CURRENT CTE-MITIGATION RECOMMENDATIONS

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June 4, 2020

HST's continued exposure to harsh radiation in its low-earth orbit means that its CCD detectors are subjected to continuing degradation of their CTE (charge-transfer efficiency). This makes mitigation of CTE losses a continually moving target.

We have developed a new model for the CTE losses and will soon be releasing it in the pipeline as a pixel-based correction. Details of the new model and how it differs from the previous model are provided in a new ISR (WFC3/ISR 2020-08, Anderson). **The main result is that we are now recommending that the optimum target background level be raised from 12 e^- to at least 20 e^- to ensure that CTE losses remain at a manageable level.** This brief White Paper is designed to provide a high-level summary so that the typical user can plan his or her observations wisely. GOs that need more detailed guidance should consult the ISR or their CS.

In 2016, when the UVIS CTE model was most recently developed, it was recommended that GOs use post-flash to ensure that their background would be at least 12 e^-, since below this level CTE losses became pathological. At the time, this guidance kept losses to below 25%, which allowed the pixel-based reconstruction algorithm to be successful. HST has now been in orbit almost twice as long now, and losses are now approaching 50% for the faintest sources on backgrounds of 12 e^-. For this reason, we began to explore whether raising the recommended background level might be beneficial.

Figure 1 demonstrates how imperfect CTE affects the central column of a faint star and a medium-brightness star under various background conditions. Parallel readout of the detector moves the star images to the *left* in these figures. It is clear that with low backgrounds of 2 e^- or 8 e^-, the stars suffer over 50% losses. A background of 15 e^- provides some mitigation, but only backgrounds of 20 e^- or higher provide adequate mitigation, keeping the losses below 25%. The model shows that mitigation continues to improve as the background level goes up, so some users may want to do a more careful optimization of their choice of background.

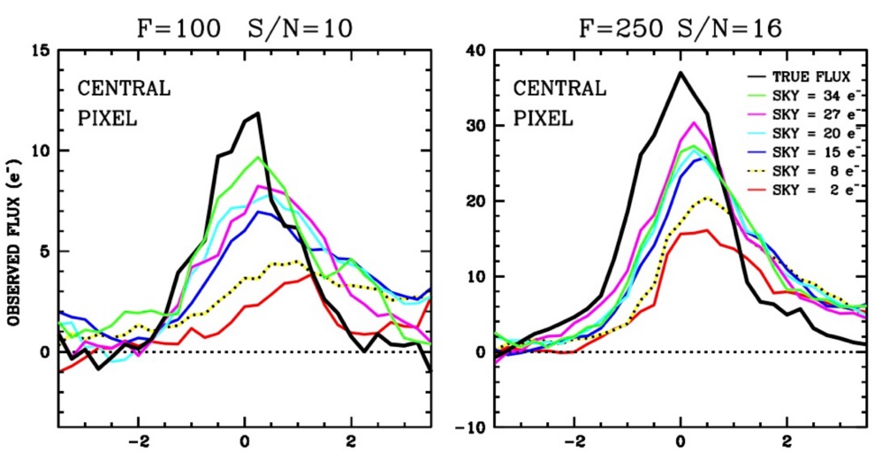

Figure 1: The composite vertical profiles of actual faint and medium-brightness stars, as observed in early 2020 at the top of the detector under various sky-background conditions. (Excerpted from Figure 4 of WFC3/ISR 2020-XX)

It is worth noting that increasing the background level provides the largest mitigation for fainter stars. This can be seen by comparing the faint-star and bright-star profiles. The outer pixels of brighter stars and extended sources provide their cores with some natural background mitigation.

The best approach observers can take to deal with imperfect CTE is to minimize the losses in the first place. The main strategies for this were discussed in the initial White Paper[1] on the subject by MacKenty and Smith. Section 6.9.2 of the WFC3 Instrument Handbook also provides options for CTE-loss avoidance. We summarize the basics below.

One effective strategy is to divide the observations into fewer — but longer — exposures. This has several benefits. First, it provides more natural background, so that less post-flash will be required to achieve the desired CTE-mitigation level. Second, it increases the source signal per exposure relative to the readnoise *and* relative to whatever postflash is eventually used. Finally, each readout avoided adds more than 90 seconds to the total exposure time available in the orbit. The downside, of course, is that fewer dithers provide less mitigation from image defects and CRs and also allow fewer sub-pixel samplings of the scene (which can limit the achievable resolution through `Drizzle` reconstruction). That said, users who plan several orbits of identical observations of the same scene in order to go extremely deep often use only two or even just *one* exposure per orbit[2] in order to lessen the impact of CTE losses.

Another strategy to lessen CTE losses is to place the target closer to the readout amplifier. Of course this isn't feasible if the target takes up the full 164″×164″ field of view, but it is a good option for smaller targets. This can be accomplished by placing the target closer to the readout and either reading out a subarray (use aperture UVIS2-C512C-SUB and UVIS2-C1K1C-SUB) or reading out the entire detector (use aperture UVIS2-C512C-CTE and UVIS2-C1K1C-CTE).

Postflash of course is a final option. APT allows post-flash levels from 0 to 25 electrons to be set by observers. The WFC3 ETC (https://www.stsci.edu/hst/instrumentation/wfc3/software-tools/exposure-time-calculators) and ISR-2012-12[3] by Baggett and Anderson provide estimates of the natural background per second for typical blank fields for most of the UVIS filters. The image background can certainly be larger than this if there is an extended object present. Users should obtain the best estimate of the expected background at the location of their targets so that they postflash only as much as is truly needed to mitigate CTE so as to minimize adding noise to the image.

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[1]See: https://www.stsci.edu/files/live/sites/www/files/home/hst/instrumentation/wfc3/performance/cte/_documents/CTE_White_Paper.pdf

[2]Whole-orbit exposures have a lot of CRs and a minimum of 8 exposures are needed to allow for effective mitigation (Marc Rafelski, personal communication). There is also a bit more blurring of the PSF than typical in the longer exposures. See also program GO-13872 by Oesch for another example.

[3]See: https://www.stsci.edu/files/live/sites/www/files/home/hst/instrumentation/wfc3/documentation/instrument-science-reports-isrs/_documents/2012/WFC3-2012-12.pdf