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LP6 Exploratory Study

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ABSTRACT The exploratory study of lifetime position (LP) 5 resulted in the decision to commission LP5 at +5.4 arcsec above LP1 for the G130M setting only. G160M, however, could not be positioned at the same location because its spectral profile projects lower on the detector and would have been impacted by gain sag from LP2. Following this assessment, the LP6 Exploratory Study was conducted to determine the optimal placement of LP6 for the G160M setting above +5.5 arcsec from LP1. Operating COS in this region is complex due to a light leak that occurs above +5.5 arcsec on the detector which prevents concurrent wavelength calibration (wavecal) exposures, combined with the inability to use the deuterium lamp for gain measurements in this region. Here we provide a summary of the investigations conducted to optimize LP6 at this previously unused region with regards to its lifetime and resolution. We additionally describe the process involved with implementing a new mode of wavelength calibrations, 'SPLIT wavecals.' An assessment of both the spectral resolution and gain modeling above LP5 on the detector determined the optimal placement of LP6 to be at +6.5 arcsec on the detector. This position provides the highest resolution possible for LP6, while also enabling a future lifetime position above LP6.

Contents

1. Introduction

Due to a phenomenon called ‘gain sag’, where areas on the COS FUV detector decrease their efficiency to convert photons into electrons due to prolonged exposure to light, it is necessary to move the position of the science spectrum to un-sagged regions on the detector, called new ‘lifetime positions’ (LPs). The COS detector has experienced five such lifetime positions at the start of this study, with the commissioning of LP5 in October 2021, which is located at +5.4 arcsec from LP1, as shown in Figure 1. Here we refer to the position on the detector (i.e., the position that an external target would fall on the detector) in terms of arcseconds, where 1 pixel on the detector corresponds to ~ 0.11 arcsec.

The exploratory effort for LP5 (James et al. 2023a) formed the basis for the LP6 Exploratory Study, which we summarise here. Between February 2019 and September 2020, the COS Team conducted a feasibility study to assess where and how LP5 could be operated at the top of the detector. The dominant issue to consider within the LP5 exploratory study was the existence of a light leak that occurs when the aperture block is placed at a location greater than $\sim$+5 arcsec from LP1 and the wavecal (wavelength calibration) lamp is turned on. Within the LP5 study, it was found that the light leak in fact starts at +5.5 arcsec on the COS FUV detector when the lamp is in medium current mode. As such, the highest aperture block placement that LP5 could be operated with concurrent wavecals was found to be +5.4 arcsec. With this restriction in mind, spectral profiles were measured at this position on the detector and compared to gain map predictions. It was found that G130M could be placed at +5.4 arcsec without being affected by gain sagged regions from LP2. Consequently, LP5 was commissioned for G130M only, as described in Frazer et al. 2023 (in prep) and Fischer W. et al. 2022.

Since G160M projects lower on the detector, the gain sag effects from LP2 on G160M at +5.4 arcsec would be too great (see Figure 5 of James et al. 2023a). Moreover, according to gain modeling predictions, G160M could only be placed at this position for 2–3 years (Johnson et al. 2024). Due to these reasons it was deemed necessary to place G160M above +5.5 arcsec on the detector, despite the inability to perform concurrent wavecals at this position or use the Bright Object Aperture (BOA) at this position due to a soft stop limitation (see Rafelski et al. 2023). This option for G160M was further confirmed to be viable after (i) realizing that the BOA does not have to be at the same location on the detector as the PSA for that particular LP; and (ii) determining that non-concurrent wavecals ('SPLIT-wavecals') could be performed both accurately with regards to aperture stability (Fox et al. 2020) and without excessive overheads for the user by minimizing the number of wavecal exposures (see Rowlands et al. 2023 in prep and James et al. 2023a). Therefore it was determined that the G160M 'long' exposures (i.e., those equal or greater than half an orbit) would be placed at the next new lifetime position LP6, located above LP5. G160M 'short' exposures would remain at LP4, where normal wavelength calibrations are operable. With regards to BOA restrictions, it was decided that BOA observations would not be allowed at LP6 and instead keep them at LPs where they were already calibrated (i.e., G130M and G160M BOA observations remaining at LP4, and G140L BOA observations at LP3). In order to preserve the lifetime of LP4, to keep overheads low for as long as possible and enable the operation of COS out to 2030 and beyond (Rafelski et al. 2023 in prep), it was necessary to commission LP6 in time for Cycle 30.

In September 2020, the LP6 exploratory study group began and was tasked with the goal of examining the upper regions of the FUV detector (>5.4") in order to assess the feasibility of placing G160M, and potentially future lifetime positions, at previously unexplored areas on the FUV detector. Below we outline the considerations that were assessed as part of this exploratory study and the special calibration programs that were designed and executed in order to optimize operations at LP6. Since LPs are typically placed at 2–3 arcsec intervals, several of these programs were designed to characterize the detector at +7, +9, and +11 arcsec. A summary table detailing each of the programs used within this study is shown in Table 1, along with references within the text to the corresponding ISRs which provide a full analyses. Here we provide a brief summary of these programs and several other investigations and their results, each of which played an important role within the exploratory process. As a whole, these programs and investigations led us to the conclusions described at the end of this report.

