The exploratory phase for Lifetime Position 7 in the Cosmic Origins Spectrograph FUV channel

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The Cosmic Origins Spectrograph (COS) was installed in the Hubble Space Telescope (HST) in 2009. In anticipation of a move of spectra to a seventh lifetime position (LP7) on the FUV detector in 2025, we are completing exploratory work to model the instrument performance over the full range of possible positions for the spectra on the detector. This effort includes (1) optical modeling of the spectrograph; (2) creating simulated science spectra and evaluating their resolving power and other spectral properties at a range of positions; (3) evaluating the detector properties at potential lifetime positions while considering mechanical limitation of the hardware; and (4) reserving sufficient space for later LPs. We have used this information to formulate preliminary plans for moving to the next position, which includes identifying which observing modes should be adjusted, and providing our initial thoughts on future Lifetime Positions.

A New Lifetime Position

In order to maximize the life of the COS FUV cross delay line detector, spectra are placed on the active area at multiple cross-dispersion locations, or Lifetime Positions (LPs), to spread the gain sag effects over the detector.

The optical design of COS was optimized for LP1 (zero arcsecond offset position). The choice of each subsequent Lifetime Position on the detector is a complex, multi-dimensional optimization problem. An ideal LP for a given choice of wavelength and cenwave must ensure that the spectrum falls on a part of the detector with high gain and minimal defects; has high enough spectral resolution over the full bandpass; is optimized over all the cenwaves for the grating while the focus mechanism is within its allowable range; keeps the aperture mechanism within its allowable range; and minimizes unintended light from reaching the detector.

New gain prediction models have been developed that account for the nonlinear correlation between counts and gain sag, while also incorporating updated 2D profiles for each grating/cenwave combination. These profiles accommodate enhancements to the detector's Y-walk and geometric corrections. The models have also been updated to include the most recent detector usage statistics. Due to significantly higher count levels in the LP5 and LP6 regions over the last ~2 years, our gain models now predict that some G130M modes will need to move to LP7 in late 2025. However, these modes may last 1-2 years longer at LP5 should the usage return to more typical levels (Figure 1).

