

Phase II Update and Guidelines for Cycle 17 Users of COS

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ABSTRACT

This ISR presents a summary of recommended practice and suggestions for observers preparing their Phase II COS program submissions for Cycle 17. Several important modifications to the COS Instrument Handbook and the COS Exposure Time Calculator are noted. Procedures for Bright Object Protection checking are described.

Contents

1. Introduction (page 2)
2. **Special Notice: Hands-On Phase II Support at STScI (page 2)**
3. Corrections and Changes to the Instrument Handbook (page 3)
4. Exposure Time Calculator Changes and Corrections (page 9)
5. Recommendations for COS in Phase II (page 12)
6. Bright Object Protection Procedures (page 18)
7. Change History for COS ISR 2008-01 (page 22)
8. References (page 22)

1. Introduction

The Cycle 17 *Instrument Handbook* for the Cosmic Origins Spectrograph (Soderblom et al. 2007) was issued in December, 2007. At that time the COS Exposure Time Calculator was also released for Cycle 17 proposers. Since that time some improvements have been made and some errors have been identified and corrected. A new version of the COS ETC has been released in time for use in Phase II of Cycle 17, and here we note some of the alterations made to that package. This new version of the COS ETC *must* be used for all Cycle 17 Phase II programs. A revised COS *Instrument Handbook* will not be issued, however, and its corrections need to be documented.

In addition, the COS team at STScI is continuing to learn more about how the instrument is used as we prepare the detailed Phase II programs for Servicing Mission Observatory Verification (SMOV), the critical period after the servicing mission when the instrument is tested, characterized, and verified for scientific use.

This COS *Instrument Science Report* has been prepared to provide Cycle 17 users with up-to-date information and suggestions on how to prepare Phase II programs. Your own experiences with Phase II and any problems you identify can help us improve the scientific productivity of COS and of HST. Please send any comments to help@stsci.edu.

2. Special Notice: Hands-on Phase II Support at STScI

Because COS is a new instrument that may be unfamiliar to users, Cycle 17 COS observers are invited to visit STScI during June, 2008 to get help with their Phase II programs. To do this, send an e-mail to these individuals:

- Nolan Walborn, User Support Lead (walborn@stsci.edu);
- Francesca Boffi, Data Analysis Group Lead (boffi@stsci.edu); and
- Dixie Shipley, Administrative Assistant (shipley@stsci.edu).

Please respond immediately so that we may schedule you at a time that works for all concerned, and please limit the visit to one person per program. Let us know of any specific time constraints that you may have. We expect visitors to bring their own laptop to work on, but access to a desktop can be arranged, and we anticipate that these visits can be completed in one or two days.

Travel Costs for this Opportunity

Travel costs to the STScI for the purpose of working on Phase II programs can be incurred as “pre-award” travel costs (see General Grant Provision

below), in anticipation of preparatory funding to be awarded in September. If you plan to do this, be sure to include these costs as specific line items in your GO budgets (to be submitted by July 3), and refer to our invitation to COS GOs to travel to the STScI for working on Phase II proposals. These travel costs will then be allowable when grants are officially awarded in this fall. The STScI will not be able to provide funds in advance of the grants awards in the fall.

In accordance with the General Grant Provisions of the Space Telescope Science Institute (8/06): “Pre-award costs that were incurred for project activities directly related to a specific STScI program, and are otherwise allowable under the terms and conditions of the grant, are an allowable expense. However, such costs are incurred at the grantee's own risk and will not impose an obligation on the part of STScI or NASA if an award is not subsequently made, or if an award is made for a lesser amount than the grantee anticipated.”

3. Corrections and Changes to the Instrument Handbook

3.1 New COS “User” Coordinate System

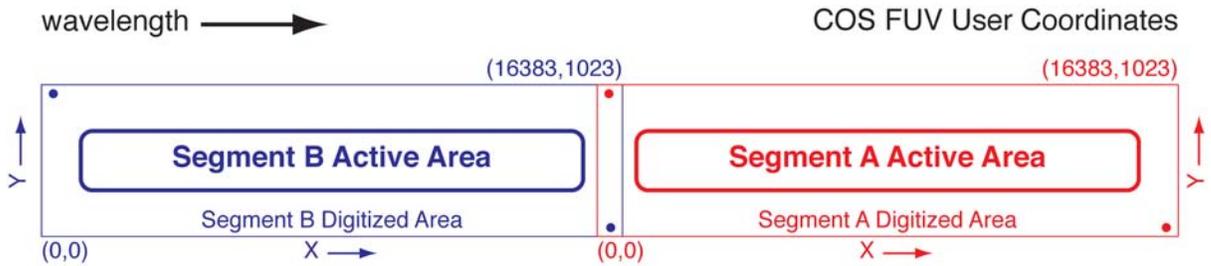
The data produced by the COS detectors is an array. In the original “detector” coordinate system, which was shown in the *COS Instrument Handbook*, the definitions of x and y were based upon specific detector characteristics and that system did not take into account the orientation of the detectors in the COS optical path. As a result, the image coordinate definitions were not consistent with either HST norms nor were the two COS detectors consistent with one another.

A new “user” coordinate system has now been defined that is consistent between the FUV and NUV channels. By doing this now we can ensure that all data from COS will use the same coordinate system to relate spatial and wavelength dimensions. From a user standpoint, all references to COS (including POS TARG specifications in APT, for example, as well as output data quantities and science header keywords) will employ the new “user” coordinate system.

In this “user” coordinate system, x lies along the wavelength (dispersion) axis and increases with increasing wavelength for both the FUV and NUV channels. Also, for both channels the y spatial (cross-dispersion) dimension is such that it increases in the direction of positive V_2 , V_3 on HST.