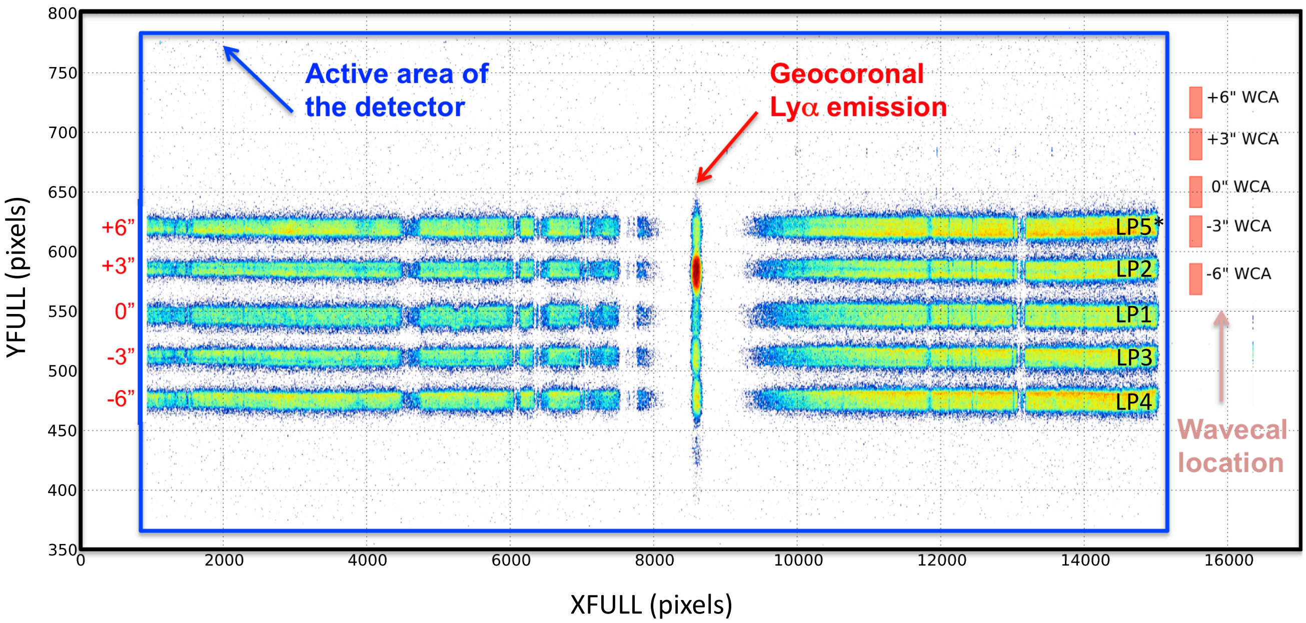

Figure 1. A schematic representation of the COS FUV detector, showing the G130M 2D profiles from program 12678. Each LP is noted, along with its corresponding PSA position in arcsec on the left (red text). On the right, the WCA aperture positions are shown as red boxes. *For LP5 we show a simulated G130M profile at +6 arcsec above LP1 (simply to clearly separate profiles and improve the clarity of the figure), while LP5 is actually located at +5.4 arcsec above LP1.

Table 1. Special calibration programs designed and executed as part of the LP6 Exploratory Study.

PID	Program Title	PI	Date
16472	COS/FUV Gain Map and Aperture Placement at LP6	D. Dashtamirova	12/24/20, 03/15/21
16491	FUV Focus Sweep Exploratory Program for COS at LP6	T. Fischer	03/20-22/21, 04/20-25/21, 06/09-10/21
16495	FUV Exploratory Spectral Resolution Program at LP6	K. Rowlands	07/17-19/21

2. Exploring Gain and Aperture Placement at LP6

In order to map the modal gain at the top of the COS FUV detector, special calibration program "COS/FUV Gain Map and Aperture Placement at LP6" (PID:16472, PI: Dashtamirova) was executed. The goal of the program was to provide gain measurements from +6" to +14" in order to determine the optimal placement of LP6 and possible future lifetime positions. This data would also allow us to identify any regions of low gain in this previously unmapped region of the detector. A full description of this program and its results can be found in Johnson et al. 2024 (in prep), while here we provide a brief summary. Using external exposures of WD0308-565 with G130M/1222 and G160M/1623, the program was able to provide sufficient coverage and distribution of counts to map the gain across the detector (Figure 2). Typically this is done with the deuterium lamp but these exposures cannot be made because the FCA cannot be moved beyond a position that corresponds to where an external target at 5.8 arcsec would fall. The gain maps generated from this data, which we show in Figure 3, showed that the modal gain was > 10 between +5.4 arcsec and +13 arcsec for the HV values of 167/169 used in the program. For context, the typical modal gain for new LPs is $\sim$8–10. Moreover, this region of the detector did not show any artefacts that would affect operations, such as low response regions or holes.

In addition to the modal gain, this program also enabled us to characterize the shape of the spectral profiles for G130M/1222 and G160M/1623. As shown in Figure 4, the 2D profiles get wider with increasing aperture position. Combining these spectral profiles with the gain maps provided guidance on the placement of LP6 with regards to its predicted lifetime (Johnson et al. 2024 in prep). In summary, if the profiles of LP5 and LP6 are placed too close to each other, their respective lifetimes would depend heavily on each other's usage. As such, the profiles from Program 16472 were overlaid on the predicted gain maps from LP5 (after 2 years of LP5 usage) to optimize the placement of LP6 with respect to its potential lifetime at each position. This investigation found that a minimum distance of $>$7.9 arcsec is required to avoid LP5 and LP6 affecting the lifetime of each other due to overlapping continuum traces. Moreover, it was found that in order to fully avoid the Lyman α gain sag regions from LP5, LP6 would need to be placed at > 8.4 arcsec on the detector. However, the spectral resolution, which decreases with position moving up on the detector, also needed to be taken into account at these aperture positions (Section 4).

Ultimately, a decision was made to prioritize spectral resolution over the lifetime and wavelength continuity of an individual LP, and the final placement was placed lower than 8.4 arcsec on the detector. Gain modeling predictions showed that placing G160M at +6.5 arcsec would decrease the lifetime of both LP5 and LP6 by about 1-2 years, but the impact on LP2 would be minimal. At this position, LP6 would start with pre-existing Lyman alpha gain sag holes from G130M/1291 observations at LP5. However, spectral dithering with multiple FP-POS will mitigate the impacts of gain sag holes on producing continuous G160M spectra at LP6. Not only does this enable the best

