COS Instrument Science Report 2002-01.0

COS Bright Object Protection

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11 September 2002

ABSTRACT

We describe the onboard bright object protection mechanisms of the Cosmic Origins Spectrograph and the associated count rate limits. Using the rules developed before for STIS, we recommend a set of ground screening limits for observations of targets with COS.

1. Background

The Cosmic Origins Spectrograph (COS) utilizes two channels to detect photons: a far-UV (FUV) channel for the 1175 – 1775 Å wavelength range, and a near-UV (NUV) channel for the range 1750 – 3200 Å. The FUV detector system is a microchannel-plate (MCP) array with a cross delay-line (XDL), very similar to the double-delay line detector flown on the FUSE mission. The system is divided into two segments, each of them operable independently, in order to record the full length of the projected COS spectrum. In the NUV, a multi-anode microchannel array (MAMA) is used. This detector is functionally identical to the STIS MAMA detector.

In common with all photon-counting devices, both the FUV XDL-MCP and the NUV MAMA detector can be damaged if exposed to excessively high illumination levels. Therefore, COS is subject to similar bright object restrictions as STIS. The STIS IDT provided Constraints and Restrictions Document (CARD) items to define the damage levels for the STIS MAMA detectors. Since the effect of an overillumination can be catastrophic, depending on the overlight level, STIS has hardware and software protection mechanisms to protect itself from accidental overlight conditions. Since these mechanisms do not guarantee full protection, STScI screens all target fields prior to scheduling in order to prevent observations of targets that would trigger the safety mechanism or even cause an over-illumination of the detector. A corresponding screening procedure for COS is described here and will be applied to all COS targets.

2. COS FUV Overlight Limits

COS has three levels of bright object protection (BOP) for the FUV detector which have been implemented as hardware and software count rate monitors:

1) HV Overcurrent Protection – This current limit protection task monitors the HV current and reports over-limit events. If consecutive out-of-limit events are detected, the power to the HV supply is turned off. This is the most basic protection mechanism.

2) Global Rate Monitoring – The Global Rate Monitor continuously compares the number of photon events during a commandable interval against a rate limit that can be specified. If the limit is exceeded, the high voltage is turned off. The Global Rate Monitor operates on each segment separately.

3) Local Rate Monitoring – A localized region of the FUV detector can be permanently damaged due to gain degradation. The local rate BOP algorithm performs a threshold test over a binned area in either segment at the beginning of each exposure. If the threshold test fails, the external shutter is commanded to close.

The primary consideration in protecting the FUV detector is minimizing the charge extraction from the plates. The COS detector operates at a gain of about 10^7 e^- per event. This is about 100× higher than the value for the NUV MAMA detector. Therefore, charge is extracted much more quickly from the FUV XDL-MCP than from the NUV MAMA. This is the main consideration driving the overlight restrictions. The CARD local rate limit for the FUV XDL-MCP is 1500 counts s^{-1} RE^{-1}. At that rate, all the charge in the localized region being exposed will be extracted in a single 10,000 second exposure. The trigger limit for the Local Rate Monitor was set by applying a safety factor of 15 to the CARD limit of 1500 counts s^{-1} RE^{-1}, i.e., 100 counts s^{-1} RE^{-1}. If this limit is exceeded, the flight software commands the external shutter closed. The latter value is well below the maximum rate the MCPs can support before the plates suffer from significant gain sag. The MCPs experience a 5% drop in gain for a local rate of 5 counts s^{-1}pore^{-1}. No measurable gain drop has been found for lower local rates. Since a resolution element has about 50 pores, the 5% drop corresponds to a local rate of 250 counts s^{-1} RE^{-1}. Therefore the trigger limit of 100 counts s^{-1} RE^{-1} is in the regime of no significant gain decrease.

There is no global detector related limit in the CARD because it is so far above the threshold set by the local rate limit that it is very difficult to state meaningfully. The MCPs can in principle support global count rates of several hundred thousand counts s^{-1} without immediate damage, provided the local limit is not exceeded. However, damage will occur from extended exposure to those count rates since the local rate limit is exceeded. For instance, the local limit of 100 counts s^{-1} RE^{-1} exceeded over the total 2300 resolution elements per segment translates into a global limit of 223,000 counts s^{-1} per segment.

The Global Rate Monitor is set to trigger at rates above 60,000 counts s^{-1} per segment. This limit is not related to detector damage; rather it is driven by dead-time performance considerations. Above this rate, the dead-time correction exceeds several percent of the count rate. If a global rate of 60,000 counts s^{-1} per segment is exceeded, the FSW turns off the FUV HV. This results in the external shutter being closed and the internal lamps being turned off.

