SWIFT-UVOT-CALDB-##
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SWIFT UVOT CALDB RELEASE NOTE

SWIFT-UVOT-CALDB-##: NAME OF CALDB PRODUCT

0. Summary:

The coincidence loss CALDB file contains an empirical polynomial correction to the theoretical relation for coincidence loss in the photon-counting UVOT detector. It applies to photometry with an aperture radius of 6".

1. Component Files:

FILE NAME	VALID DATE	RELEASE DATE	VERSION
swucountcor20010101v101	2004-11-20	2006-05-04	101

2. Scope of Document:

This document describes the empirical determination of polynomial coefficients which modify the theoretical coincidence loss correction to provide optimal linearity for UVOT photometry.

3. Changes:

This is the first post-launch release note for this CALDB file.

4. Reason For Update:

This is the first measurement of the post-launch coincidence loss correction. There are significant changes from the earlier CALDB file (swucountcor20041115v011.fits) which was based on prelaunch data.

5. Expected Updates:

There has been a minor correction to the estimated UVOT frame time (from 11.088ms to 11.033ms for a full-frame image) so the coincidence loss polynomial will need to have this correction applied.

Much additional data is now available for testing the coincidence loss correction, and further refinement is expected. In particular, it is not certain whether the small correction to the theoretical coincidence loss introduced by the current CALDB file consistently improves the linearity.

6. Caveat Emptor:

The coincidence loss correction is derived for a point-source aperture radius of 6" and may not apply to other aperture sizes. In particular, a smaller radius of 5" is now being used for optimal photometry work and the coincidence loss correction has not been extensively tested for this smaller aperture.

The coincidence loss correction is nonlinear and diverges at the coincidence loss limit of 1 count per frametime (about 92 cts/s). At count rates near this limit, small errors in the accuracy of the coincidence loss correction can cause large errors in the corrected count rate.

The CALDB file contains information on the CCD clocking parameters (e.g. the number of horizontal clocks per row) which can be used to determine the frametime and the deadtime. Although this information is believed to be correct, it is not actually used by any of the UVOT software.

7. Data Used:

ObsID	***Target***	***Date***	***Filter***	***ExpTime***
00054210004	NGC 188	Oct 13, 2005	B	325
00130088002	GRB050525	May 26, 2005	B	3251

ObsID	Target	Date	Filter	ExpTime

8. Description of Analysis:

From Poisson statistics, the theoretical correction for coincidence loss for a point source is given by

$$C_{theory} = -\ln(1 - C_{raw} ft(1 - df)) / ft(1 - df)$$

where C_{theory} is the theoretical coincidence loss corrected count rate, C_{raw} is the raw observed deadtime-corrected count rate, *ft* is the frame time, and *df* is the deadtime fraction. This equation applies to a single physical (4") CCD pixel and assumes that all coincidences are directly on top of each other with minimal blurring of a single event profile. The theoretical relation should be best approximated when using an aperture size comparable to the 6 physical CCD pixels used for centroiding the photon splash. Here we use a 6" radius aperture, and determine a empirical polynomial function of the counts per frametime, which is used to correct the theoretical coincidence loss correction. This correction is determined by observing a star field (NGC 188) with known precision photometry, applying the theoretical coincidence loss correction, and determining any adjustments needed to ensure linearity.

A pre-launch calibration of the coincidence loss polynomial was derived by comparing the response of the UVOT detectors to that of a photomultiplier tube. However, the accuracy of the ground-based calibration was suspect, because the illumination source was not point-like.

The flight calibration of the coincidence loss polynomial was derived using a B band observation (00054210004) of the open cluster NGC 188 which has superb photometry to V=21 by Peter Stetson (2004, PASP, 116, 1012). The calibration was then checked using other fields with accurate ground-based photometry and by observing stars observed with different frame rates.

Frametime and Deadtime:

Until about March 2006 there was some uncertainty about values of the frametime and deadtime to be used in the theoretical coincidence loss equation. Since V3.5 of the UVOT pipeline, the CCD frametime for an UVOT exposure has been stored in the FITS header, and has a value of 11.0322 ms for full frame exposures. The deadtime fraction is computed from the frametime by the formula *df = vtrans*nvpi / ft*

where *vtrans=6e-7s* is the vertical transfer time on the CCD, and *nvpi = 290* is the number of vertical pixel transfers per image. This formula yields a deadtime fraction for a full frame image of 0.01577. The deadtime correction = *1 – df* is now also recorded in the DEADC keyword in the FITS header.

Prior to March 2006, the task UVOTMAG (which computes the coincidence loss correction) had incorrect values of the frametime (=11.088ms) and deadtime = 0.0025974 hardcoded. (The frametime value was taken from the XMM/OM detector, and the deadtime value was a factor of six too small.) Currently, UVOTMAG obtains the FRAMETIME from the FITS header when possible and computes the deadtime as above.