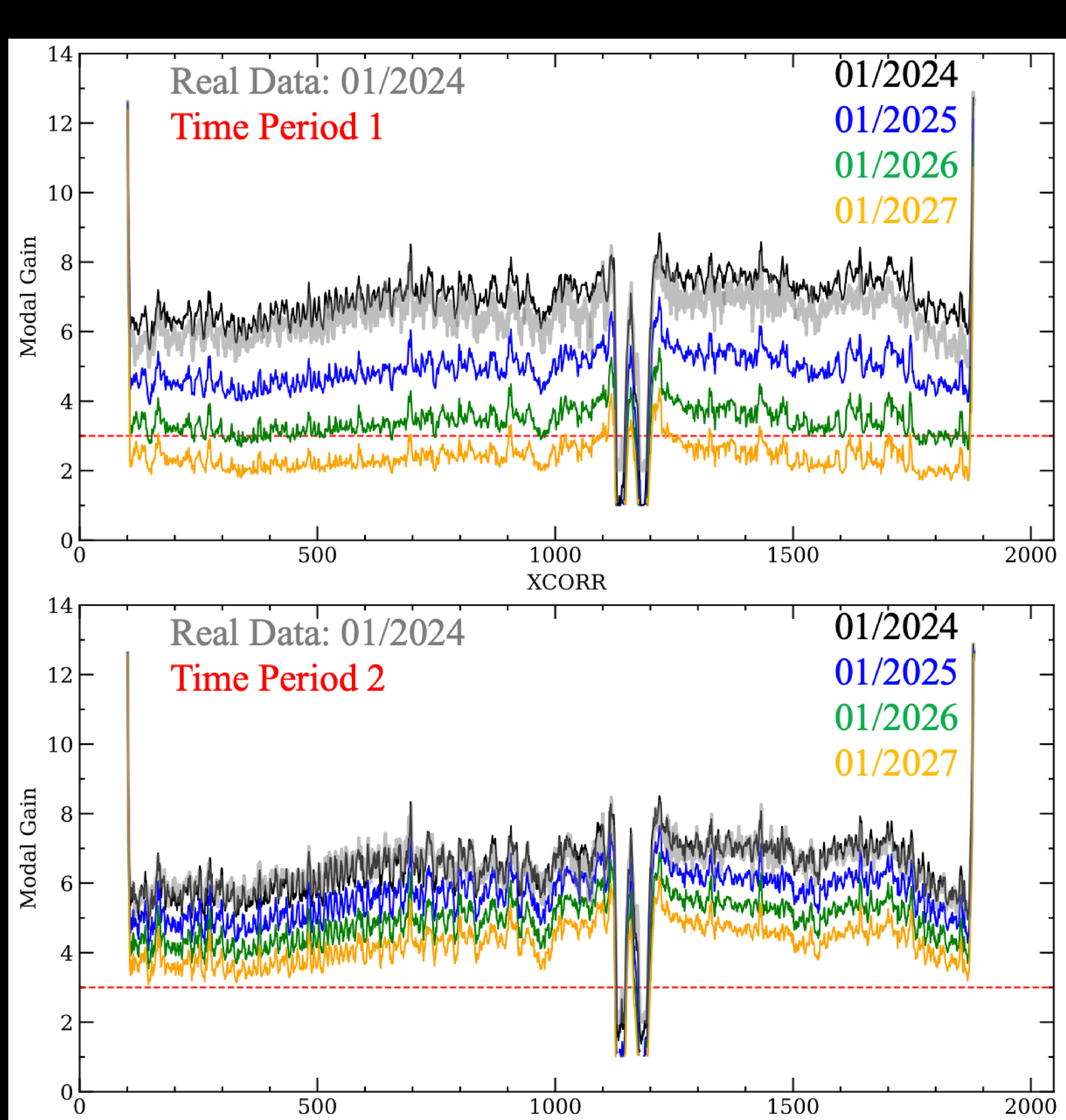

Figure 1 *Predicted modal gain as a function of x pixel (binned by 8) for two models of detector usage at LP5. The top model assumes that the usage of G130M continues at the higher than normal rate seen over the past year. The bottom plot assumes a lower usage which more closely matches what was seen previously. When the modal gain in the 'continuum' drops to 3, it is time to move those modes to a new LP; the two low gain holes between binned pixels 1100 and 1200 are due to Lyman-α airglow.*