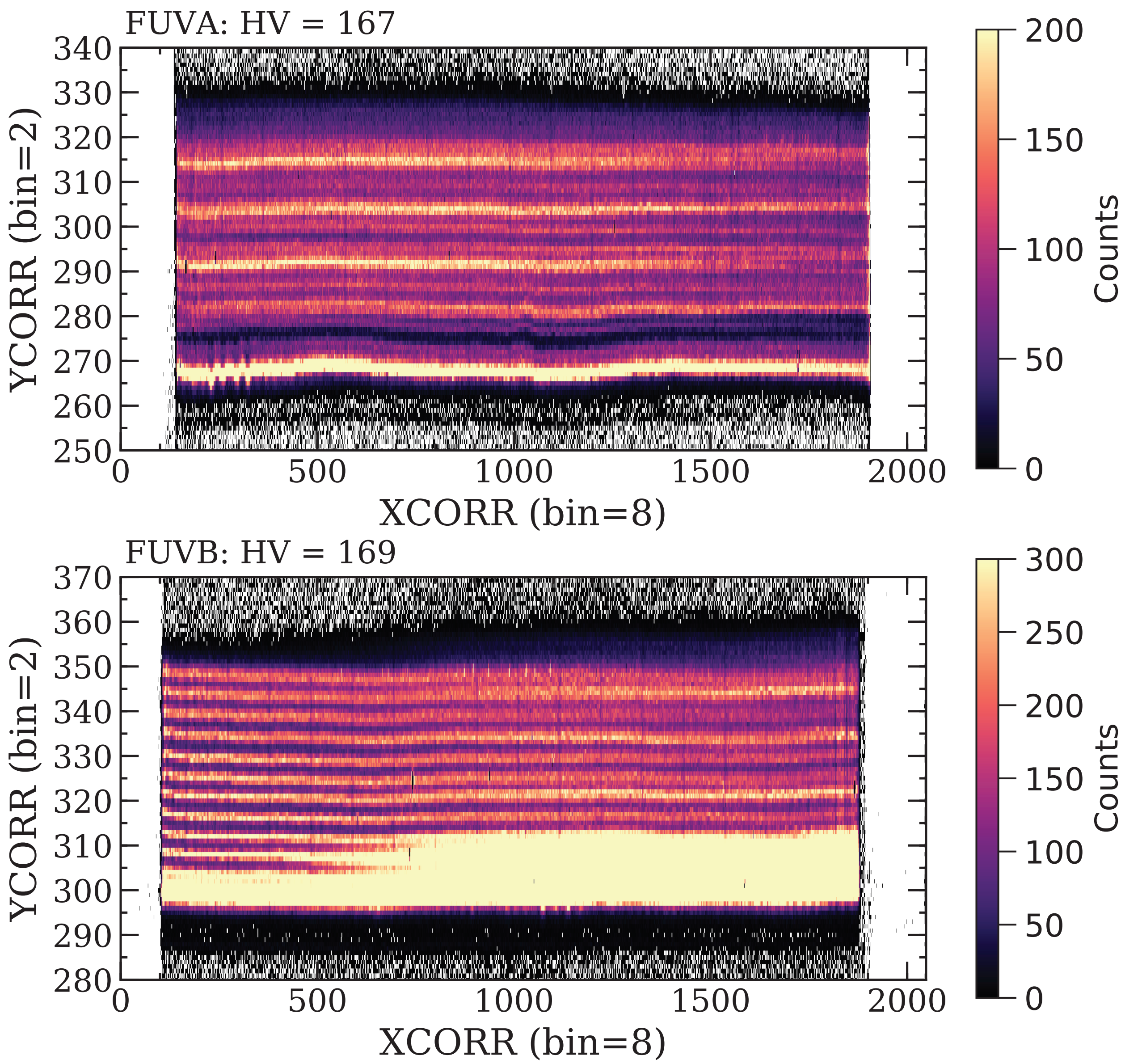

Figure 2. The panels show binned count maps for the FUVA (top) and FUVB (bottom) segments in binned XCORR and YCORR coordinates, based on a combination of data from programs 16106 and 16472. The data cover target offset positions ranging from +5.4 to +13 arcsec with respect to LP1. A minimum of ∼30 counts is needed in each binned pixel in order to obtain an accurate modal gain measurement.

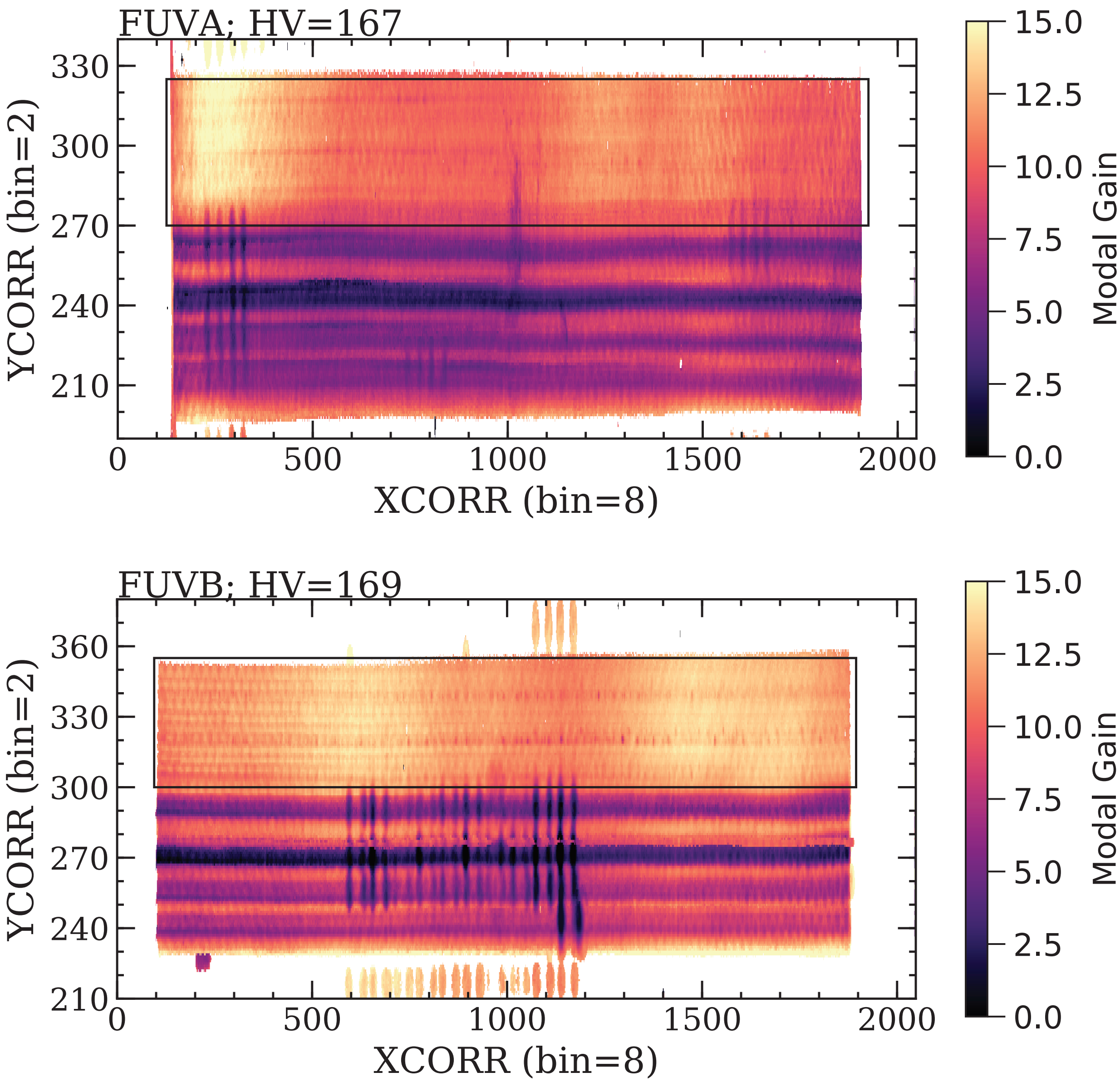

Figure 3. The panels show binned modal gain maps for the FUVA (top) and FUVB (bottom) segments, derived from programs 16106 and 16472. New regions included in the LP6 exploratory programs, which span +5.4 to +13 arcsec, are highlighted with the black box. The upper regions of the detector were found to have modal gain values >10, and did not show any areas of unexpected gain sag. The features at the very top and bottom of the FUVB gain maps are due to airglow through the BOA.

science over the next five years, it also allows us to place another LP above LP6 while maintaining sufficient resolution to address the primary science of COS. We describe these conclusions in Section 7.

