted charge. After sufficient charge has been extracted the rate of the gain sag reaches a plateau. This is why the COS plates are preconditioned (or “scrubbed”) with a long exposure to UV radiation in the lab until *the rate of change* of the gain reaches an acceptable level for the mission. This rate of change in gain is quoted in terms of the percent change in modal gain for every coulomb of charge extracted per unit area. The microchannel plates in FUV01 have undergone extensive scrubbing during their processing. Laboratory measurements show that the rate of gain degradation to be < 100%/C/cm^2. Thus, if the modal gain is at channel 10 and then 0.5 C/cm^2 is extracted from the microchannel plates, the modal gain will drop to channel 5 at the location of the charge extraction.

The actual amount of charge extracted per event, or pulse height, is distributed about the modal gain in a pseudo-gaussian distribution, referred to as the pulse-height distribution (see Figure 5.3-2 which shows the measured pulse-height distributions for FUV01 segment A and segment B). The time-to-digital converters have upper- and lower-level thresholds on the charge amplifier output signal. If the pulse height for an event falls between the thresholds, the event is processed and results in a digital event. If the pulse height falls below the lower level threshold or above the upper level threshold the event is rejected.

Now consider the relationship between the lower level threshold and the event pulse height. As the modal gain begins to drop over time (referred to as "gain sag") then those events at the lower end of the pulse height distribution will fall below the lower level threshold. Thus, while the event did initiate an electron cascade in the microchannel plate stack, the event will go unprocessed by the electronics and is therefore undetected. This effect will lower the detection quantum efficiency of the detector and thus the accuracy of the sensitivity calibration of the instrument will degrade.

There are several ways to monitor the gain sag directly and indirectly. The most informative method for monitoring the gain of the microchannel plates is to acquire a time tag data set and create a pulse height image. The pulse height image is a 2-D array where each pixel contains the average value of gain for that position. To form a high quality gain map requires a minimum of 10 events/pixel. Relative variations in the pulse height image are then direct tracers of gain sag. This technique provides the best information as it tracks the local variations in the gain performance. It is expected that a gain map of the detector will trace the region where the spectrum falls and highlight regions where charge has been preferentially extracted. It is worth noting that the pulse height information contained in time tag data contains only 5-bits of information, or 32 bins.

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The second method is to acquire a full pulse height distribution at 7-bit resolution for the entire detector. The full pulse height distribution provides a good measure of the performance of the microchannel plates where the events were detected, but it does not provide the spatial information necessary to fully understand the state of the microchannel plates. For example, if one region of the active area has seen more light than the rest of the detector due to spectral variations, this may not be evident in a pulse height distribution collected from a different spectral distribution. However, it is still a useful tool for monitoring the microchannel plate detector and is the only tool for monitoring an ACCUM image.

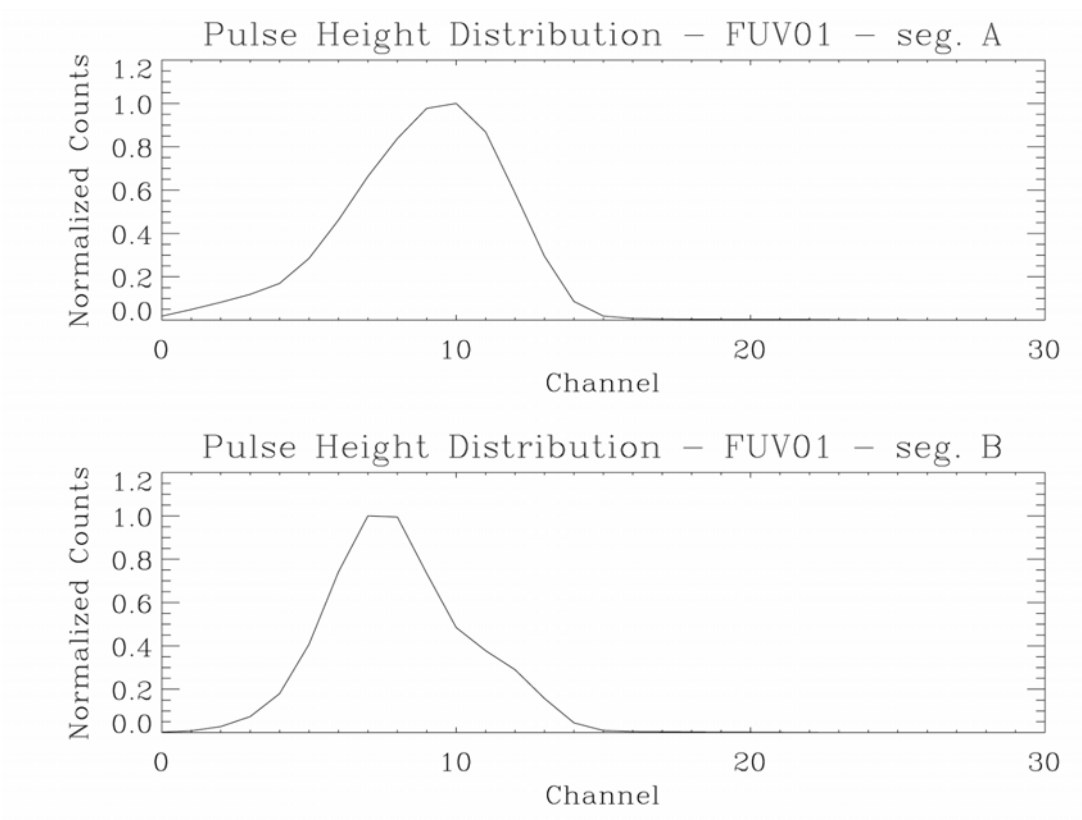

Figure 5.3-2: This figure presents the pulse-height distribution from FUV01 segments A and B in 5-bit resolution mode, the digitization used in TTAG mode.