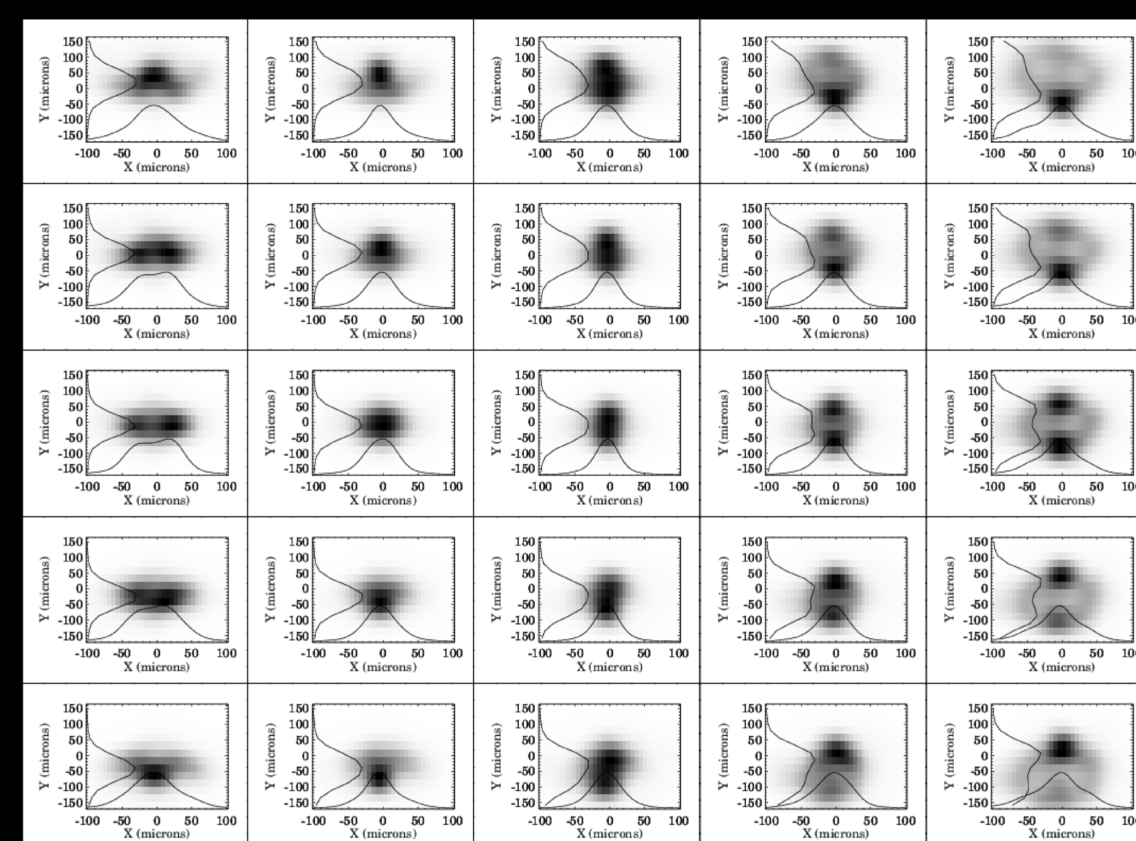

Figure 2 *Variations in the modeled PSF shape for a range of focus positions and cross-dispersion locations at 1600Å in G160M/1600. Cross-dispersion positions vary from -5.0" (top row) to +5.0" (bottom row), and focus positions cover -500 to +500 focus steps (columns).*

Optical Models

We have continued to refine our CODE V Optical models of the COS instrument. The Point Spread Functions (PSFs) can change significantly as a function grating wheel focus position and cross-dispersion location (Figure 2), in addition to central wavelength (cenwave) and wavelength.

We have created a grid of raytraced PSFs over the full range of focus and cross-dispersion in order to aid in identifying the best focus (highest resolving power) at anticipated future LPs (Figure 3). However, there is not necessarily an unambiguous choice of 'best focus' because of tradeoffs between the shape of the PSF, cross-dispersion height, variation with wavelength, and other factors. Using raytrace models rather than on-orbit spectra allows a more detailed exploration of the parameter space.

We are continuing to investigate different options for parameterizing the PSFs to automate the process of identifying best focus and avoid the necessity to individually assess thousands of raytraced PSFs

