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Cycle 24 HST+COS Target Acquisition Monitor Summary

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ABSTRACT

HST/COS calibration program 14857 was designed to verify that all three COS Target Acquisitions (TA) modes (NUV imaging, NUV spectroscopic, and FUV spectroscopic) were performing nominally during Cycle 24. The program was designed not only to determine if any of the COS TA flight software (FSW) patchable constants need updating, but also to determine the values of any required parameter updates. During all of Cycle 24, the COS FUV channel was operated at lifetime-position 3 (LP3) location, and the NUV channel was at the nominal (LP1) position. Accordingly, all FUV observations in 14857 were performed at FUV LP3 or NUV LP1.

All TA modes were determined to be performing nominally during the Cycle 24 calendar period of October 1, 2016 – October 1, 2017. No COS SIAF, TA subarray, or FSW parameter updates were required as a result of this program.

1. Introduction

There are 3 modes of COS target acquisition (TA); NUV imaging, NUV and FUV spectroscopic. There are 4 COS TA (ACQ) procedures; ACQ/SEARCH, ACQ/IMAGE, ACQ/PEAKD, and ACQ/PEAKXD. ACQ/PEAKD and ACQ/SEARCH step the telescope through dwell patterns on the sky. As long as the target light falls completely within the TA detector subarrays, ACQ/PEAKD and ACQ/SEARCH will continue to operate nominally. In addition to proper TA subarrays, ACQ/IMAGE, and ACQ/PEAKXD[1] require accurate TA-associated flight software (FSW) patchable constants. HST program 14857 verifies that all Cycle 24 NUV and FUV TA subarrays are

[1] At FUV LP3 all ACQ/PEAKXD observations use the optional parameter **NUM_POS**=1.

proper, and evaluates if the actively used WCA-to-PSA offsets[2] are correct. The initial HST/COS target pointing is based upon definitions of the physical locations of the COS apertures in terms of [V2,V3] in the Science Instrument Aperture File (SIAF). All of the actively used NUV (LP1) and FUV (LP3[3]) SIAF entries used for TA are also verified in this program.

In both ACQ/IMAGE and ACQ/PEAKXD[4], the internal wavelength calibration lamp is flashed to locate the wavelength calibration aperture (WCA). From its measured location on the detector, the center of the science aperture (SA) in use can be predicted by applying the FSW constants that give the SA offset compared to the WCA center for the combination of optics in use. For ACQ/IMAGE, the offset is in both the along-dispersion (AD) and cross-dispersion (XD) directions. For ACQ/PEAKXD, which uses dispersed light, this offset is only in the XD direction.

- The ACQ/IMAGE procedure has four combinations of two SAs, the Primary Science Aperture (PSA) and the Bright Object Aperture (BOA), and two mirror modes, MIRRORA and MIRRORB. Each combination is commonly used, and has a different WCA-to-SA offset in both AD and XD, which must be verified[5]. ACQ/IMAGEs also rely upon accurate AD and XD plate scales. These physical plate scales should remain constant for the NUV MAMA and are not monitored or tested by this program.

- The ACQ/PEAKXD procedure used in Cycle 24 relies upon FSW XD WCA-to-PSA offsets[6], and grating-specific XD plate scales[7] Each COS grating, SA, and lifetime position (LP) combination has a different offset. This program verifies all 4 NUV LP1 and 3 FUV LP3 grating-specific WCA-to-PSA offsets, but does not test or monitor the FSW XD plate scales.

- This program does not attempt to monitor the AD accuracy of the COS spectroscopic TA modes.[8]

[2]No BOA spectroscopic TAs were performed in Cycle 24, so these offsets were not verified.

[3]The default COS FUV spectral location was moved to LP3 on February 15, 2015 for all central wavelength settings except G130M/1055 and G130M/1096, which still operate at LP2. On October 2, 2017, the default location of COS FUV spectra were moved to LP4, with additional observing and TA constraints as outlined on the COS2025 website (http://www.stsci.edu/hst/cos/cos2025).

[4]Beginning in Cycle 25, the ACQ/PEAKXD algorithm was enhanced so that two distinct algorithms can be employed. The original ACQ/PEAKXD, used in Cycles 19-24, is referred to as **NUM_POS**=1, while the Cycle 25 (LP4) algorithm uses the ACQ/PEAKD algorithm, but in the cross-dispersion (XD) direction and is referred to as the **NUM_POS**>1 ACQ/PEAKXD.