A total exposure map can be used to correlate observed variations in gain with measured fluence. However, a total exposure map is a lower limit on the number of events detected, since only those events acquired during an exposure are downloaded from the spacecraft. Thus, an exposure map should be considered a secondary technique for monitoring and managing the fluence through the microchannel plates. Also note that is a total exposure map is maintained, which the IDT recommends, the FUV detector must be corrected for thermal and geometric distortions prior to being added to the total exposure map.

The absolute photometric accuracy of HST scientific instruments is typically only 2-3%. Based on this accuracy the IDT recommends that the losses of more than 1% in the detection quantum efficiency warrant one of two corrective actions. One, the instrument sensitivity curve can be recalibrated, or two, the spectrum can be moved. Operationally, this first option of recalibrating the sensitivity may prove expedient while preparations are made for moving the spectrum. When the spectrum is moved to a pristine region of the active area, the modal gain will increase to the nominal value, since minimal charge has been extracted at the new location. This means that another 10^7 events/resol can be extracted from the microchannel plates before the detector experiences a 1% loss in detection quantum efficiency. It is also acceptable to choose to not take corrective action until 2 or 3% of the detection quantum efficiency, thus extending the periods between recalibration efforts. However, the decision to extend the charge extraction limit beyond the IDT's recommendation is left to the Space Telescope Science Institute.

Examining Figure 5.5.-3, we see that as more charge is extracted from the plates the rate at which the quantum efficiency drops increases and that each segment exhibits slightly different performance. In fact, in segment A the integrated percentage drops approximately linearly with modal gain out to channel 3. The integrated percentage is essentially a drop in detection quantum efficiency as it represents events falling below the lower level threshold. The integrated percentage for segment B varies more slowly with channel out to channel 3 and then becomes more non-linear.

Based on the measured performance of the FUV01 microchannel plates the IDT recommends the sensitivity of the COS FUV channel be recalibrated for every drop of 1 channel count in the modal gain for observed decreases in the modal gain of <30% (three channel counts) from the in-flight pulse height distribution as measured during SMOV. Once the modal gain has dropped 3 channels or more the spectra should be repositioned and COS FUV channel completely recalibrated. This will insure that the COS calibration remains accurate.

Practically speaking this means that a recalibration is sufficient for up to a 30% change in the modal gain. This corresponds to 0.3 C/cm^2 of charge extracted. Converting this to events/resol we find that 3.8×10^7 events per resolution element can be expected before repositioning the spectrum is required.

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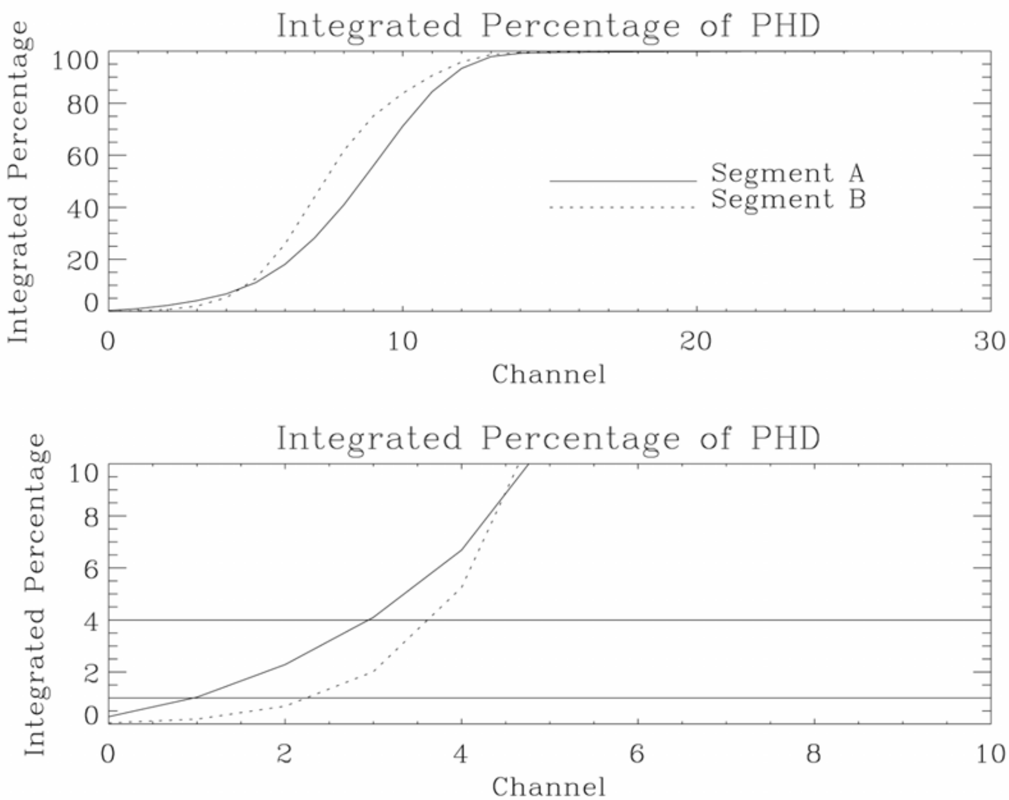

Figure 5.3-3: The integrated pulse-height distribution for FUV01 segments A and B. The top panel is full scale and the lower panel shows the same data, but with an expanded y-scale. The horizontal lines in the lower panel represent 1% and 4% loss of detection quantum efficiency. The vertical line denotes the maximum allowable change in the modal gain before the spectra must be repositioned on the detector.