ENGINEERING CHANGE ORDER

Center for Astrophysics & Space Astronomy
University of Colorado, Boulder

ECO No. COS-057
Date 13 February 2001
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OP-01	COS-01-0001	9	10	
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Description of Change:

1. Replace Table 5.3-2 in Section 5.3.2.1 with the following updated table, which includes a parameter called BFACTOR that is used in the Doppler correction algorithm.

Table 5.3-2: Maximum Doppler Shifts and BFACTORs

Grating	$\lambda_{central}$ (Å)	Dispersion * (Å/pixel)	BFACTOR (=$\lambda_{central}$/Disp) (pixels)	Max shift (integer pixels)
G130M	1300	~0.0094	138298	+/- 3
G160M	1590	~0.0118	134746	+/- 3
G140L	1400	~0.0865	N/A	+/- 0
G185M	1875	~0.0273	68681	+/- 2
G225M	2250	~0.0342	65789	+/- 2
G285M	2850	~0.0400	71250	+/- 2
G230L	2300	~0.3887	N/A	+/- 0

* Dispersions are based on ray trace models. These values should be updated with the “as built” values, as determined during instrument integration & test.

Reason for Change:
Updates to COS operations in OP-01.

Disposition/Effectivity				
To Comply With ECO				
Use As Is				
Rework To ECO				
Scrap And Rebuild				
Record change Only				
Other (See Above)				

Prepared By: Jon Morse Date 13 Feb 2001
Approved By: Date
Approved By: Date
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Approved By: Date
Approved By: Date
Project Mgr: Date

CCB Required ❑Yes ❑No
❑Approved ❑NotApproved
❑Class I ❑Class II
Immediate Incorporation ❑Yes ❑No
Completion
Date

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2. Replace Section 5.3.5 with the following text, which has been updated based on improved understanding of the FUV MCPs.

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 data to distinct detector regions.)

The specification on the FUV detector is that there be only a 1% loss in QE after $1.3\times10^{11}/\text{cm}^2$ events are recorded. 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 $\times\ 10^9$ events will be observed *over the entire COS (~5 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 resels results in each resel observing $\sim 2 \times 10^6$ events.

On the FUV detector, there are ~2400 independent spectral resolution elements (resels) per segment (R = 20,000 modes), with each resel occupying ~40×200 microns ($\approx 7\times10$ pixels $\approx 0.008\ \text{mm}^2$/resel). Therefore each resel would suffer a 1% DQE loss after 1×10^7 events. 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, as observed in periodic gain maps), perhaps at 1 or 2 year intervals. Section 5.3.5.1 discusses the physical mechanism responsible for loss in DQE, the diagnostics for monitoring the DQE, recommendations for 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 ~1×10^7 e^-/event. This gain will decrease over time with total extracted charge due to physical and chemical reactions in the microchannel walls. Initially, the gain can decrease quickly with extracted charge and then reaches a plateau. This is the reason that 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. As of 26 January 2001, the only information regarding the lifetime of the COS microchannel plates has been derived from surrogate plates. These plates are of the same material and underwent the same processing as the flight microchannel plates. After a scrub of 0.2 Coulombs/cm^2, the gain degradation rate was measured to be 100%/C/cm^2. Thus, if the modal gain is at channel 100 and then 0.5 C/cm^2 is extracted from the microchannel plates, the modal gain will drop to channel 50 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, top panel). 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.

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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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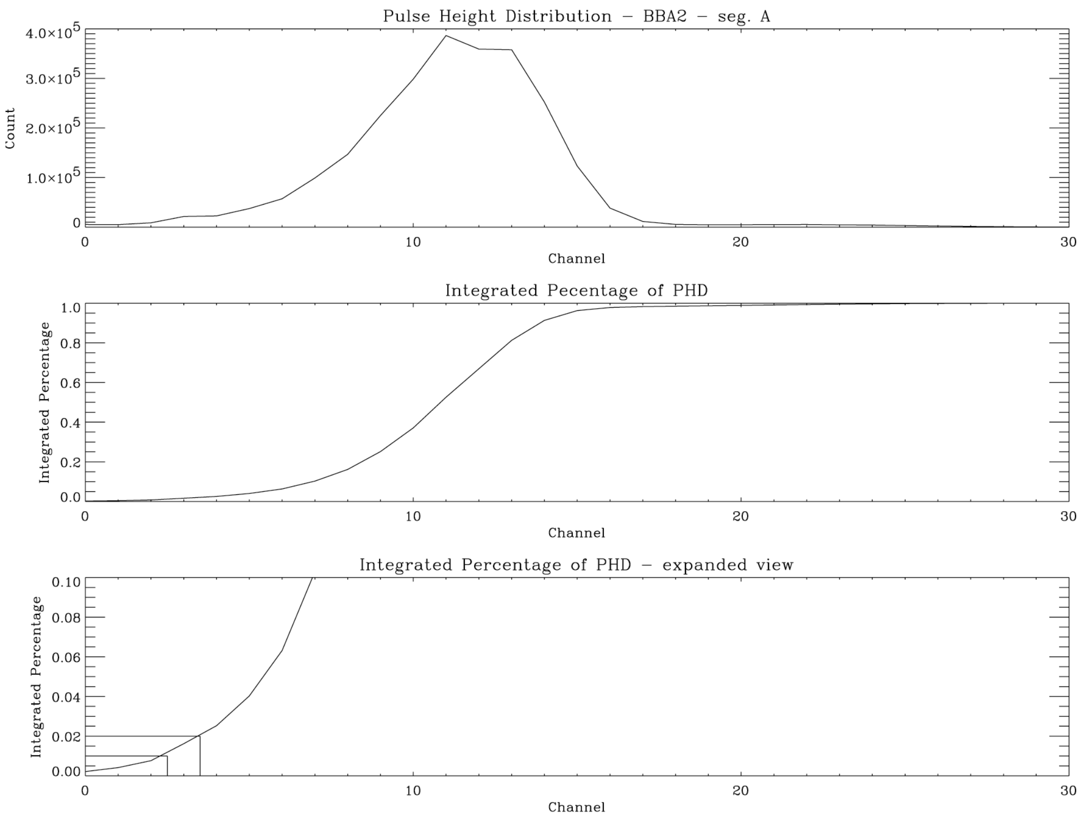

Figure 5.3-2: This figure presents *preliminary* pulse-height distribution from the flight microchannel plates (top panel). The middle panel is the integrated pulse-height. The bottom panel shows the same data as the middle panel, but with a greatly magnified y-scale. It shows that for a 1% drop in quantum efficiency to occur the modal gain must drop more than 20%. A 20% drop in the modal gain corresponds to ~10^7 events/resel or 2X10^{10} events across the entire spectrum.

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 it is the only tool for monitoring an ACCUM image.

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.

The photometric accuracy of the HST scientific instruments is typically only accurate to 2-3%. Based on this accuracy, the IDT recommends that 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. Examining the lower panel of Figure 5.3-2, we see that as more charge is extracted from the plates the rate at which the quantum efficiency drops increases. In fact, it takes only about 1/3 as much extracted charge to lose the second 1% of detection quantum efficiency as it does to lose the first 1%. 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/resel can be extracted from the microchannel plates before the detector experiences a 1% loss in detection quantum efficiency. The decision to extend the charge extraction limit beyond the IDT's recommendation should be based on COS usage on orbit and availability of calibration orbits.