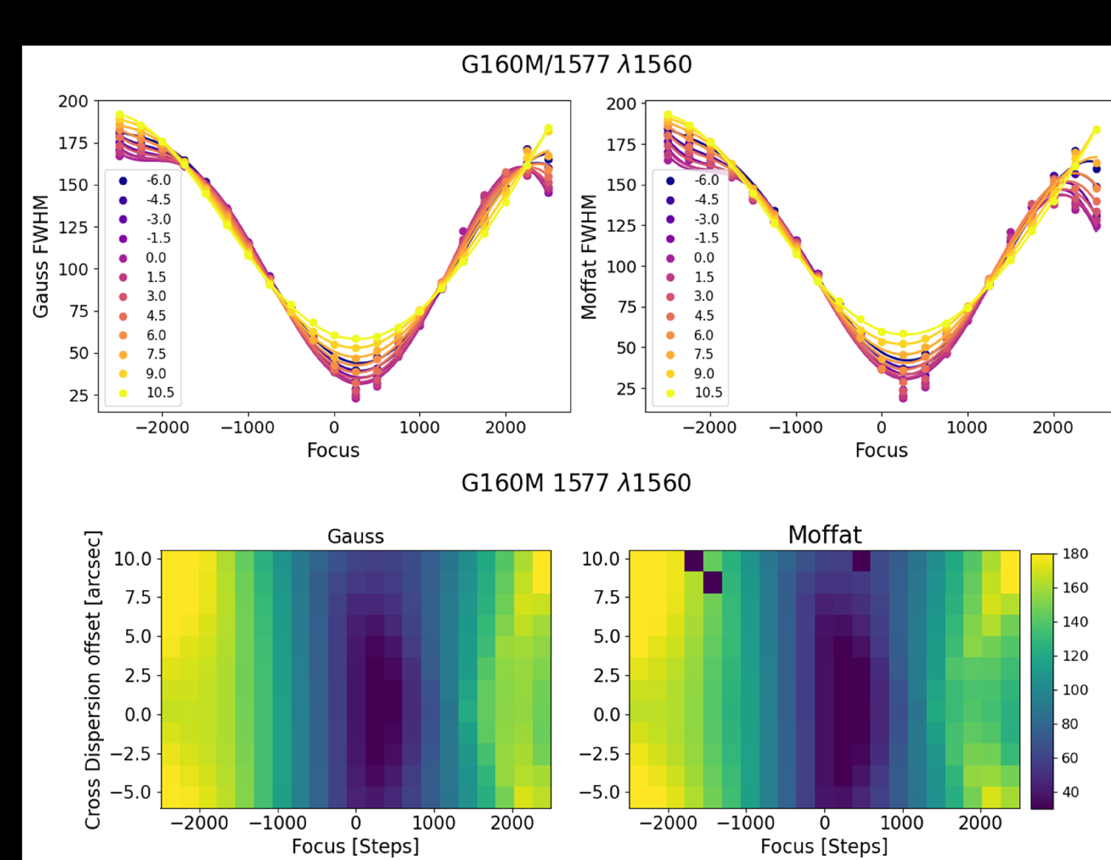

Figure 3 *Top: Measured FWHMs of raytraced PSFs for G160M/1577 at 1560 Å as a function of focus position for a range of cross-dispersion locations on the detector, for both a gaussian (left) and Moffat (right) function. The width of the line profile increases and the focus position shifts as the cross dispersion location moves away from zero.*
Bottom: A two dimensional representation of the same data.

Simulated Spectra

The PSFs can be used to generate simulated two-dimensional absorption line spectra similar to those that are collected in on-orbit observations. These can be processed in a manner analogous to the way real spectra are processed in order to assess the effects of variations in the shapes of the PSFs on the ability to characterize weak features (Figure 4).