[5]These offsets are maintained in the FSW as the patchable constant tables *pcta_XImCalTargetOffset* (XD) and *pcta_YImCalTargetOffset* (AD).

[6]Maintained in the FSW patchable constant table *pcta_CalTargetOffset* for both NUV and FUV.

[7]Maintained in the FSW patchable constant tables *pcta_NUVMilliArcsecsPerPixelXDisp* and *pcta_FUVMilliArcsecsPerPixelXDisp*.

[8]For ACQ/PEAKD, short term fluctuations of the detector background rate due to environmental conditions remains the largest source of along-dispersion pointing error.

COS centering requirements are based on wavelength accuracy in the AD, and flux and resolution in the XD. The strictest NUV requirements are [AD,XD] = [0.041, 0.300]$''$. For the FUV channel, they are [AD,XD] = [0.106, 0.300]$''$. The XD requirement for all TAs is centering to within $\pm$ 0.3 $''$ with a 1σ goal of $\pm$ 0.1$''$.

2. Differences from previous HST+COS Monitoring programs

There are several important differences between the Cycle 24 program (14857) and the Cycle 23 program (14440).

In the Cycle 23 HST+COS monitoring program, Visit '01' was an on-hold contingency visit in case visit '2A' of 14452[9], the Cycle 23 FGS-to-SI alignment program did not execute as planned in the fall of 2016. The 14452 visit '2A' executed on Oct 2, 2016 with a COS PSA/MIRRORA ACQ/IMAGE followed immediately by a PSA/MIRRORB ACQ/IMAGE followed by internal lamp exposures. This visit was used to verify the co-alignment of the 'PA" and 'PB' ACQ/IMAGE modes, which the Cycle 23 needed for co-alignment verification of all ACQ/IMAGE modes. The Cycle 24 version of the FGS-to-SI program was replaced with a better program (HST PID 14867[10] for aligning the FGSs which did not allow the inclusion of these ACQ/IMAGE exposures[11]. For Cycle 24, we activated this visit to obtain the needed PSA/MIRRORA to PSA/MIRRORB ACQ/IMAGE alignment verification.

Each visit begins with a comparison of the centering of two ACQ/IMAGE modes out of the possible four (PSA or BOA) × (MIRRORA or MIRRORRB). The visit names were changed from '01', '02', and '03' to 'BA', 'BB' , and 'PB' to indicate which ACQ/IMAGE mode was being tested; PB = PSA/MIRRORB, BA = BOA/MIRRORA, and BB = BOA/MIRRORB. Visits 'BA' and 'BB' of the Cycle 24 program are identical to Visits '01' and '02' of the Cycle 23 program in all other regards. Visit 'PB' of the Cycle 24 program is noticeably different than the contingency visit '03' in Cycle 23 program. The 'PB' visit only includes those exposures absolutely required to compare the ACQ/IMAGE accuracy of PSA/MIRRORA to PSA/MIRRORB, while the Cycle 23 program also obtained spectra of all three FUV gratings for additional monitoring of spectroscopic TA performance under the assumption that detector 'Y-walk' monitoring would benefit from additional observations near the end of the FUV LP3 lifetime. As all three visits of 14857 executed near the end of the LP3 lifetime, these additional exposure were not required.

[9] HST Cycle 23 Focal Plane Calibration (SI-FGS alignment), PI = Colin Cox.

[10] HST Cycle 24 Focal Plane Calibration (SI-FGS alignment), PI = Edmund Nelan.

[11] The FGSs were used as the prime science instrument in this proposal, which precluded the use of COS during the visit as COS is not an allowed parallel HST instrument.

3. Program Structure

Each visit begins with a comparison of the centering of two $\mathrm{ACQ/IMAGE}$ modes out of the possible four (PSA or BOA) $\times$ (MIRRORA or MIRRORRB). This will involve not only the $\mathrm{ACQ/IMAGE}$s, but NUV detector images of the WCA lamp image and, if possible, coeval target images. These direct comparisons are only available for the PSA modes. For the BOA modes, the WCA lamp images and target images are taken consecutively. The assumption is that the PSA/MIRRORA $\mathrm{ACQ/IMAGE}$ centering has not changed since SMOV (questionable). Each of the other science aperture (SA) and MIRRORA/B ACO/IMAGE combinations were co-aligned during SMOV and rely upon the flight software (FSW) WCA-to-SA along-dispersion (AD) and cross-dispersion (XD) offsets.