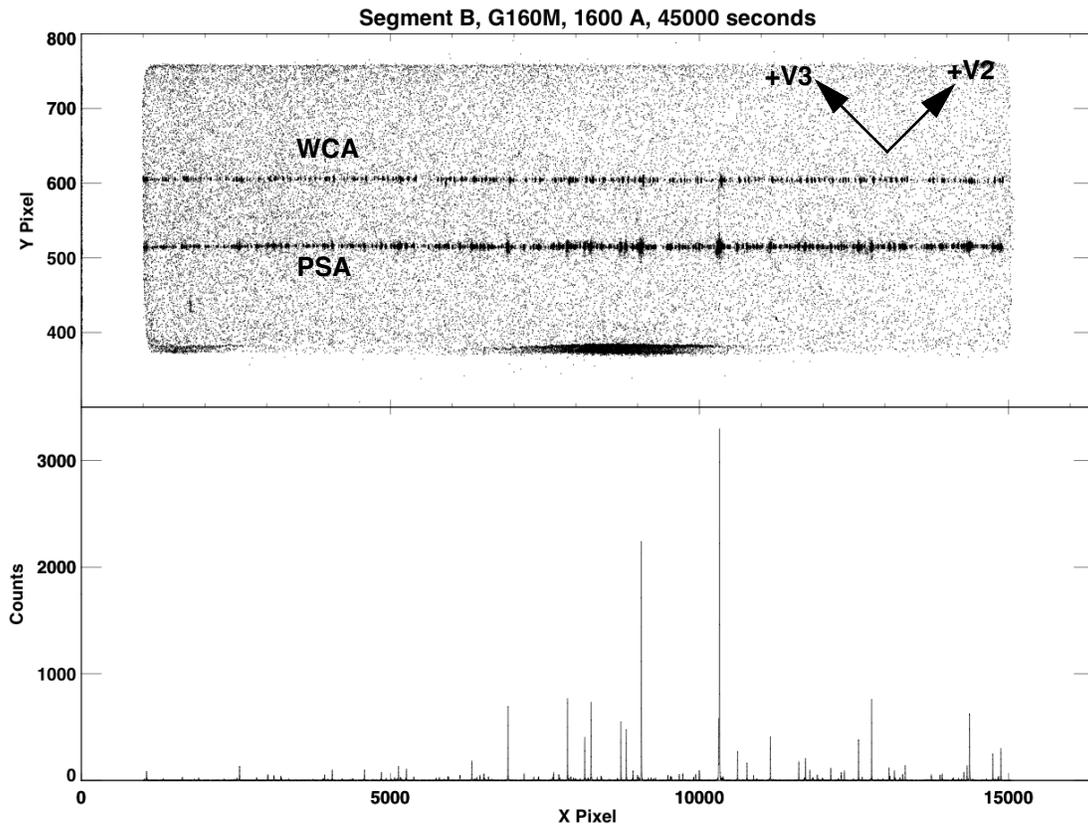
Because of this change, we here provide updated illustrations for Chapter 4 of the *COS Instrument Handbook*. Note that Figure 4.4 will no longer appear in the *Instrument Handbook* because its information is included in Figure 4.3.

Figure 4.1: The FUV XDL Detector.



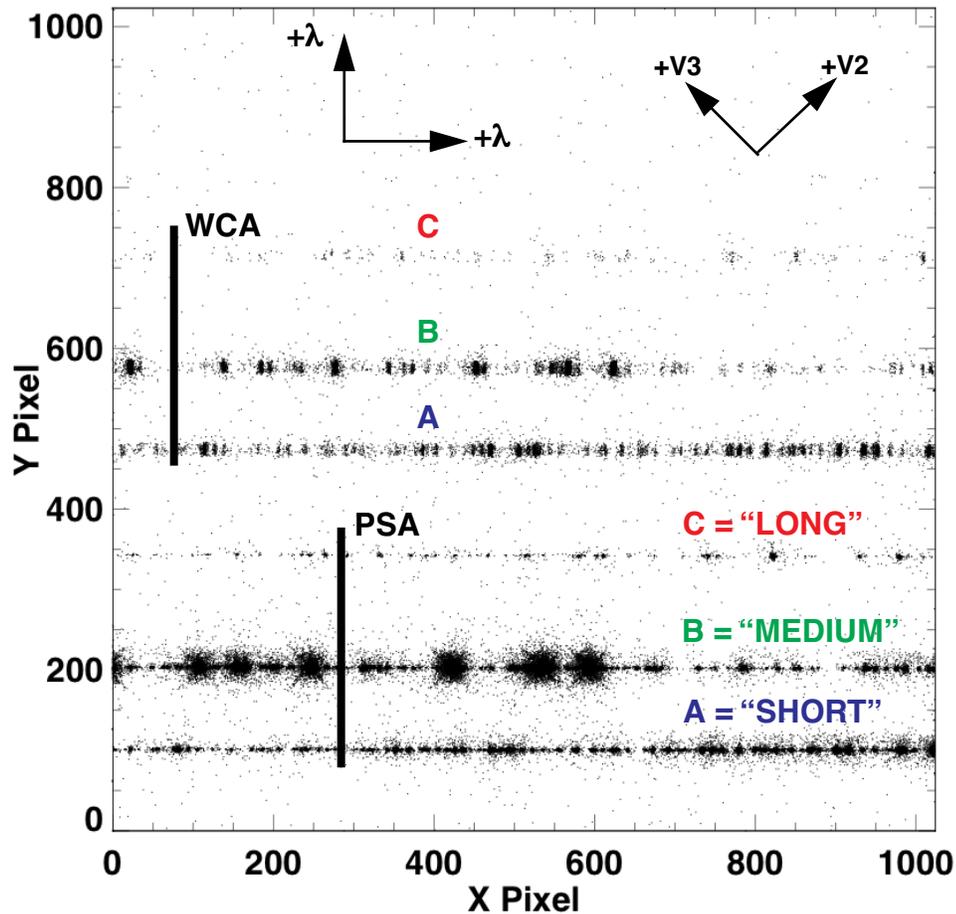
This is drawn to scale, and the slight curvature at the corners of the active areas is also present on the masks of the flight detectors. The red and blue dots show the approximate locations of the stim pulses. Note that the numbers in parentheses show the pixel coordinates at the corners of the segment's digitized area.

Figure 4.2: Example of a COS FUV Spectrum.



Shown is a wavelength calibration spectrum for one FUV segment obtained during ground testing. The internal wavelength calibration lamp (WCA) spectrum is at the top, while the lower spectrum is from a lamp external to COS (PSA). The bright streak at the bottom is due to an area of enhanced background on the detector segment. Note the size of the active area compared to the overall digitized area, and also note that the y axis has been stretched. At the bottom is the extracted spectrum of the PSA trace. The stim pulses are not shown here but are located at (389, 984) and (16000, 33).

Figure 4.3: Example of a COS NUV Spectrum.



Shown is a wavelength calibration spectrum, with both the WCA and the PSA illuminated by separate lamps. Note the “science” spectrum on the bottom and the wavelength calibration spectrum (on the top); each has three stripes. These stripes are designated A, B, and C, in going from bottom to top in this illustration. Wavelength increases going to the right and in going up. Note that the SHORT, MEDIUM, and LONG designations are used in Phase II with the ACQ/PEAKXD command and the STRIPE Optional Parameter.

3.2 The PSF for COS in NUV Imaging Mode

Figure 6.2 on page 62 of the *COS Instrument Handbook* showed a calculated Point Spread Function. An observed NUV imaging PSF, taken from ground test observations in 2006, is shown below. A revised Figure 6.3 is also shown below, and a 2-dimensional gaussian fit has these characteristics:

- FWHM: 1.97 pixels = 46.4 mas
- Fraction of light in brightest pixel: 13.9%.

Figure 6.2: Two-dimensional PSF for COS in imaging mode.