In addition, the FUV XDL-MCP is subject to a global rate limit of 21,000 counts s^{-1} in TIMETAG mode due to the science data buffer management. This is not a safety related limit. Exceeding this limit would only lead to a loss of science. Therefore this limit is not relevant for the COS BOP. The only instrument limits that should drive the screening limits for the FUV XDL-MCP are the Local Rate Monitor trigger limit of 100 counts s^{-1} RE^{-1} and the limit of 60,000 counts s^{-1} per segment imposed by the Global Rate Monitor.

3. COS NUV Overlight Limits

The COS NUV MAMA has the same protection mechanisms as the STIS MAMA. The STIS hardware and software protections are discussed in STIS ISR 96-31.

1) Bright Scene Detector (BSD) – The BSD monitors the output of two anode wires at every 32^{nd} row of pixels. For COS, the dispersion direction is parallel to the rows. A count rate of 117,000 counts s^{-1} will lead to a shut down of the HV. Only about $1/17^{th}$ of the total rate is counted for uniform illumination. (There are 1024 rows, but only

60 are counted because rows 1,2 and 1023,1024 are excluded.) This threshold corresponds to a field rate of 2×10^6 counts s^{-1} for uniform illumination over the full detector. The scaling factor of 17 does not apply to point source illuminations since a narrow spectrum can either miss the monitored anodes entirely or if it happens to lie on a monitored pixel row, the HV turn-off can occur at a rate of 117,000 counts s^{-1}. This is the reason why the BSD often sets the BOP threshold for STIS 1^{st} order spectroscopy.

2) Software Global Monitor (SGM) – The SGM monitors the global count rate and turns off the HV if the count rate exceeds 770,000 counts s^{-1}. The CARD limit for global illumination is 1.5×10^6 counts s^{-1}. The SGM is intended to be the primary means of overlight protection for the NUV MAMA. It has a faster sampling time of 0.1 s than the BSD, whose sampling time is 0.138 s. However, the SGM becomes ineffective at input rates above 4×10^6 counts s^{-1}, where the event rate is too high for the signal processing electronics.

3) Local Rate Check (LRC) – The LRC is designed to prevent local over-illumination of the MAMA pixels and the associated gain degradation. Prior to the start of the science exposure, a rate check is performed and if the rate is found to be above 200 counts s^{-1} $pixel^{-1}$, the exposure is aborted, the external shutter is closed, and the lamps are turned off. The corresponding CARD local limit is 500 counts s^{-1} $pixel^{-1}$ or 4500 counts s^{-1} RE^{-1}, as there are 9 pixels per RE.

Special considerations apply to the MAMA BSD limits with COS. The NUV spectrum is recorded in three spectral stripes. There is the potential risk of tripping the BSD at relatively low count rates if all three stripes are placed on three BSD pixel rows simultaneously. It is intended that the three spectral stripes will be aligned on the MAMA such that they are separated by values which are not divisible by 32 ±3. (Three pixel rows are added as a safety pad to account for the spatial profile of the spectral stripes.) With this spacing, the anode wires would never be illuminated by all three spectral stripes simultaneously, irrespective of the source location on the detector. Thus, one can observe point sources having a *flat* spectrum whose fluxes are three times larger than for a situation where the three stripes are separated by 32 pixels. This would raise the "effective" BSD onboard limit for such sources to $117{,}000 \times 3 \cong 350{,}000$ counts s^{-1}, still a factor of 2.2 more conservative than the SGM limit of 770,000 counts s^{-1}.

The same science data buffer management restrictions as for the FUV XDL-MCP apply to the NUV MAMA channel as well. The global rate limit is 21,000 counts s^{-1} in

TIMETAG mode. As this is not safety related, we will not consider this restriction for setting the ground screening limits.

If data are taken in ACCUM mode, an additional restriction exists. The flight software of the detector interface board cannot process the counts fast enough above a global count rate of 170,000 and 230,000 counts s^{-1} for observations taken with and without subarrays, respectively. If these limits are exceeded, data loss occurs without high voltage shutdown and/or the instrument entering safemode. Again, as these limits are unrelated to instrument safety, they will be ignored. Note that the same ACCUM limits exist for the FUV XDL-MCP as well, but they are far less stringent than the FUV global limit of 60,000 counts s^{-1} per segment.

To summarize, the most restrictive local and global NUV limits are 200 counts s^{-1} $pixel^{-1}$ and 350,000 counts s^{-1}, respectively.

4. Purpose of Bright Object Protection

The rationale behind the screening of STIS observations was discussed in STIS ISR 96-028. Since STIS and COS share similar detector characteristics, the purpose of the bright object protection, as laid out in the STIS document, applies to COS as well. STScI will perform the ground screening in addition to the on-board protection mechanisms for the following reasons:

a) To protect the detectors from damage where the on-board safety mechanisms may fail. This applies in particular to the NUV MAMA, whose Global Software Monitor is subject to deadtime effects and may not provide adequate protection at extremely high count rates.

b) To minimize bright object related high-voltage-off occurrences. While the onboard safety mechanisms will normally shut down the high voltage in the case of an over-illumination, this is undesirable from an instrument-health point of view and is costly in terms of the resources needed for recovery.

c) To maintain the efficiency of HST by reducing the number of lost science observations. It is the goal of STScI to maximize the COS science by not scheduling observations that have count rates around and above the onboard trigger limits, leading to science loss and a disruption of the schedule.