This back-to-back $\mathrm{ACQ/IMAGE}$ process allows us to test that TA modes are centering the target to the same point in the aperture. The Lamp+target exposures are interleaved throughout the visit to measure and verify the imaging WCA-to-SA offsets are still accurate for the remainder of the current HST Cycle. Images will usually use the PtNe#2 (P2) lamp, as it is the primary TA lamp, but some images will use PtNe#1 (P1) to monitor the lamps in imaging mode.

Visit PB was an on-hold contingency visit in case, for whatever reason, visit 2A of 14452, did not execute as planned in the fall of 2017. This program was replaced with an improved process for aligning the FGSs so we needed to activate this visit to obtain the PSA/MIRRORA to PSA/MIRRORB $\mathrm{ACQ/IMAGE}$ alignment. Visit BA of this program takes back-to-back PSA/MIRRORB & BOA/MIRRORA $\mathrm{ACQ/IMAGE}$s and target TIME-TAG images (with lamp flashes) and also takes G230L, G285M as well as FUV LP3 G130M and G140L spectra to test the WCA-to-PSA offsets. Visit BB of this program repeats the $\mathrm{ACQ/IMAGE}$ sequence for BOA/MIRRORA & BOA/MIRRORB and takes G225M, G185M, and FUV LP3 G160M spectra to test the WCA-to-PSA offsets. To test Ywalk, we also take G160M/1600 exposures offset by **POS_TARG**s by +/- 0.7". As shown in Figure 1, Visit BB of this program also takes a "family portrait" of all the P1/P2 MIRRORA/B WCA lamp images to track any drifting of the centroids, or changes in the lamps.

4. Results

The main results of the HST Cycle 24 COS TA monitoring program are as follows:

SIAF: All COS NUV $\mathrm{ACQ/IMAGE}$s use identical SIAF entries (*LFPSA* or *LFBOA*). Previously, the exposures in the Cycle 23 FGS-to-SI Alignment program (14452) gave a good estimate of the accuracy of the existing NUV LP1 *LFPSA*/*LFBOA* SIAF entries as 14452 performed a PSA/MIRRORA ACQ/IMAGE on a target whose position was already determined by cross-calibration of the other HST Science Instruments (SI). For Cycle 23, data from 14452 indicated that the NUV SIAF entry was accurate to at least [AD,XD] = [0.02,0.08]″.[12] No SIAF adjustments were identified as being needed for NUV (LP1) or FUV (LP3) from this program.[13]

TA Subarrays: Visual inspection of NUV images, and a review of the photon lists of the NUV and FUV spectra, indicate that all TA subarrays are appropriately defined for Cycle 24 and no adjustments were necessary.

NUV Imaging TAs: The COS $\mathrm{ACQ/IMAGE}$ tests in HST 14452 indicate that the centering achieved with a PSA/MIRRORB $\mathrm{ACQ/IMAGE}$ is co-aligned with a PSA/MIRRORA $\mathrm{ACQ/IMAGE}$ to within [AD,XD] $\approx$ $[0.010, 0.020]''$, with a measurement error of approximately $0.014''$. $\mathrm{ACQ/IMAGE}$ tests in HST 14857 reveal that BOA/MIRRORA is co-aligned with PSA/MIRRORB to within [AD,XD] $\approx [0.015, 0.100]''$, [14] and that BOA/MIRRORB is co-aligned with BOA/MIRRORA to within [AD,XD] $\approx [0.007, 0.062]''$.

As shown in Figure 1, HST 14587 obtained a 'family portait' of Cycle 24 wavelength calibration aperture (WCA) lamp images. These images of PtNe lamp light seen through the WCA are used during the LTAIMCAL portion of the LTAIMAGE (ACQ/IMAGE) TA FSW routine to locate the position of the aperture mechanism before centering the target. While COS TAs have used the PtNe#2 lamp for all TAs since installation, images of both lamps (PtNe#1 & PtNe#2) are taken annually with both MIRRORs (MIRRORA & MIRRORB) to monitor the observed count rates. No changes were observed in the PtNe lamp count rates between Cycles 23 and 24.

[12] As determined from the initial pointing before the first COS $\mathrm{ACQ/IMAGE}$ of the program.

[13] Long term SIAF monitoring is used to track any mechanical drift in the location of the COS aperture mechanism, or any changes to the FGS-to-SI alignment that will need adjusting. The last such adjustment was in Cycle 22 (February 2, 2014), while COS FUV observations were at LP2. At this time, all COS entries (NUV and FUV) were adjusted in [V2,V3] by [0.077, -0.070]".