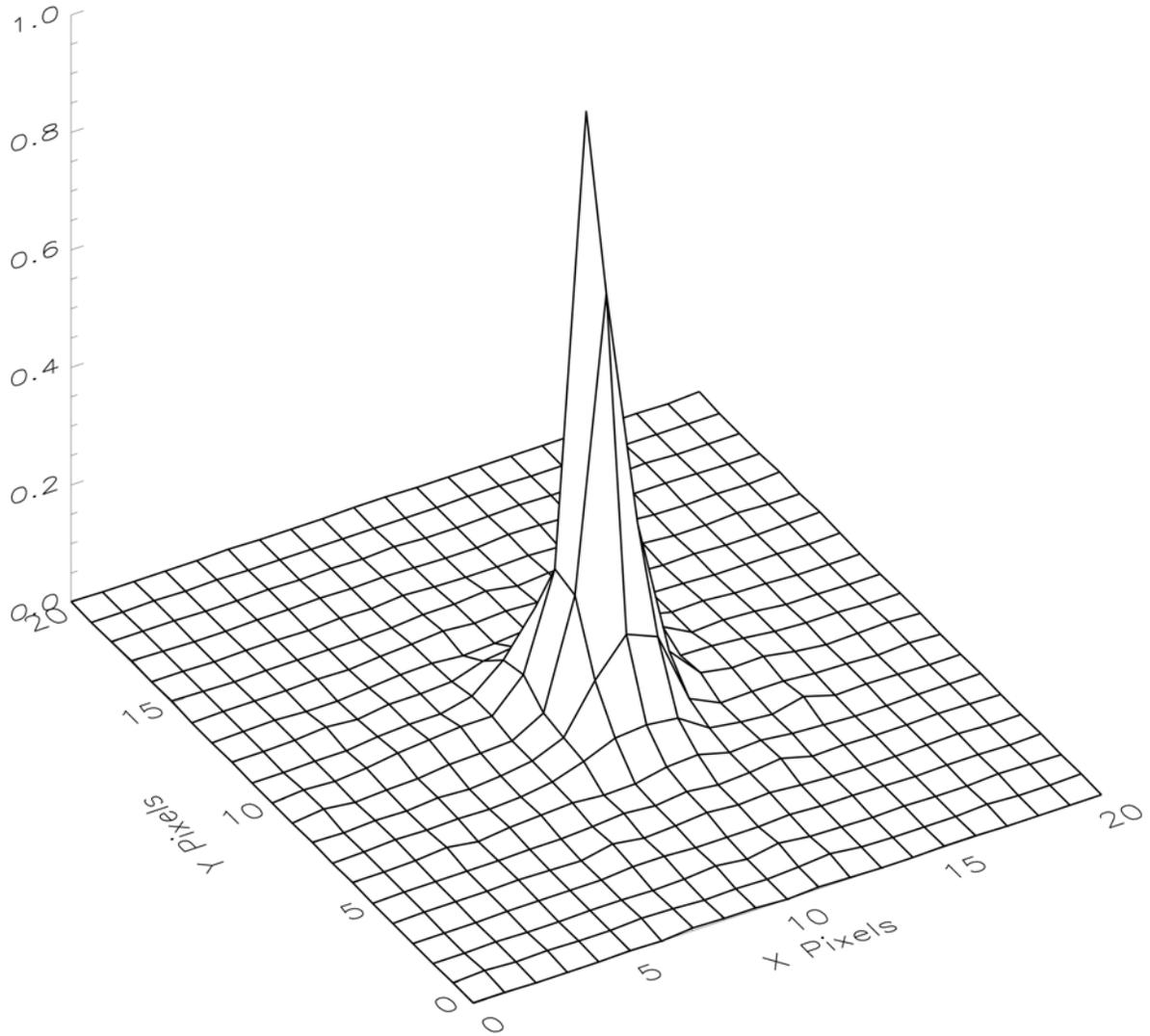
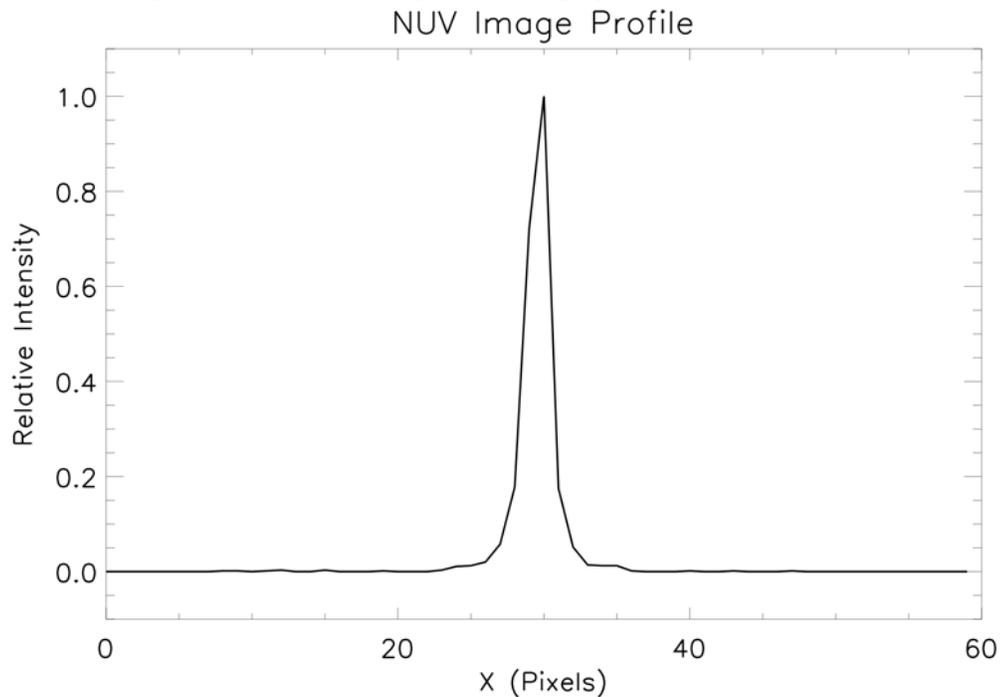


Figure 6.3: Profile through COS imaging PSF in the x direction.

This is a slice through the center of the profile.