There was also some uncertainty as to whether the value of the EXPOSURE keyword in the UVOT FITS header already had a deadtme correction applied. Prior to processing version V3.5, the correction was applied to image mode data but not to event mode data. Currently, the correction is applied to all data, and is recorded in the DEADC keyword.

NGC 188

To compare the UVOT photometry of NGC 188 with the B magnitudes in the Stetson catalog, we first selected stars in the Stetson catalog that had no neighbors within 12". A total of 198 of these isolated stars had matching sources on the UVOT image. The UVOT photometry was performed using a 12 pixel radius aperture with the sigma-clipped sky background taken between 15 and 30 pixels. The theoretical coincidence loss correction was applied to the raw UVOT counts prior to the background subtraction. These counts were then multiplied by a fourth-order polynomial correction factor

$$cts = cts * (1 + a_1 x + a_2 x^2 + a_3 x^3 + a_4 x^4)$$

where x is the observed number of counts per frametime, and the polynomial coefficients a_i are adjusted by a least squares program to provide the best match with the catalog photometry. No color correction term was applied. The zero point was also kept as a free parameter, to account for any possible exposure time problems for this particular exposure. The derived polynomial coefficients are shown in Table 1 as the current CALDB. Also shown in this table are the pre-launch coefficients, and the slight update current CALDB using the current best frametime and deadtime. A plot of the empirical corrections as a function of *x,* the number of counts per frametime*,* for the three cases is shown in Figure 1. It can be seen that the empirical correction in the current CALDB is quite small, and never exceeds 3%. In contrast, the pre-launch calibration exceeds 10% at x = 0.65, with increasing deviation for larger x values.

Table 1: Polynomial Correction Coefficients

	X	*X^2*	*X^3*	*X^4*
PreLaunch	***0.2966***	***-0.4920***	***-0.4183***	***0.2688***
CurrentCALDB	***-0.1256***	***0.1963***	***-0.1405***	***0.0904***
Current Best	***-0.2070***	***0.5471***	***-0.7171***	***0.3863***