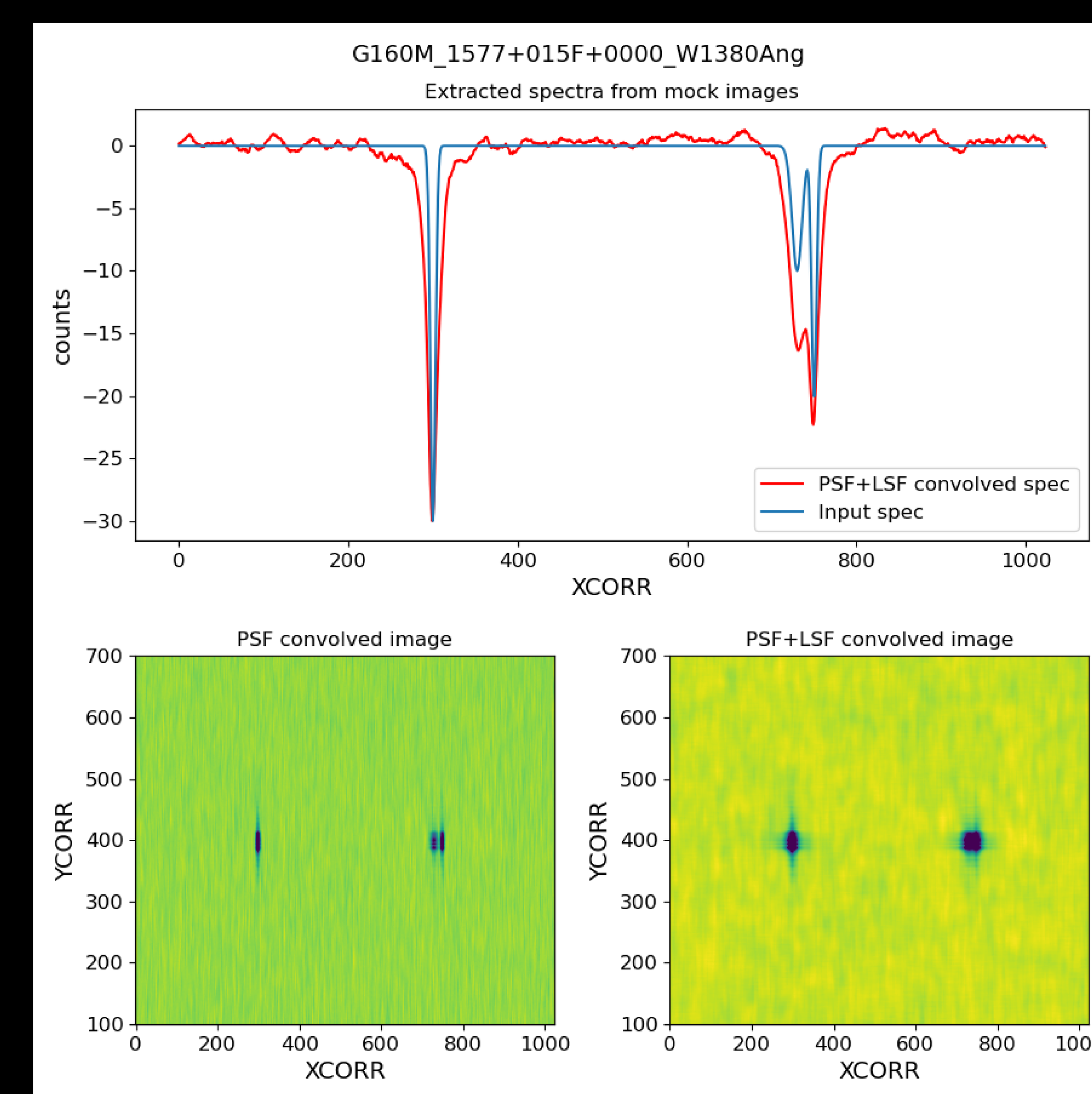

Figure 4 *A 2D spectrum containing three absorption lines using model PSFs (bottom left), and then convolved with a simulated detector response function (bottom right). The top panel shows the extracted 1D spectrum for both cases.*

Next Steps for LP7

The LP7 exploratory phase described here will be used to identify potential cross-dispersion locations for the LP7 spectra. This will be followed by an LP7 enabling phase, during which on-orbit data will be obtained to validate the models and determine the final positions. Once these final values are selected, a calibration phase will follow in order to collect data in the selected configuration.

Beyond LP7

Although the primary objective of this work is to identify the best set of parameters for LP7, keeping our options open for later Lifetime Positions is an additional goal, since we want to maintain the FUV capability of COS for the lifetime of HST.

The current version of the Flight Software (FSW) can only support eight LPs, so we are exploring ways to expand this number. To avoid increasing the size of the FSW tables in the on-board memory, we are investigating the possibility of repurposing the LP8 table entries by changing them on the fly for each exposure. If this can be implemented, we will effectively remove any limitations on the number of future LPs.