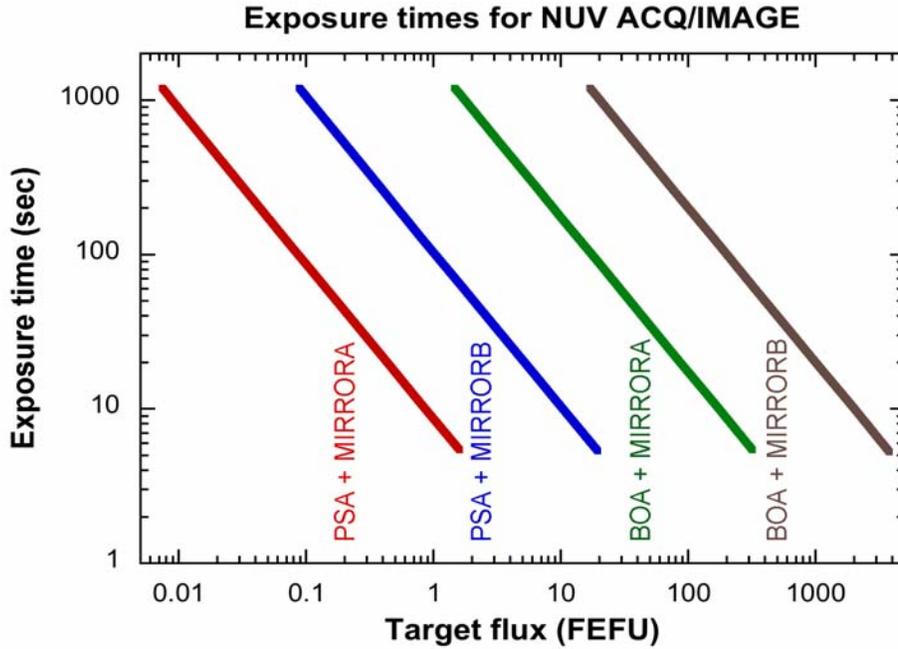
3.3 Acquisition Exposure Times

Since the publication of the *COS Instrument Handbook* several important updates to the COS ETC and the throughputs for imaging have been made (see Sec. 4 in this update). Shown below are revised Figures 7.3 and 7.9, illustrating the exposure times for various COS acquisition modes. All are based on achieving $S/N = 40$ and assume a flat-source spectrum. Please note that these times are only provided for illustrative purposes and that the ETC should always be used to get a reliable estimate for an astrophysical source.

In Figure 7.9 on the next page note that all three FUV gratings returned the same exposure time to within 10-20% and so the numbers shown are for G130M. All of the NUV medium-resolution gratings gave similar exposure times to within about 3%, and are shown as “NUV-M.” The times for G230L at 3000 \AA are shown as “G230L.”

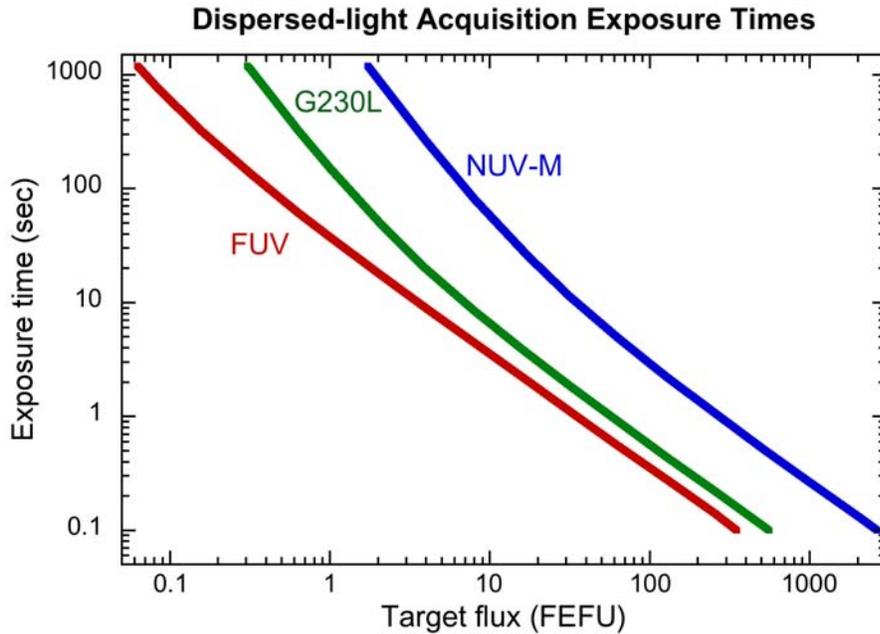
Although the exposure times are in some cases substantially different from what is shown in the *Instrument Handbook*, the total time needed to acquire an object is affected little, if at all. These illustrations, in any case, are only intended to provide a very rough guide, and acquisition exposures that you specify in APT should always be based on a specific calculation using the COS ETCs.

Figure 7.3: Exposure Time Needed for NUV ACQ/IMAGE Mode.



The time is given as a function of target flux. This calculation assumes a flat source spectrum and that S/N = 40 is achieved.

Figure 7.9: Exposure Times Needed for Dispersed-light Acquisitions.



The calculations have been made for a flat source spectrum and are based on achieving S/N = 40. "FUV" refers to all the FUV gratings, and "NUV-M" refers to the medium-resolution gratings of the NUV channel.

4. Exposure Time Calculator Changes and Corrections

A new version of the COS Exposure Time Calculator (ETC) was released on May 19, 2008 for Cycle 17 Phase II (version 17.2). This version contains several changes compared to the old version available to users for Phase I (version 17.0). The following sections briefly describe the major changes that affect ETC calculations. Please check the following web page for additional information on the changes incorporated into COS ETC version 17.2 (including cosmetic improvements) and for all the known issues that will be fixed in future releases:

http://www.stsci.edu/hst/cos/software/etc_help/COS_ETC_17.2_updates.pdf

4.1 Background rates and extraction boxes

Version 17.2 of the COS ETC estimates the background rates differently for both imaging and spectroscopic modes. This is because the ETC software used an extraction box for an image that included a larger region of the detector than is actually used in the flight software. (The extraction box used is was the default for a spectrum in the pipeline processing.)

- The extraction box height for NUV spectroscopy has been decreased from 25 to 8 pixels; this mainly affects situations that are background-limited. A height of 8 pixels includes about 80% of the encircled energy. This change produces better signal-to-noise calculations for faint sources without compromising the results for bright sources, and it allows for a better comparison between STIS and COS.
- The extraction box used for imaging target acquisitions (TAs) has been decreased from 345×816 to 9×9 pixels. The larger box resulted from a misinterpretation of the flight software procedures for imaging TAs. The smaller box size dramatically reduces the exposure time needed for imaging TAs, particularly for fainter sources.

The COS ETC released for Cycle 17 Phase II should now provide more reliable estimates of exposure times for the affected modes. The sensitivities of COS will, of course, be verified and measured once the instrument is installed into HST. We will also review the extraction boxes at that time to ensure they are optimum.

4.2 NUV MAMA Red Leak and Imaging Throughput

New throughput curves for the NUV imaging modes using MIRRORA and MIRRORB (with either the PSA or BOA) have been loaded into the COS ETC since Phase I. They supersede the old curves that were based on predictions of

the throughput from the individual optical components and are now based on measurements obtained with the assembled instrument during thermal vacuum tests.

An estimate of the red leak has also been included into the new throughput curves. This red leak is due to the fact that the MAMA detector used in the NUV channel of COS has non-zero sensitivity above 3200 Å. While very low, this can matter when acquiring very red objects. For objects with effective temperatures above 6000 K the effect is negligible, but it grows to about 20% at 5000 K, and below 5000 K the effect quickly becomes large.

The new MIRRORA curves for both the PSA and BOA are about 20% lower overall, and, in addition to the red leak, now has a cutoff at short wavelengths that has been moved from 1400 to 1650 Å. This results in a significant reduction in the count rate of blue objects.