3. Focus Sweep Exploratory Program

One of the significant unknown characteristics about spectral performance at the top of the COS FUV detector was the spectral resolution. In order to measure the spectral resolution, the spectrograph needs to be in focus. The best focus of the spectrograph above +5.4 arcsec on the detector was also unknown. As such, with the goal of measuring the spectral resolution at +7, +9, and +11 arcsec on the COS/FUV detector, a special calibration program was executed: “FUV Focus Sweep Exploratory Program for COS at LP6” (PID: 16491, PI: Fischer, T.). Focus sweeps were performed with G130M/1222 (FUVB only) and G160M/1600 settings at each position using Feige 48 (a subdwarf B star). A full description of the program and its analysis can be found in ISR 2022-12 (Fischer T. et al. 2022). Initial estimates of the focus position at +7, +9, and +11 arcsec were made by extrapolating from the focus values used at previous Lifetime Positions. The best focus values found in this program differed by 500 – 1000 steps from these extrapolated values due to changes in the shape of the point spread function as the spectra moved further off axis. Absolute focus values were found to be -967, -908, and -897 steps for G130M/1222 and +78, +219, and +267 steps for G160M/1600, at the +7, +9, and +11 arcsec positions, respectively. These absolute focus values were subsequently used to measure the resolution of G160M/1577 and G130M/1222 at +7, +9, and +11 arcsec, as detailed in Section 4.

4. Resolution Exploratory Program

As discussed above, an essential part of determining the optimal aperture position for LP6 was measuring the spectral resolution over this previously unused region of the detector. With this goal in mind, a special calibration program was executed: “FUV Exploratory Spectral Resolution Program at LP6” (PID: 16495, PI: Rowlands). A detailed overview of this program and its analysis can be found in Rowlands et al. 2023 (in prep). To briefly summarize here, this program performed observations of SMC star AV80 (O5 spectral type) using G130M/1222 and G160M/1577 settings at +7, +9, +11 arcsec from LP1, utilizing the respective absolute focus values provided in Section 3 from Fischer T. et al. 2022. In comparison to previous spectral resolution programs, here high S/N observations (S/N$\sim$40) were made using only two FP-POS settings after binning by 6 pixels. This was due to the large number of overheads involved with performing wavecal exposures at LP2, which were incorporated by-hand into APT at this stage, since SPLIT-wavecals were not yet implemented into TRANS and APT. The analysis of this data showed that the resolution decreased as a function of increasing detector position, as described below. It is important to note that in order to perform

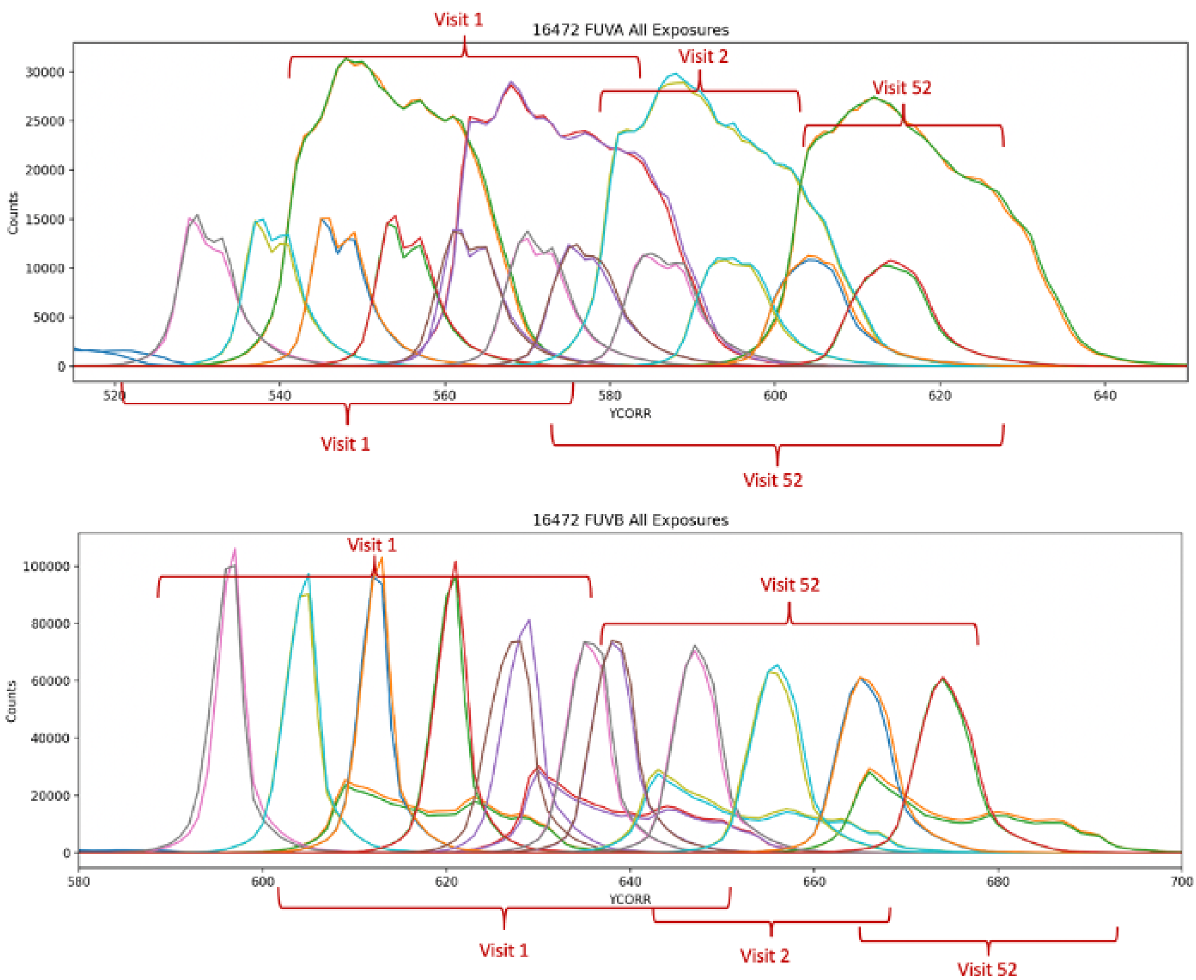

Figure 4. Spatial profiles (i.e. counts collapsed over the dispersion direction) as a function of YCORR position on the detector for G160M/1623 and G130M/1222, as obtained from program 16472. It should be noted that since this program executed before Program 16491 (Section 3), observations were made using focus values predicted from ray trace models. For each exposure, we show the FUVA and FUVB profiles (top and bottom panels, respectively), annotated with the program's visit number.