STScI will establish ground screening limits for COS observations similar to those already in place for STIS. These limits will be chosen to maximize both instrument protection and science return.

5. Screening Limits and Procedure at STScI

The STIS rule is to adopt ground screening limits which are about a factor of 4 below the threshold of the global monitors and a factor of 2.5 below the local rate check monitors. Since both monitors are about a factor of 2 below the CARD safety limits, this gives total safety limit factors of 8 and 5 for the global and local limits, respectively. The STIS safety limits for the local rate check are somewhat less stringent because the impact of a local overlight condition is less severe than that of a global violation.

These STIS baseline limits apply to a non-variable point source. If an irregularly variable object is observed, the global screening limit becomes more conservative by a factor of 2.5 (one stellar magnitude). Taking again into account that a local rate violation is less severe, this more conservative limit applies only to the global rate. The local limit remains unchanged.

Corresponding screening rules are applied to COS. The screening limits are below the global and local onboard limits by the same factors of 4 and 2.5 as for STIS, respectively. A summary of the COS limits is in Table 1, together with the COS onboard limits determining these screening limits.

The NUV global screening limit of 30,000 counts s^{-1} per stripe translates into a grating and source-type dependent flux limit if the three spectral stripes on the MAMA will be aligned such that their separation in pixels will not be divisible by 32 ±3. For M mode observations of point sources with flat spectra, the count rates in the three stripes are comparable. The maximum allowable NUV target flux of these sources becomes about three times larger than for a strongly peaked source having the same total NUV flux, but with all the counts coming from one spectral stripe. For L mode observations, one spectral stripe will almost always be dominant in brightness, and the 30,000 counts s^{-1} per stripe screening limit will translate into similar NUV flux limits, irrespective of the stripe alignment.

The local limits for the FUV channel are stated per resolution element. For a point source spectrum, they translate into a per pixel rate by dividing the values by a factor of 60. The screening limits for other types of astronomical objects can be easily inferred from this table. If an object of uniform surface brightness completely filling the aperture were observed on the NUV side, the global screening limits would be lower by an additional factor of 3 (i.e., 30,000 counts s^{-1} for a non-variable source). In this case, all three spectral stripes would be placed on BSD pixel rows, and the point source scaling factor of 3 does not apply.

Table 1: Recommended COS ground screening limits for point sources

Target	Limit	Channel	Screening Limit	Constraint
Non-variable	Global	FUV	15,000 counts s^{-1} (per segment)	Global Rate Monitor / 4
Non-variable	Local	FUV	40 counts s^{-1} RE^{-1}	Local Rate Monitor / 2.5
Irregularly Variable	Global	FUV	6,000 counts s^{-1} (per segment)	Global Rate Monitor / 10
Irregularly Variable	Local	FUV	40 counts s^{-1} RE^{-1}	Local Rate Monitor / 2.5
Non-variable	Global	NUV	30,000 counts s^{-1} (per brightest stripe)	Bright Scene Detector / 4
Non-variable	Local	NUV	75 counts s^{-1} $pixel^{-1}$	Local Rate Monitor / 2.5
Irregularly Variable	Global	NUV	12,000 counts s^{-1} (per brightest stripe)	Bright Scene Detector / 10
Irregularly Variable	Local	NUV	75 counts s^{-1} $pixel^{-1}$	Local Rate Monitor / 2.5

If a target comes within one magnitude (or a factor of 2.5 in flux) of the limits in the table, the observer must provide an existing UV spectrum (e.g., obtained with IUE, HUT, FOS, GHRS, STIS, or FUSE) of the object, which proves that neither the global nor the local absolute limits will be exceeded. If there are no such data, a “pre-exposure” with a different HST UV instrument must be obtained, or the COS BOA aperture must be used.

STScI will perform a screening of not only the target in the COS aperture, but also of targets within 5 arcsec of its boundaries. If objects are found which would exceed the screening limits for the particular instrument configuration, the observations will not be executed. Field objects falling in an annular region extending from 5 to 13.5 arcsec from the edge of the COS aperture have additional restrictions. Any object in this zone will be disallowed if it produces either a global count rate in excess of 1.5×10^6 counts s^{-1} in the NUV, or a local count rate above 500 counts s^{-1} $pixel^{-1}$ (corresponding to 4500 counts s^{-1} RE^{-1}) and 100 counts s^{-1} RE^{-1} in the NUV and FUV, respectively.