Please remember that if you upload a spectrum into the ETC to calculate an exposure time, particularly for an acquisition, that spectrum must cover the full range of wavelength that the NUV channel is sensitive to, meaning from about 1650 Å to 12,000 Å (because of the red leak). Failure to include the full wavelength range can lead to a significantly misleading result, and the software expects input data fully to 1.2 μm.

4.3 NUV local count rate limits

The Phase II COS ETC includes an additional change related to the allowed brightest pixel count rate in both imaging- and NUV spectroscopic modes. The new lower values are based on a better knowledge of the instrument performance as inferred from ground testing. This change may especially affect your target acquisition (TA) strategy. Again, be sure to use the latest release of the COS ETC when preparing your Phase II program. The correct screening limits are given in the following tables, which are revised versions of Table 11.2 and Table 11.3 from the *COS Instrument Handbook*.

For NUV imaging – often used for TA – the local count rate (LCR) limit had been specified in terms of the brightest pixel under the assumption of observing a point source. However, for extended sources this assumption no longer holds. In this case it is important to understand how the flight software protecting the detectors actually works for COS. This software in fact takes a very short-duration image at the start of an exposure, checks the total counts within a certain box and stops the exposure if these counts exceed the specified limit. For this reason, the most reliable way to assess the safety of a target for an imaging TA is to look at the output from the Imaging TA ETC. The most recent COS ETC for imaging TA shows the source's total predicted count rate for a 9×9 box. To be considered safe, this rate must be 300 or lower. In certain cases it may be possible to observe an object if this rate is above 300, but in general only if additional information exists to accurately predict the total count rate.

The LCR limit for NUV spectroscopic mode has also changed slightly. For a continuum source, the global count rate (GCR) limit would be exceeded

before the LCR limit is. However, emission-line objects can cause problems with the LCR limit. This may be a particular concern for objects with far-UV spectra that are red-shifted into the NUV. Again, please be sure to use the most recent version of the COS ETC and be sure to include possible maximum fluxes for emission lines that may be present.

The following tables and text provide updated values calculated using current best estimates of COS sensitivities.

Table 11.2: Global Flux Limits for COS

Detector	Wavelength	Global limit ^a	
		M gratings	L grating
FUV	1300	460 FEFU V = 15.0	170 FEFU V = 15.4
	1600	470 FEFU V = 14.3	
NUV	1800	15,000 FEFU V = 10.2	470 FEFU V = 12.3
	2300	13,000 FEFU V = 9.5	
	2800	9,700 FEFU V = 9.0	

a. The second value listed in the cells is the equivalent V magnitude of an O5 star.

Limiting Magnitudes for NUV Imaging

The following are the V magnitudes of an O5 star that is safe to observe with COS using NUV imaging. Therefore anything brighter for which measured UV flux data are not available is judged to be unsafe to observe.

- PSA with MIRRORA: V = 19.06
- PSA with MIRRORB: V = 16.68
- BOA with MIRRORA: V = 13.39
- BOA with MIRRORB: V = 11.07

Limiting Fluxes for NUV Imaging

The following fluxes are the highest permissible for a flat-spectrum source being acquired in ACQ/IMAGE mode:

- PSA with MIRRORA: 2 FEFU.
- PSA with MIRRORB: 23 FEFU.
- BOA with MIRRORA: 400 FEFU.
- BOA with MIRRORB: 4,400 FEFU.

Table 11.3: COS Count Rate Screening Limits.

Detector	Source type ^a	Type of limit	Limiting count rate ^b
FUV	predictable	global	15,000 per segment;
		local	0.67 per pixel ^c
	irregular	global	6,000 per segment
		local	0.67 per pixel ^c
NUV	predictable	global	30,000 per stripe
		local	50 per pixel ^d (imaging), or 70 per pixel (spectroscopic)
	irregular	global	12,000 per stripe
		local	50 per pixel ^d (imaging), or 70 per pixel (spectroscopic)

- a. "Predictable" means the brightness of the source can be reliably predicted for the time of observation to within 0.5 magnitude.
- b. Entries are counts per second.
- c. An FUV resel is 6 pixels wide by 10 high.
- d. This is properly assessed for imaging acquisitions by staying under a count rate of 300 for the entire 9x9 box as shown in the COS Imaging Acquisition ETC. See the main text.

5. Recommendations for COS in Phase II

5.1 Acquisitions

Is an acquisition a requirement?

You are not required to perform an acquisition with COS at the start of a visit, but it is strongly recommended, both to ensure that your target is acquired at all, and to ensure good data quality. APT will issue a warning if an acquisition is not included. However, please see the warning below about the need for an ACQ/SEARCH at the start of a visit. If an observer fails to include an ACQ/SEARCH exposure in Cycle 17 then if an observation fails because of a failed acquisition it will not be repeated.

What happens if an acquisition fails

The COS flight software takes the information gathered in an ACQ/SEARCH or ACQ/IMAGE exposure and applies a centroiding algorithm. The procedure expects a minimum level of contrast in order to ascertain that an object has, in fact, been found. If the centroiding algorithm cannot return a valid pointing then subsequent acquisition procedures in that visit (such as ACQ/PEAKXD or ACQ/PEAKD) are not executed, but science exposures will

be executed. Note that HST will be left pointing at the last location it was at. This would be, for instance, one of the corners in an ACQ/SEARCH spiral.

How much time is needed to acquire with COS?

Use the COS ETC to get a reliable estimate of exposure time for your object (there is more on this below), and use APT to see how much orbit time the acquisition uses. Be sure to use the latest release of APT that goes with Cycle 17 Phase II (version 17.2). An overhead time at the beginning of a COS visit has been significantly shortened, and this should make most acquisitions very fast.

Do I need to use the same set-up to acquire as to observe?

No. An NUV imaging acquisition is recommended in many cases because it is fast and accurate, even if you are then obtaining a spectrum with the FUV channel. If it is advantageous, you could, for instance, acquire with the FUV channel using dispersed light and then take an NUV spectrum. Any combination in any order is permissible because both COS channels are active at the same time. There are overheads involved in switching between various optical elements, however, that can cost time; these can be evaluated using APT. We suggest that you compare using an NUV ACQ/IMAGE and a dispersed-light acquisition that uses the same configuration as your science exposure to see the relative times needed.

Start with a 2x2 or 3x3 ACQ/SEARCH

It is our expectation that COS should be able to acquire targets that have precise and accurate GSC2/ICRS coordinates. However, in Cycle 17 we will not yet have experience with using COS and the precise locations of instrument apertures relative to one another will change, particularly the location of the COS aperture relative to the FGSs. We will be carefully monitoring and measuring these positions throughout Cycle 17.

Therefore in Cycle 17 we recommend that all COS acquisitions start with an ACQ/SEARCH phase. If your acquisition uses ACQ/IMAGE, you should start with an ACQ/SEARCH that uses SCAN-SIZE=2 or even larger if the coordinates are uncertain. If you are using a dispersed-light acquisition with PEAKXD and PEAKD, the ACQ/SEARCH phase should use SCAN-SIZE=3 or larger. In either case we recommend using the default STEP-SIZE of 1.767 arcsec with all uses of ACQ/SEARCH.