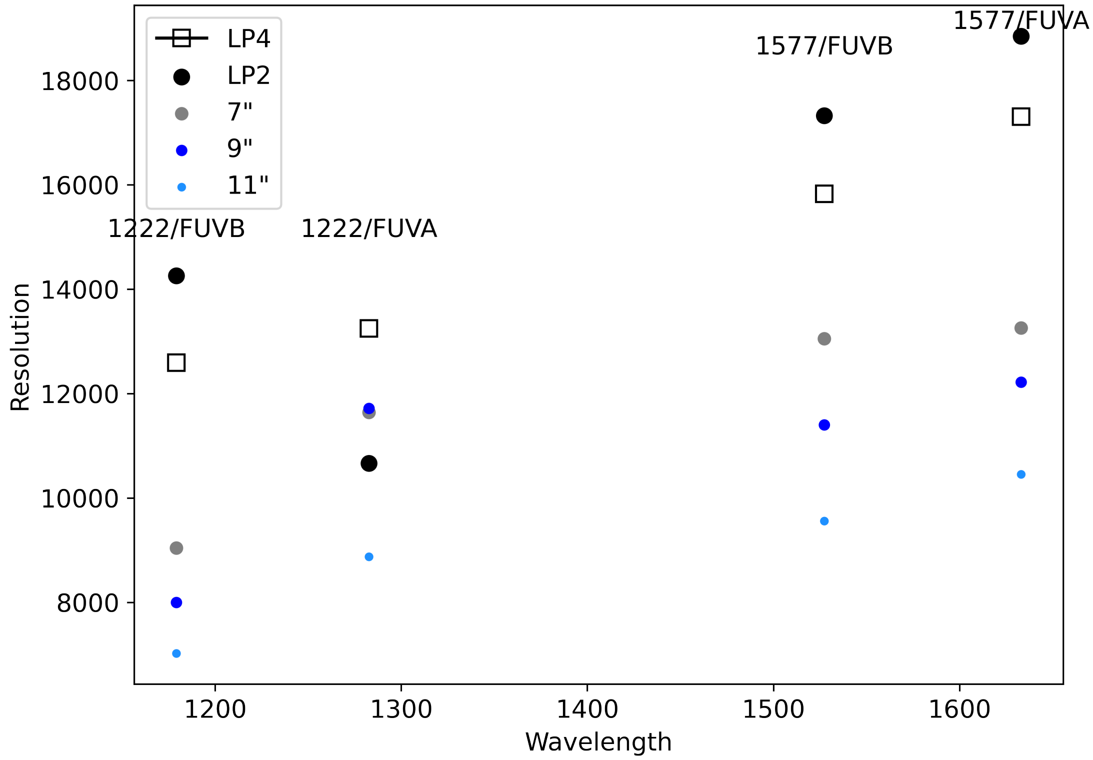

Figure 5. Spectral resolution as a function of detector position, as measured from program 16495 and detailed in Rowlands et al. (2023 in prep). Measurements were made at 7, 9, 11 arcsec on the FUV detector for G130M/1222 and G160M/1577, using the focus values derived from program 16491 and presented in ISR 2022-12 (Fischer T. et al. 2022). For comparison, the resolution values at LP4 and LP2 are also shown.

this analysis, line spread functions (LSFs) were generated using ray trace models at the exact same aperture positions (+7, +9, +11 arcsec from LP1) and as such, the values represent the absolute resolution at that position (Sahnow et al. 2022).

We show a summary figure of this analysis in Figure 5, with the resolution values measured at +7, +9, +11 arcsec compared to LP2 and LP4. Unfortunately, a rather substantial decrease in resolution for G160M/1577 was found between LP2 and 7 arcsec from $R \sim 17,000$ to $R \sim 13,000$, respectively. However, the decrease in resolution between 7 and 9 arcsec was smaller, on the order of $\Delta R \sim 1,000$. From 9 to 11 arcsec the decrease was somewhat larger, $\Delta R \sim 2,000$. From this investigation, we concluded that placing LP6 as close as possible to LP5 would be most beneficial with regards to maintaining high resolution observations with COS at this lifetime position. In addition, by placing LP6 as close to LP5 as possible while maintaining most of the lifetime of LP5 and LP6, we allow for an additional new LP to be placed above LP6 with good spatial resolution. The resolution results, coupled with the gain modeling and profiles shapes from Section 2, were used to define the optimal placement of LP6 as described in Section 7.

5. WCA Position

The use of SPLIT-wavecals requires defining the WCA position at LP6 independent from the PSA position. The PSA and WCA apertures have a fixed spacing in the cross-dispersion direction on the aperture block, so that when wavecals and spectra are obtained in the same exposure, the aperture block position remains fixed. While this is the case for all previous LPs, at LP6 it was necessary to have different aperture block positions for the PSA and WCA. The optimal position of the WCA at LP6 was considered to be: (1) close to LP6 (to minimize the overhead involved in moving the aperture to perform SPLIT-wavecals); (2) in a non-sagged area of the detector; and (3) in a region of the detector with sufficient space to allow WCA locations for future LPs that may also require SPLIT-wavecals.

The method used to define LPs within the pipeline keyword rules requires that for a given aperture (e.g., the WCA) the range in LAPXSTP assigned to each LP must not overlap with any other LP. For LPs that normally operate in tagflash mode, the PSA and WCA are defined using the same range of values in LAPXSTP, since no movement of the aperture mechanism is required to obtain wavecal spectra. This method of definition is valid for LP1 through LP5, and the commanded values of LAPXSTP for each LP have been determined primarily by desired placement of the PSA science spectrum on the detector. Based on these constraints, and utilizing the gain map data derived from program 16472 (Sahnow et al. 2023 in prep), the optimal position for the LP6 WCA was found to be $17 < LAPXSTP < 27$, in between the LP5 WCA and the LP2 WCA.