[14] The larger XD alignment error is due to a frequent 1 aperture XD (XAPER) step mechanism position error (1 step $0.048''$).

NUV Spectroscopic TAs: The G285M and G230L WCA-to-PSA offsets were measured after a PSA/MIRRORB $\mathrm{ACQ/IMAGE}$, and were within a XD offset of $0.020''$ of the FSW value for each grating. [15] The G185M and G225M offsets were measured after a BOA/MIRRORA $\mathrm{ACQ/IMAGE}$, and were measured to be within a XD offset of $0.070''$ and $0.060''$, respectively, of the FSW value. Spectroscopic TAs for all NUV gratings met both the $0.3''$ requirement and the $0.1''$ goal.

FUV Spectroscopic TAs: The G130M and G140L WCA-to-PSA offsets were measured after the same PSA/MIRRORB $\mathrm{ACQ/IMAGE}$ as the G285M and G230L observations. The measured offsets were determined to be offset from the FSW values by $\approx -0.030''$ and $-0.170''$, respectively, with a measurement error estimated at $0.070''$. The G160M offset was measured after the BOA/MIRRORA $\mathrm{ACQ/IMAGE}$ used for the G185M and G225M observations. The G160M offset was determined to have a WCA-to-PSA XD offset of $-0.020 \pm 0.070''$ of the FSW WCA-to-PSA value. footnoteSpectroscopic FUV WCA-to-PSA offsets are determined using a mean photon lamp and/or target XD position in the appropriate subarray. The difference between the positions is compared to the FSW value, accounting for any measured offset in the preceding $\mathrm{ACQ/IMAGE}$. Spectroscopic TAs for all FUV gratings met the $0.3''$ requirement and the G130M and G160M gratings achieved the $0.1''$ goal.

[15] Spectroscopic NUV WCA-to-PSA offsets are determined using a median photon lamp and/or target XD position in the appropriate subarray. The difference between the positions is compared to the FSW value, accounting for any measured offset in the preceding $\mathrm{ACQ/IMAGE}$.