The specifications of a COS acquisition are left to the observer. However, in Cycle 17 if your observations fail because the acquisition failed to find the target and you did not use an ACQ/SEARCH at the start then STScI will not repeat that observation.

Suggestions on acquisition strategy

An observer has many options for acquiring an object with COS, and each of these options has some strengths and limitations. In particular, imaging acquisitions can be fast and precise, but the restrictions on Local Count Rate (discussed below) can prohibit use of the PSA, even with MIRRORB. In general, the BOA is to be avoided, both because its attenuation leads to long exposure times and because of the degraded image it produces. We suggest that you try these options in this order:

1. ACQ/IMAGE with the NUV channel, using the PSA and MIRRORA.
2. ACQ/IMAGE with the NUV channel, using the PSA and MIRRORB.
3. Dispersed-light acquisition using the same configuration as for the first science exposure that follows the acquisition.
4. Dispersed-light acquisition with a different configuration if it will use less time overall.

Recommended STEP-SIZE for PEAKD

The STEP-SIZE value recommended when using ACQ/PEAKD during dispersed-light acquisitions depends on the number of positions sampled. If NUM-POS = 3 or 5, then we recommend STEP-SIZE = 1.2 arcsec. If NUM-POS = 7 or 9, then STEP-SIZE = 1.0 arcsec is recommended.

Calculating acquisition exposure times

As mentioned, you should use the COS ETC to calculate acquisition exposure times. There is an Imaging Acquisition ETC and a Dispersed-Light ETC available to do this. In either case be sure you bracket the situation that pertains to the source you are acquiring. For example, if you are acquiring a star and its unreddened color corresponds to about A5V, you may wish to try the different versions of "A5V" that are available as options in the ETC to see what range of exposure times results; they will not be identical. In general, the Kurucz models are to be preferred in the ultraviolet. The library spectra that are used to carry out these calculations can be downloaded from the ETC so that one can examine the alternatives. In addition, we recommend that you try model atmospheres that are one type hotter and cooler than the nominal type to get a sense of the possible range of UV brightness the source may produce. Estimating ultraviolet fluxes from optical data introduces many uncertainties. These can be reduced if actual UV data are available; see below.

Acquisition exposure times for variable objects

With variable objects (such as AGNs) it is important to calculate the acquisition exposure time carefully. The following strategy has been adopted by the COS GTOs in preparing their Phase II programs:

1. Start by using the brightest observed flux that has been observed for the object. Use this brightest flux both for BOP checking (discussed below) and for the acquisition strategy. If only one observation is avail-

able for the source, use a value higher by a factor of 2.5 (one magnitude) for BOP checking.

2. When calculating the Time_per_exposure to reach $S/N = 40$, use the minimum flux that has been observed. If only one observation is available, use 1/2 that flux.

Using Galex fluxes to calculate exposure times

Much of the sky has now been mapped by the *Galaxy Evolution Explorer*, or Galex. Galex images are taken in two broad UV passbands that are centered at about 1400 Å (Galex FUV) and 2300 Å (Galex NUV).

The Galex NUV images are especially helpful for planning acquisitions since the Galex NUV passband is similar to the NUV imaging passband for COS. Within APT, you can retrieve Galex images from MAST (on the left side of the Load window), and the Galex source catalog as well (click the bottom button on the right side of the Load window). The Galex images can be helpful for clearing objects when doing Bright Object Protection (BOP) checking, which is discussed below. For acquisitions, the Galex NUV AB magnitude can now be used in the COS ETC as a value to which the calculation is normalized. The choice of source type can still be important even with this measured UV flux.

Note that in some cases the display of Galex catalog sources within Aladin may appear odd. This is because only 10,000 sources can be displayed at one time. This problem should go away once you zoom in on your target of interest, or if you specify a smaller region to display from the Galex catalog.

5.2 TIME-TAG and BUFFER-TIME

As noted in the *COS Instrument Handbook*, all observers are expected to use TIME-TAG mode to obtain data unless their object causes too high a count rate. If TIME-TAG mode is used, you must specify Optional Parameter BUFFER-TIME, and that can be confusing. Recall that BUFFER-TIME is the length of time needed to read out one-half of the available COS memory buffer. These guidelines for specifying BUFFER-TIME may help:

1. The value of BUFFER-TIME you specify must be an integer number of seconds, and the minimum value of BUFFER-TIME you can specify is 80 seconds. Use a value of 80 seconds if your exposure time is less than 80, as might be the case with NUV imaging, for example. If the ETC returns a BUFFER-TIME value that is less than 80 then the source count rate is very high and ACCUM mode is probably to be preferred.

2. Use the COS ETC to estimate the exposure time. When you do so, the ETC will also indicate a value of BUFFER-TIME. However, the current values of sensitivities for COS are preliminary ones from ground testing, and, in addition, the ETC estimation is limited by how well the flux model chosen matches the actual object you are observing.

Because of these uncertainties, the `BUFFER-TIME` specified in your Phase II program in APT should be about $2/3$ the `BUFFER-TIME` value returned by the ETC.

3. At the same time, to avoid possible data loss the value you specify for `BUFFER-TIME` should be less than or equal to the exposure time. One obvious exception to this rule occurs for exposures less than 80 seconds long. If the exposure is less than 80 seconds then set `BUFFER-TIME = 80`. The buffer will be read out immediately after the exposure ends, and there will be no idle time.

4. If your expected `BUFFER-TIME` ($2/3$ of the calculated value returned by the ETC) lies between 80 and 110 seconds, a high event rate of 21,000 to 30,000 per second is implied. Such rates are allowed with `TIME-TAG` mode, but some special considerations apply. If the count rate exceeds 21,000, the COS data buffer fills with recorded events before it can be read out fully (because of the minimum allowable `BUFFER-TIME`). You have two options to deal with this situation. You can adopt a no-loss-of-data strategy that could restrict your exposure time, or you can accept gaps in the recorded data stream. In either case the COS data processing pipeline will properly account for the actual exposure times realized and so will calculate fluxes correctly.

- Option A: You wish to get all the data, but in a limited exposure time. In this case, use $2/3$ of the `BUFFER-TIME` returned by the ETC. If the `BUFFER-TIME` is set to a value from 80 to 110 seconds inclusive, however, a special situation arises. This occurs in this `BUFFER-TIME` range because APT forces the exposure time not to exceed twice the `BUFFER-TIME` in order to ensure that all data are recorded. In such a case APT will issue a warning and will truncate the exposure time at $2 \times \text{BUFFER-TIME}$. This situation corresponds to count rates of 21,000 to 30,000.
- Option B: You can tolerate some loss of time series information, but the desired overall exposure time is to be achieved. In this case choose a `BUFFER-TIME` of 111 seconds or longer. Doing so will enable the exposure time to be the value you specify. You will lose some fraction of the data stream during each `BUFFER-TIME` interval (see example below). Any gaps are minimized by specifying `BUFFER-TIME` to be 111.