To maximize free space for new WCA LPs, we investigated how well the observed aperture position matched the commanded aperture position throughout the history of COS. Observed distributions are narrow with full widths of about 5 steps, so the aperture definitions currently in use (20 steps wide) are much wider than necessary. These can safely be reduced to $\sim$9 steps wide and still provide ample padding on both sides to fully allow for potential observed vs. commanded aperture mismatches. By reducing the width of the LP2 WCA to 10 steps and also using 10 step widths for LP5, LP6, and future LPs, it was found that we can fit a total of three WCA lifetime positions in between LP2 and LP5, as shown in Figure 6.

6. Operating COS with SPLIT-Wavecals

As discussed in Section 1, performing spectroscopic exposures above +5.5 arcsec on the detector requires the use of SPLIT-wavecals due to the existence of a light leak through the FCA aperture (James et al. 2023a, Oliviera et al. 2013). While the LP5 Exploratory Study found that SPLIT-wavecal operations are feasible with regards to wavelength calibration accuracy and minimized overheads, much work remained with regards to how these new wavecal procedures would be implemented at LP6. Moreover, it was decided that while LP6 would be the default LP setting for G160M observations, in order to avoid an overhead increase $>$15% we would also allow users to use LP4 for

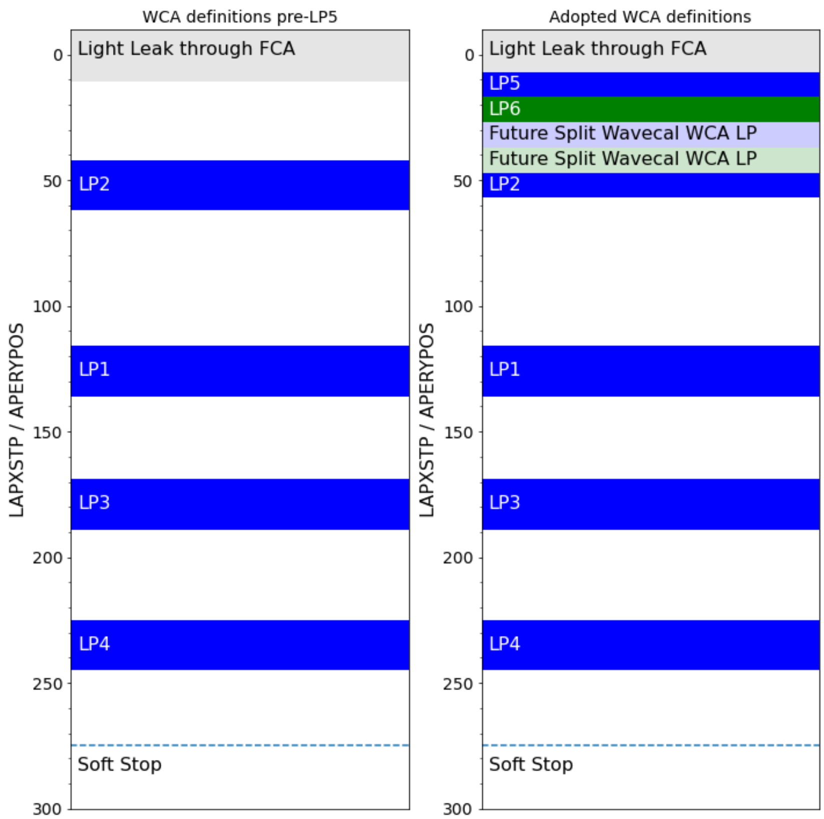

Figure 6. The left panel shows the WCA definitions through LP4, where all apertures have widths of 20 steps in LAPXSTP space. The right panel shows the addition of LP5 and LP6, the shrinking of LP2, and the space available for two future WCA LPs between LP2 and LP6. All of these apertures have widths of 10 steps in LAPXSTP.

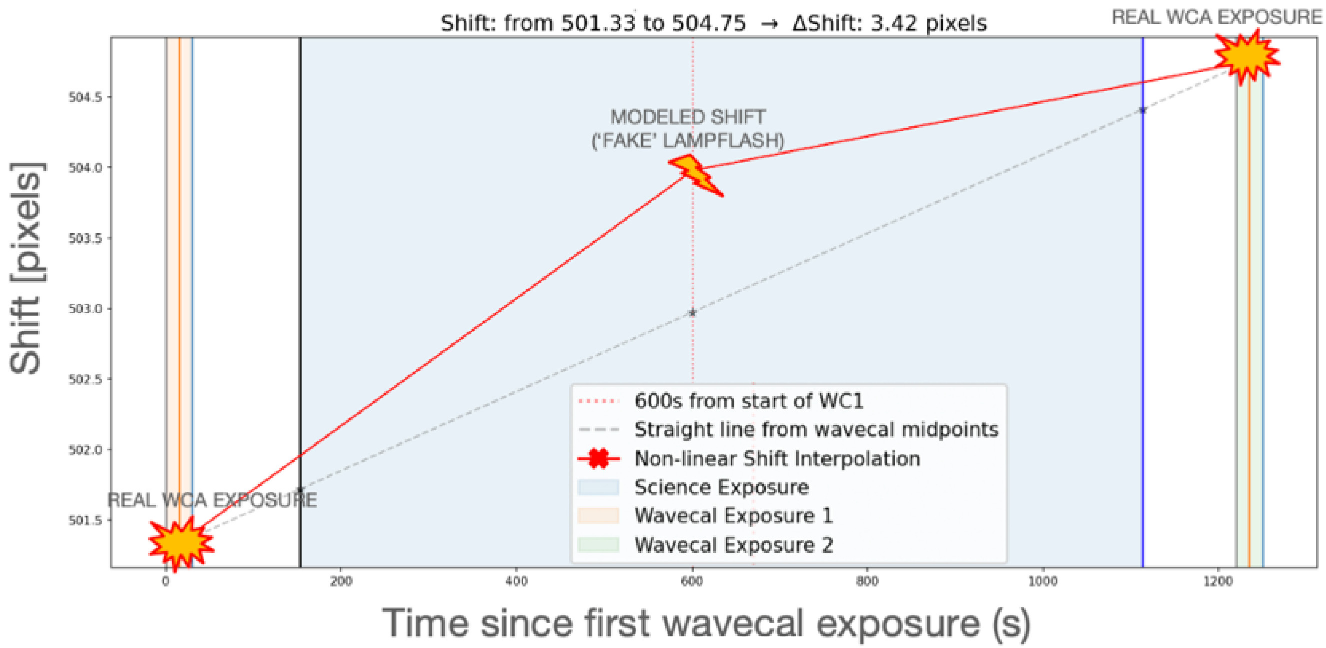

Figure 7. A schematic representation of the SPLIT-wavecal as implemented in CalCOS, showing drift as a function of time since the first wavecal exposure. The solid red line shows a straight line interpolation between the wavecal exposures at the beginning and end of the exposure, via a modelled shift at 600 s. For comparison, the grey dotted line represents a linear interpolation without the modeled shift. In this particular case, the simulated "SPLIT wavecal" improves the shifts for events recorded at or near 600s by 1.5 pixels. Image credit: Nathaniel Kerman.