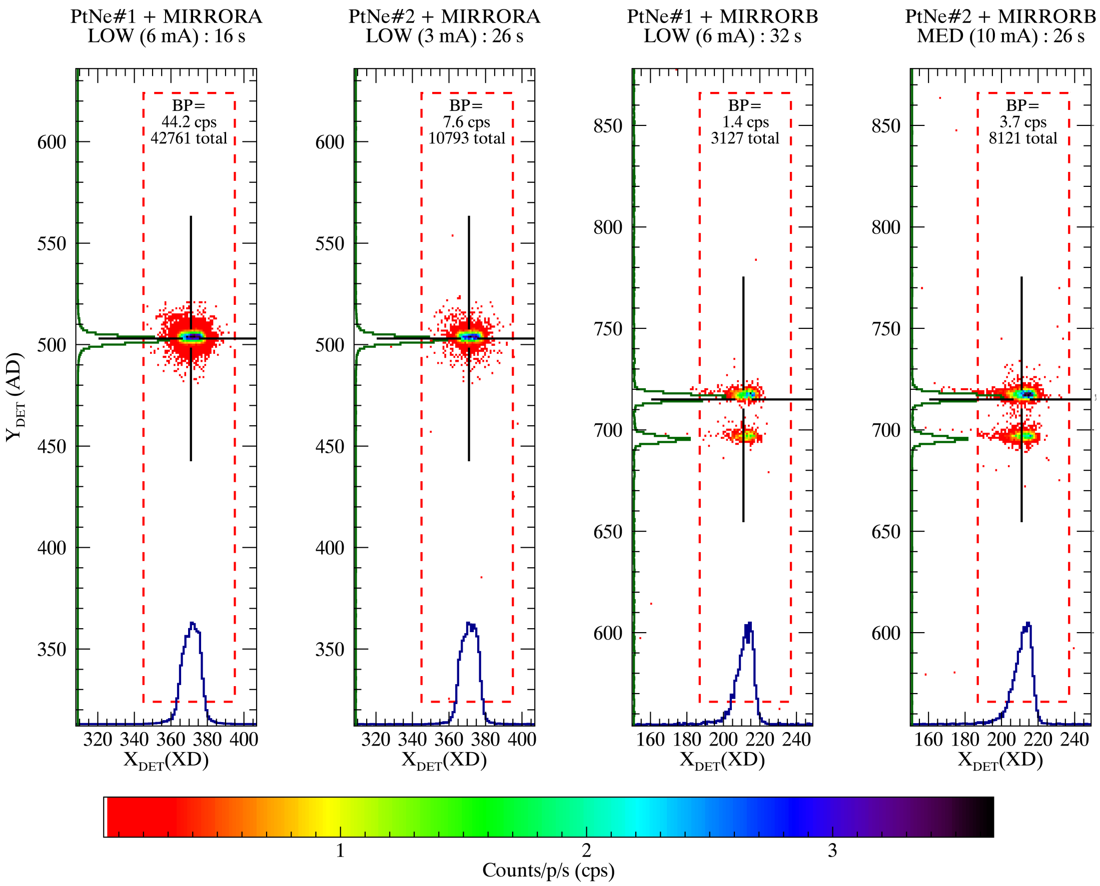

Figure 1. These four panels show a 'family portrait' of the available COS PtNe Lamp + MIRROR combinations possible with ACQ/IMAGE. Panel titles give the lamp and mirror combination, along with the current setting (in milli-amps, mA) and the exposure times in this program. These images are in 'detector' coordinates, as used on-board COS. The images show the observed counts/pixel/s (cps) as given by the colorbar on the bottom. The red dashed boxes show the Cycle 24 ACQ/IMAGE WCA subarrays. At the top of the subarrays, text provides the count rate in the brightest pixel (BP) in units of counts per second per NUV MAMA pixel (cps). The blue histogram on the bottom edge shows the cross-dispersion (XD) lamp profile in detector 'X' coordinates, while the green histogram on the left edge shows the along-dispersion (AD) lamp profile in detector 'Y' coordinates. The cross-hairs show the median location of the given configurations' lamp events within the TA subarray. PtNe#2 lamp was used for all ACQ/IMAGEs during Cycle 24, and was operated at LOW current (6 mA) for those using MIRRORA and MEDium current (10 mA) for those using MIRRORB.

5. Conclusions.

All COS TA modes were verified to be operating within the requirements during HST Cycle 24. All COS SIAF NUV (LP1) and FUV (LP3) entries were determined to be accurate to the needs of COS operations, and all TA and science mode NUV (LP1) and FUV (LP3) subarrays were determined to be correctly defined. Spectroscopic TAs for all NUV gratings met all XD centering requirements. All three FUV gratings indicated some level of Y-walk in the WCA-to-PSA offsets are they were all in the -XD direction. Only the G140L WCA-to-PSA offset indicates a potential Y-walk problem as its offset error ($0.17''$) is larger than the $0.1''$ XD centering goal and is $\approx 60\%$ of the XD centering requirement. Continued monitoring of the LP3 FUV WCA-to-PSA offsets is warranted in Cycle 24 to ensure that FUV spectroscopic TAs are properly centering targets in the XD. Further details on HST Cycle 22 and 23 COS TA monitoring can be found in the annual summary ISRs; COS ISR 2016-09 (Cycle 22, HST PID 13972) and COS ISR 2017-18 (Cycle 23, HST PID 14440). Complete details of program HST PID 14857 and the complete Cycle 19–24 HST+COS TA monitoring program can be found in COS ISR 2018-**XX**.

Further details about COS TA strategies can be found in COS ISR 2010-14 (Keyes, COS Target Acquisition Guidelines, Recommendations, and Interpretation) with detailed information about the on-orbit performance of early COS target acquisitions, including signal-to-noise requirements can be found in COS TIR 2010-14 (Penton, On-Orbit Target Acquisitions with HST+COS).

Change History for COS ISR 2018-XX

Version 1: 7-Dec-2017 Original Document

References

Keyes, T., & Penton, S. COS 2010-14 (v1) (HST+COS Target Acquisition Guidelines, Recommendations, and Interpretation)
Penton, S. 2011, COS TIR 2010-03 (On-Orbit Target Acquisitions with HST+COS)
Penton, S. 2016, COS ISR 2016-09 (Cycle 22 HST+COS Target Acquisition Monitoring Summary (HST PID 13972))
Penton, S. 2017, COS ISR 2017-18 (Cycle 23 HST+COS Target Acquisition Monitoring Summary (HST PID 14440)
Penton, S. & White, J. 2018, COS ISR 2018-**XX** (HST+COS Target Acquisition Monitoring during Cycles 19-24.)