As an example, suppose that you calculate that $2/3 \times (\text{BUFFER-TIME}$ returned by the ETC) is 100 seconds and you specify `Time_per_exposure = 360` seconds:

- With Option A, you would specify `BUFFER-TIME = 100`. However, it takes longer than that to read out the buffer and so APT limits you to an exposure time of $2 \times 100 = 200$ sec. In this case COS records all the events that arrived during the exposure time.

- With Option B, you would specify **BUFFER-TIME = 111**. Since the COS buffer may be full after the first 100 seconds, the last 11 seconds' worth of data may not be recorded and are lost each time the buffer fills, but the COS shutter will remain open for the full 360 seconds. With this option you will get a series of data blocks as follows: **100**, 11, **100**, 11, **100**, 11, **27**, where the bold numbers are when the data is actually recorded, with the data being lost during the three 11-second intervals. The data will be properly flux calibrated by the pipeline.

Bearing in mind the discussion just presented, the above recommendations for **BUFFER-TIME** can be summarized as follows.

Step 1: Calculate $\mathbf{B}_{2/3} = 2/3 \times (\text{ETC value of } \mathbf{BUFFER-TIME})$.

Step 2: In the following table, use $\mathbf{B}_{2/3}$ to determine the provisional **BUFFER-TIME**, \mathbf{B}_{pro} :

$2/3 \times \text{ETC value of } \mathbf{BUFFER-TIME} = \mathbf{B}_{2/3}$	Provisional BUFFER-TIME = \mathbf{B}_{pro}
less than 80	must use ACCUM mode
80 to 110	See text above. Can be either: a. Short, continuous time series (use $\mathbf{B}_{2/3}^{\text{a}}$), or b. A longer time series with regular data gaps (use 111)
111 or more	use $\mathbf{B}_{2/3}$

- a. Time_per_exposure must be less than $2 \times \mathbf{B}_{2/3}$.

Step 3: Use \mathbf{B}_{pro} as your **BUFFER-TIME** in APT with the following two additional considerations: **BUFFER-TIME** must be the minimum of (Time_per_exposure , \mathbf{B}_{pro}), and **BUFFER-TIME** must be at least 80.

BUFFER-TIME for variable sources

The remarks made earlier about acquisition exposure times for variable objects also pertain here. To ensure no loss of data, calculate **BUFFER-TIME** assuming that the source is in its brightest possible state.

Avoiding a too-low BUFFER-TIME

Given all the complexities involved in determining a best value of **BUFFER-TIME** for your observation, it may be tempting to choose a very low value as an easy way out. Please do not, as doing so would severely inhibit adding parallel observations. We will check for the appropriate value of **BUFFER-TIME** when your Phase II program submission is reviewed.

BUFFER-TIME and “auto-adjust”

APT includes a feature that will automatically expand an exposure to fill the time available when it is scheduled, but this feature does not alter the specified **BUFFER-TIME**. As long as the **BUFFER-TIME** specified is based on the source's count rate, this feature should not cause a problem for observers.

5.3 Using FP-POS

Use of the FP-POS Optional Parameter is recommended when obtaining a spectrum with COS as a way of improving S/N. The simplest way to do this is to use FP-POS=AUTO, and, if you do, your overall exposure will be split into four sub-exposures of equal length. However, it can be more efficient to specify FP-POS explicitly, and, if you do, you also gain flexibility in assigning exposure times to the individual sub-exposures. If you use FP-POS in this explicit way, we recommend adding FP-POS=1 to the first exposure, FP-POS=2 to the second, FP-POS=3 to the third, and FP-POS=4 to the fourth. You can also elect to only do two or three sub-exposures, for instance. Ordering the FP-POS positions in numerical order (such as 1-2-3-4 or 1-2-4) minimizes the overhead times associated with the OSM movements that are needed. Also, by specifying FP-POS in this way you can alter individual exposure times slightly to make more effective use of a visibility period.

FP-POS at low S/N

In cases where a spectrum with low S/N will suffice, multiple FP-POS positions can be disadvantageous. We recommend that two FP-POS positions be used so that you can confirm that an apparent feature is real.

FP-POS and gap coverage in the FUV

As described in the *COS Instrument Handbook* and shown in Figure 4.1 above, the two segments of the COS FUV XDL detector have a gap between them. If you require a full spectrum that covers all available wavelengths at medium resolution, the best strategy is use the grating at one FP-POS but at four consecutive central wavelengths. For example, use of G130M at central wavelengths 1300, 1309, 1318, and 1327 Å, all with FP-POS=3, will efficiently cover the full range available with G130M and will provide the equivalent of four FP-POS positions.

If a complete FUV medium-resolution spectrum is sought, we recommend using G130M at its four shortest central wavelengths plus G160M at its four longest wavelengths.

6. Bright Object Protection Procedures

All COS observers are required to verify that their targets and fields do not have excessively bright objects and thus are safe to observe. This verification must be done by the Phase II deadline. The relevant policies and procedures are described here; see also the *COS Instrument Handbook*, Section 11.5, and especially Table 11.3 which gives the applicable count rate screening limits. Be sure to use the revised Table 11.3 that is shown in this ISR on page 12.

STScI has developed bright object tools (BOT) to conduct detailed field checking prior to COS program implementation. These tools provide an

automated analysis of the fields using data from the Guide Star Catalog 2 (GSC2) and displays from the Digital Sky Survey (DSS). GSC2 provides two magnitudes (photographic J and F), and hence one color, for fields down to about 22nd magnitude. These magnitudes, combined with conservative relationships between spectral type and color, are used to determine whether objects in the field may pose a risk.

In many instances the BOT allows expeditious clearing of a field for safety, but in some cases the GSC2 is inadequate because of crowding or absence of observations in one of the filters, for instance. In those cases supplementary information must be provided to STScI by the proposers to support the bright object protection (BOP) checking. The target should always be checked directly in the ETC with the more detailed information available for it, rather than relying on its field report data returned by the BOT.

By policy GOs must provide screened, safe targets for COS programs, as well as any supplementary information that is needed to verify target and field safety. The APT/BOT, including an Aladin interface, makes the BOP procedures accessible for GO use. Help files and training movies are available. All COS observers must conduct BOP reviews of their targets and fields as part of their Phase II report. You are urged to begin your Phase II review early so that you are aware of any problems, such as the need for supplementary data, which might otherwise cause delays following the Phase II deadline. (An exception is moving target fields, which must be cleared after the scheduling windows have been established.) To assist with these procedures, a COS Contact Scientist (CS) will be assigned to each COS program, to assist and advise the GO as necessary and requested during the Phase II preparations, and through program execution.

Briefly, for a COS pointing with unconstrained orientation, a field of 43 arcsec in diameter must be checked and cleared. These checks must be performed for all COS pointings, especially acquisitions. The APT/BOT automatically reports on all GSC2 stars within that field. If any displacements from the default pointing are specified (e.g., POS TARGs), the field to be cleared increases commensurately. POS TARG vectors and the enlarged, rotated field circles are displayed in APT/Aladin. No unsafe or unknown star may lie within 7 arcsec of either COS aperture at any orientation. (The BOT automatically allows for the reduced throughput of the BOA.) Alternatively, orientation restrictions may be added to a visit to avoid bright objects in the fields, although doing so limits the times at which the observation can be scheduled.