'short' exposures (i.e., if they require more than two exposures within a single orbit). As such, several items needed to be finalized and assessed, including an optimized shift value for the fixed offset method, defining the timing of the wavecal flashes and implementing these rules in TRANS, APT, and CalCOS. We describe each of these processes below.

6.1 Optimizing the Fixed Offset Shift

As described in Rowlands et al. 2023 (in prep) and James et al. 2023a, it was found that if we remove the 600 s TAGFLASH exposure (the default lampflash exposure which occurs after 600 s for exposures longer than 960 s), the overhead increase for two exposures per orbit would be reduced to 15%. No reduction in overheads was seen for the four exposures per orbit scenario because the exposure times are too short to warrant a 600 s TAGFLASH. After an extensive study into the feasibility of removing the 600 s lampflash, we concluded that for SPLIT-wavecals, removal of the 600 s TAGFLASH was acceptable with regards to wavelength accuracy (+/-3 pixels) and can be incorporated via a “fixed-offset method” (Rowlands et al. 2023 in prep) within the CalCOS pipeline (a schematic of which is shown in Figure 7). In order to predict the shift in wavelength that was previously captured by the 600 s lampflash, it was necessary to optimize the fixed-offset method. A detailed overview of the investigation that explored several different methods, and precisely optimized the fixed-offset method, can be found in Rowlands et al. 2023 (in prep). In this study, a correlation was found between the fraction of the total shift that occurred at 600 s, and the total shift at the end of the exposure, with a secondary dependence on exposure time. It was determined that we can predict the 600 s shift to better than 0.5 pixels for 90% of G160M exposures and 85% of G130M exposures. This confirmed that the 600 s lampflash can successfully be removed without significantly increasing the uncertainty on the wavelength calibration, thereby reducing overheads.

6.2 Implementation in TRANS

The implementation of the rules for SPLIT-wavecal operations in TRANS followed most of the same logic as two other wavecal options with COS (GO-wavecal and AUTO-wavecal). These two already-implemented options both automatically place a wavecal directly before a science exposure and, depending on the length of the exposure, a wavecal during the exposure and at the end of an exposure. For the SPLIT-wavecals, we always require an exposure before a science exposure and, depending on the length of the exposure *and* the time since the last major OSM movement, after the science exposure (see Figure 8). In order to keep track of the time since the last major OSM movement in TRANS, a fixed parameter was introduced in the calculation that keeps track of all COS time that has elapsed, which is only reset after a major OSM movement (this excludes changes in FP-POS). That value, along with the science exposure time, is used to calculate what interval the exposure falls in and if it should be assigned a wavecal exposure at the end, similar to the current TAGFLASH rules which are implemented outside of TRANS.

6.3 Implementation in CalCOS

The introduction of this new wavecal methodology for COS at LP6 (and any future LPs above 5.5 arcsec) required moderate modifications to the COS Calibration pipeline, CalCOS, in that many of the rules were already in place for AUTO-wavecal and GO-wavecal. The main adjustment to the pipeline was the incorporation of the fixed-offset method for predicting the removed (600 s) lampflash. According to TAGFLASH rules, the 600 s lampflash occurs for exposures longer than 960 s. Therefore, to retain the COS wavelength accuracy, CalCOS was updated such that science exposures ending $\geq$960 s after an initial wavecal exposure is taken would have a simulated wavecal shift applied at a fixed time interval (as shown in Figure 7). This effectively simulates the wavecal shift that would have been measured from the 600 s

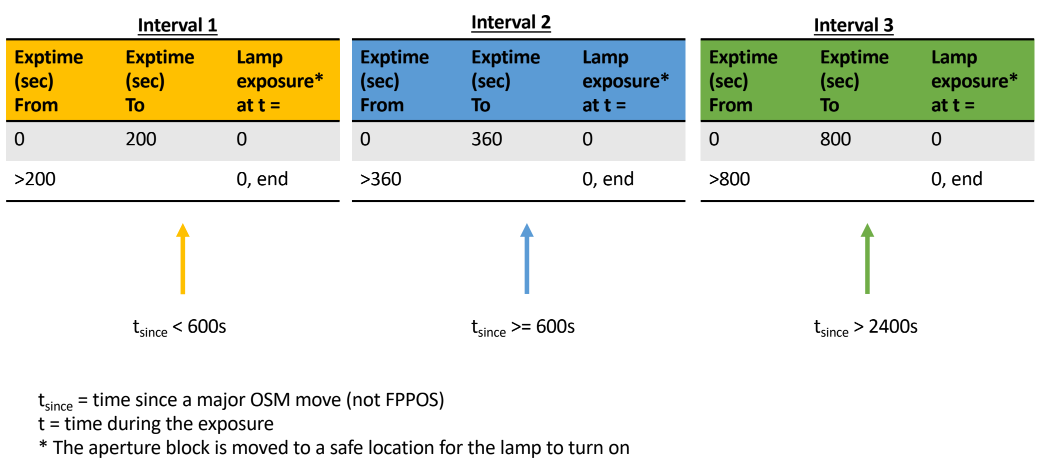

Figure 8. Schematic representation of the wavecal timing for SPLIT-wavecals. This wavecal option follows slightly different rules to the GO-wavecal and AUTO-wavecal for COS, such that we always require an exposure before a science exposure and after the science exposure, depending on the length of the exposure (t) *and* the time since the last major OSM movement (t_{since}). Image credit: Rachel Plesha.

lampflash taken during typical TAGFLASH science exposures. The parameters for this fixed-offset (MINEXPTIME, TCROSSOVER, FRACSHORT, FRACLONG, OFFSETSHORT, OFFSETLONG) were stored within the WCPTAB for LP6 and for LP= -1 (which represents an undefined LP). Additionally, new keyword rules were delivered to define where LP6 is and for it to use TWOZONE extraction by default. All updates were incorporated, tested, and released in CalCOS version 3.34 on March 3, 2022.