A COS GO must send to the CS, by the Phase II deadline, ETC calculations for each discrete target, and reports on any unsafe or unknown stars from APT/BOT for each field, either showing that the observations are in fact safe, or documenting any unresolved problems. Each ETC simulation that you run is given a unique identifying number, and it is very helpful to include that number in your Phase II information because your CS can then retrieve the calculations and input parameters. If there are unresolved problems, other photometric or spectroscopic data should be sought by the GO to clear the

fields. Many of these are available directly through APT/Aladin (although automatic BOP calculations are available only with GSC2), including the STScI Multimission Archive (MAST), which contains IUE and Galex data in addition to HST observations. An existing UV spectrum of the target or class may be imported directly into the ETC. IUE data must be low resolution and have used the large aperture for the spectrum to be useful for BOP checking (so that it is properly flux calibrated). If model spectra are used, they should be the original Kurucz (not Castelli & Kurucz) set for early-type stars. None of the provided models is entirely adequate for late-type stars, since the models lack emission lines; actual UV data must be used for them. In worst cases, new ground-based data or HST CCD UV exposures may be required to clear the fields for BOP; in general, the latter must be covered by the existing Phase I time allocation. An observer may upload their own source spectrum into the ETC, but bear in mind that spectrum must cover the full range of wavelength to which the detector is sensitive. For the NUV channel that range is 1650 Å to 12,000 Å, given the MAMA's red leak. The software expects data fully to 1.2 μm.

If a given star has only a V magnitude, it must be treated as an unreddened O5 star. (The older Kurucz O5 model with higher T_{eff} in the ETC should be used for BOP purposes.) If only one color is available, it may be processed as a reddened O5 (which will always have a greater UV flux than an unreddened star of the same color). If two colors are available, then the actual spectral type and reddening can be estimated separately. The APT/BOT now automatically clears stars with only a single GSC2 magnitude if they are safe on the unreddened O5 assumption. Any other unknowns must be cleared explicitly.

In some cases, the 2MASS JHK magnitudes may be the only photometry available for an otherwise "unknown" star. It is possible to estimate V and $E(B-V)$ from those data on the assumption of a reddened O5 star, and thus determine its count rates in the ETC. Note that Martins & Plez (2006) derive $(J-H)_0 = -0.11$ for all O stars; and $(V-J)_0 = -0.67$, $(V-H)_0 = -0.79$ for early O spectral types. (The K band should be avoided for BOP because of various instrumental and astrophysical complications.) Bessell & Brett (1988; Appendix B), provide relationships between the near-infrared reddenings and $E(B-V)$. These data determine the necessary parameters. Note that the ETC also supports direct entry of observed J , H magnitudes with $E(B-V)$.

In some cases not all problems will be resolved by the Phase II deadline, but they should at least be identified and have planned resolutions by then. Note that unlike any other instrument, for COS all acquisition exposures must also be cleared. Any COS targets or fields that cannot be demonstrated to be safe to a reasonable level of certainty in the judgement of the CS will not be observed. It is possible that equivalent alternative targets may be approved upon request in that case; but any observations that trigger the onboard safety mechanisms will not be repeated.

A related issue is COS pointing specification changes after the targets and fields have been cleared by the STScI BOP review. Any such changes must be approved by the COS Team on the basis of a specific scientific justification and

a new BOP review by the GO, which may be submitted via the CS if absolutely necessary. However, in general such requests should be avoided by ensuring that submitted COS specifications are final, to prevent a need for multiple BOP reviews.

GOs planning COS observations of unpredictably variable targets, such as cataclysmic variables, are reminded of the special BOP procedures in effect for such sources. These are detailed in ACS ISR 06-04 and they apply to all HST detectors subject to BOP.

6.1 Procedures for BOP Checking

To ensure your program will be approved for execution, these steps are suggested for each visit:

1. Check the acquisition first to confirm that your target is safe to acquire and that no nearby objects pose threats. If you are performing an acquisition using dispersed light, proceed to the next step because if the target is safe for getting a spectrum, then it is safe to acquire in dispersed light using the same configuration (grating and central wavelength).
2. Estimate the spectrum count rate for your target and compare to the appropriate global count rate (GCR) limit. Estimate spectrum count rates for nearby objects as well if you are using a dispersed-light acquisition.
3. If your target has emission lines, use the COS ETC to estimate the maximum count rate that could occur and compare to the appropriate LCR limit.

BOP Checking for NUV Imaging Acquisitions

Imaging acquisitions with the COS NUV channel are fast and accurate and ordinarily are to be preferred. However, the imaging mode concentrates the entire NUV flux of an object into a single spot, and this makes it possible to easily exceed the NUV local count rate (LCR) limit. In most cases a proper choice of aperture (PSA or BOA) and mirror (MIRRORA or MIRRORB) should enable you to get the count rate for your source under the LCR limit. (However, note that the BOA degrades the image and so an imaging acquisition that uses the BOA may not be as precise as one with the PSA.)

The BOP tool in APT provides the means to do this checking. However, the objects flagged as potential problems (“Unknown” or “Health & Safety”) are determined from Digital Sky Survey data, which is to say optical information. If your target lies in a Galex field you can retrieve the Galex image and catalog data and determine whether those objects actually pose risks. In some cases there may be objects flagged as problems that do not even appear as sources in the Galex images, and you can note this fact in your report on BOP checking (but be sure the Galex image you are viewing covers the entire field that you

need to clear; sometimes you can end up at the edge of an image). See “Calculating acquisition exposure times” on page 14 of this ISR. for more information.

Use the COS ETC to estimate count rates. In using the COS Imaging Acquisition ETC, one of the output values is the total count rate achieved in a 9×9 box. Your target will pass the screening limit and be safe to observe if this value is 300 counts per second or less.

If Galex observations do not exist for your field, you will have to determine the safety of your imaging acquisition using other information, as described above.

BOP Checking for Emission-Line Objects

In addition to verifying that a target is safe to acquire in imaging mode, the object must also be safe to observe spectroscopically. The total count rate in a spectrum must be shown to be under the GCR limit. Just as important, any emission lines in the object must be shown to produce a count rate that does not exceed the LCR limit for spectroscopic mode. For the NUV channel, the LCR limit for spectra is 70 per second in the brightest pixel, or, equivalently, 380 counts per second in a box of 4×8 pixels (with the 8 pixels being in the cross-dispersion direction).

7. Change History for COS ISR 2008-01

Version 1: 5 June 2008 – Original Document

8. References

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Martins, F., & Plez, B. 2006, *Astron. & Astrophys.*, 457, 637
Soderblom, D. R. et al. 2007, “Cosmic Origins Spectrograph Instrument Handbook”, version 1.0, (Baltimore, STScI)

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