6.4 Implementation in APT

The introduction of new lifetimes for COS subsequently require updates in the Astronomer's Proposal Tool (APT) such that default LPs are selected within APT by the user while they construct their Phase II files. Owing to the fact that COS would now be operating in a hybrid-LP fashion, with non-default LPs allowed for some gratings when in restricted mode, the updates for APT for LP6 required a significant amount of attention. In order to correctly implement all of the rules and restrictions for LP6 into APT, the COS Team were involved with testing an LP6 development version of APT. Several tests were carried out, ensuring that the correct lifetime, segment and flash rules and warnings are applied for each cenwave and exposure type, and that rules specific to the operation of LP6 such as the implementation of SPLIT-wavecals in TRANS, restrictions on the use of the BOA and on lamp flashes are correct. This development version of APT was first released in 'restricted mode' such that the LP6 calibration programs could be designed and executed with SPLIT-wavecals, and then fully released in time for Cycle 30 users of COS to create their Phase II files with LP6 as the default setting for G160M.

6.5 Communicating LP6 Policies with the User

The final stages of the LP6 Exploratory effort were to finalize the policies for LP6 and communicate them to the community. This was done via the Call for Proposals, the COS Instrument Handbook (IHB), the COS Data Handbook (DHB), and a STAN (STScI Analysis Newsletter). Within these documents we described the various restrictions for LP6 (i.e., G160M grating only at present) and how LP6 differs from other LPs with regards to wavelength calibration observations (i.e., SPLIT wavecals) and their additional overheads.

The most substantial information on LP6 was provided in the IHB, which was released in accordance with the Cycle 30 Call for Proposals. At the beginning of the IHB is a section that describes the new COS hybrid-LP mode of operation, along with corresponding information on the newly commissioned LP6 and its various features/restrictions. A section was added to the wavelength calibration section of the IHB that described SPLIT wavecals in comparison to the usual TAGFLASH wavecals. Moreover, we provided detailed information on the additional overheads involved with SPLIT wavecals, which will aid users when writing their Phase I documentation. We

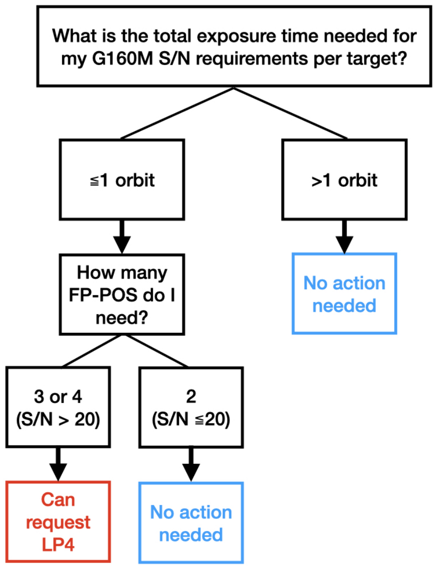

Figure 9. Flow chart designed for users of LP6 to determine whether they should use LP4 rather than the default LP6 for their G160M observations. This was introduced in Section 9.5.1 of the COS Instrument Handbook v14.0 (James et al. 2022).

also added a section that outlined new policies for the minimum number of FP-POS per target to minimize overheads at LP6 without compromising archival legacy. This included an investigation, documented in TIR COS 2022-02, that determined which FP-POS to use for the best wavelength coverage when utilizing fewer than 4 FP-POS. Based on this investigation, it was decided that G160M users at LP6 are permitted to use fewer than 4 FP-POS based on their S/N limits. LP6 users whose spectra require S/N $>$ 25 would be required to use 4 FP-POS, those who require S/N 20-25 would be required to use at least 3 FP-POS and those requiring S/N $<$ 20 would be permitted to use 2 FP-POS (Roman-Duval et al. 2023 in prep).

While LP6 would be the default LP setting for G160M observations, users are given the opportunity to use LP4 if they require more than two exposures within a single orbit (i.e., when overheads due to SPLIT-wavecals are $>$15%). In order to aid users in deciding whether they should use LP4 rather than the default LP6 for their G160M observations, we designed a simple flow-chart that utilized the S/N requirements and number of exposures, which we show in Figure 9. Finally, we added examples of two G160M-specific observational set-ups which show how and when LP6 or LP4 should be used. All of this information was also summarized in a corresponding STAN and referenced in G160M-specific warnings in APT to guide users when creating their Phase I and II documents.

7. Conclusions

A key goal of the LP6 exploratory effort was to determine the optimal placement of LP6 on the detector. The LP6 Exploratory Resolution analysis and Gain Map analysis provided the key information for determining this placement. The gain map analysis shows that a minimum distance of >7.9” is required to avoid LP5 and LP6 affecting the lifetime of each other due to overlapping traces. In addition, we found that a distance >8.4” from LP1 is required for the Lyα airglow holes at LP5 not to produce holes in the LP6 spectra. However, the resolution analysis showed that the decrease in resolution to 8” is substantial enough to justify placing LP6 as close to LP5 as possible without overly degrading the lifetime of LP5 and LP6. Moreover, despite a slight decrease of 1-2 years on the LP5+LP6 lifetime, this placement enables us to increase the overall lifetime of COS by providing space on the detector for a future LP beyond LP6, at 8.5–9 arcsec. With this in mind, the gain models determined the optimal placement to be at 6.5” above LP1, resulting in end of life (i.e., when the gain is below 3) of LP5 and LP6 expected in early 2030 or earlier, assuming that G140L is not placed at LP4, LP5, or LP6. This position was found to provide the highest resolution possible for LP6, while also enabling a future lifetime position above LP6 with intermediate-to-high resolution (R>10,000).

Within this study we also finalized the design of the SPLIT-wavecal calibration mode, which allows wavecal exposures to be executed by moving the aperture to a different position on the detector in order to use the wavecal lamp (rather than concurrently with the science exposures), while still following the basic TAGFLASH timing rules. This new wavecal procedure was subsequently implemented into the CalCOS pipeline, TRANS, and APT. Consequently, a complete description of SPLIT-wavecals, their associated overheads and policies at LP6 were documented and communicated to the user.

The completion of this study spawned the beginning of several subsequent phases. Firstly, the process of commissioning G160M at LP6 began with the LP6 Enabling Phase, which is presented in Rowlands et al. 2023 (in prep). Following this, we executed the LP6 Calibration Phase, as presented in Sankrit et al. 2023 (in prep).

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