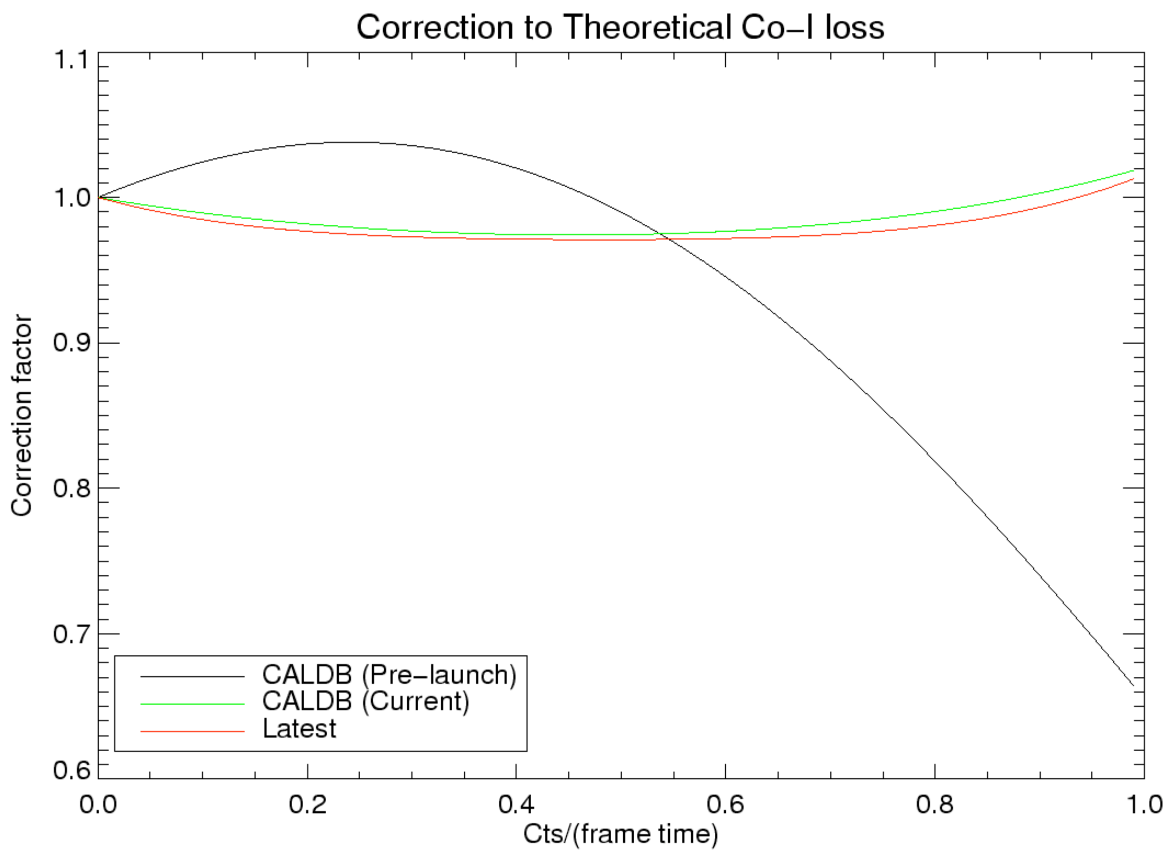


Figure 1: Polynomial Correction to the theoretical Co-I Loss

Figure 2 shows the results for NGC 188 for the case of (1) no coincidence loss correction, (2) the pre-launch coincidence loss calibration, (3) the theoretical coincidence loss correction, and (4) the current CALDB correction. This figure uses all 558 stars matched with the Stetson catalog and not just the 198 stars used to derive the polynomial coefficients. It can be seen that large deviations begin to occur at B _ 17 when no coincidence loss correction is applied. The pre-launch calibration improves the linearity until about B _ 15 but strongly overcorrects for coincidence loss at brighter magnitudes. The theoretical coincidence loss correction does quite well, over the entire range, but the use of the current CALDB coefficients can smooth out some small undulations.

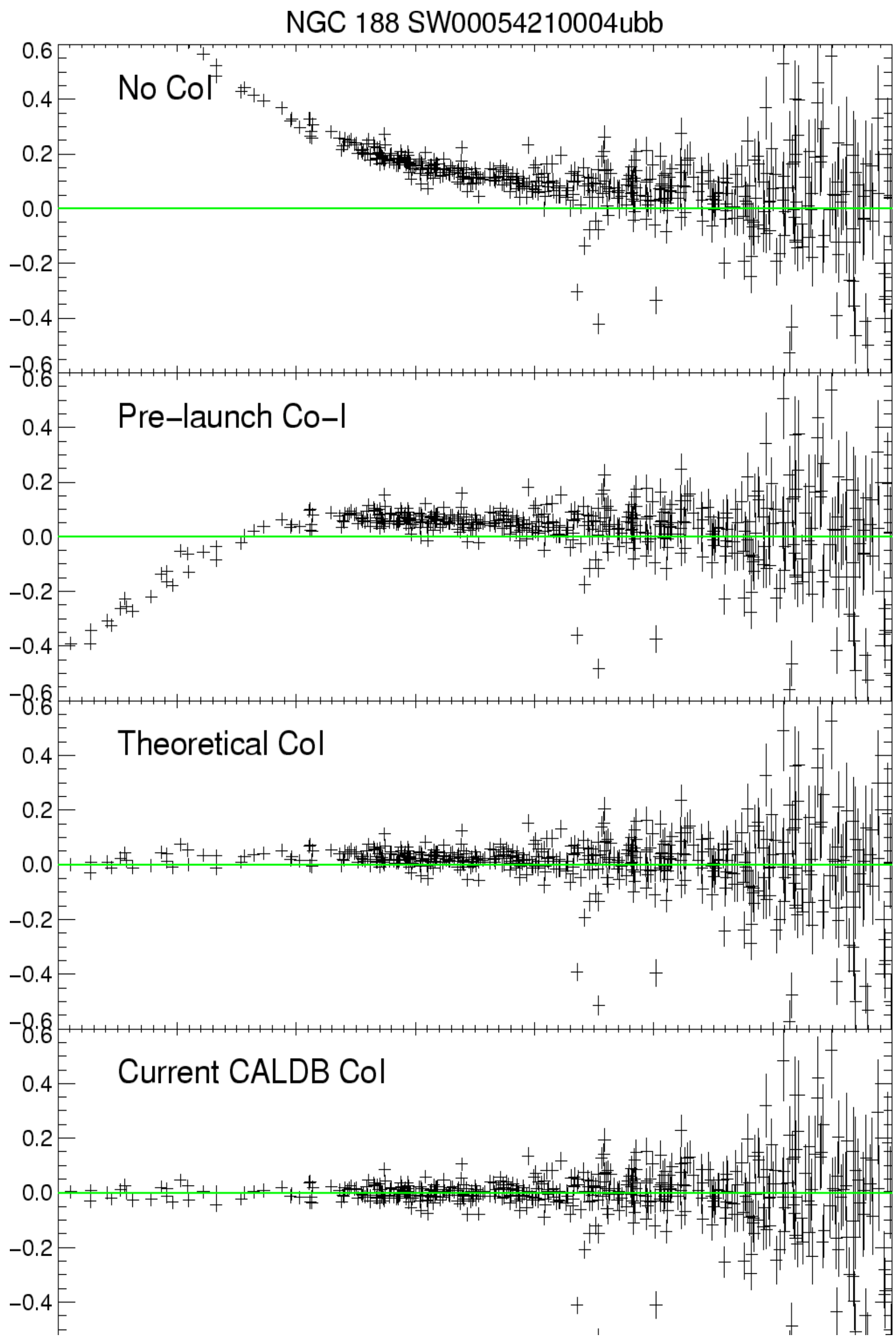


Figure 2: Different CoI corrections applied to the NGC 188 data

Figure 3 shows the residuals after determining the polynomial coefficients, as a function of both B magnitude and counts/frametime. There is no obvious trend in magnitude, but more data would be useful at higher countrates.

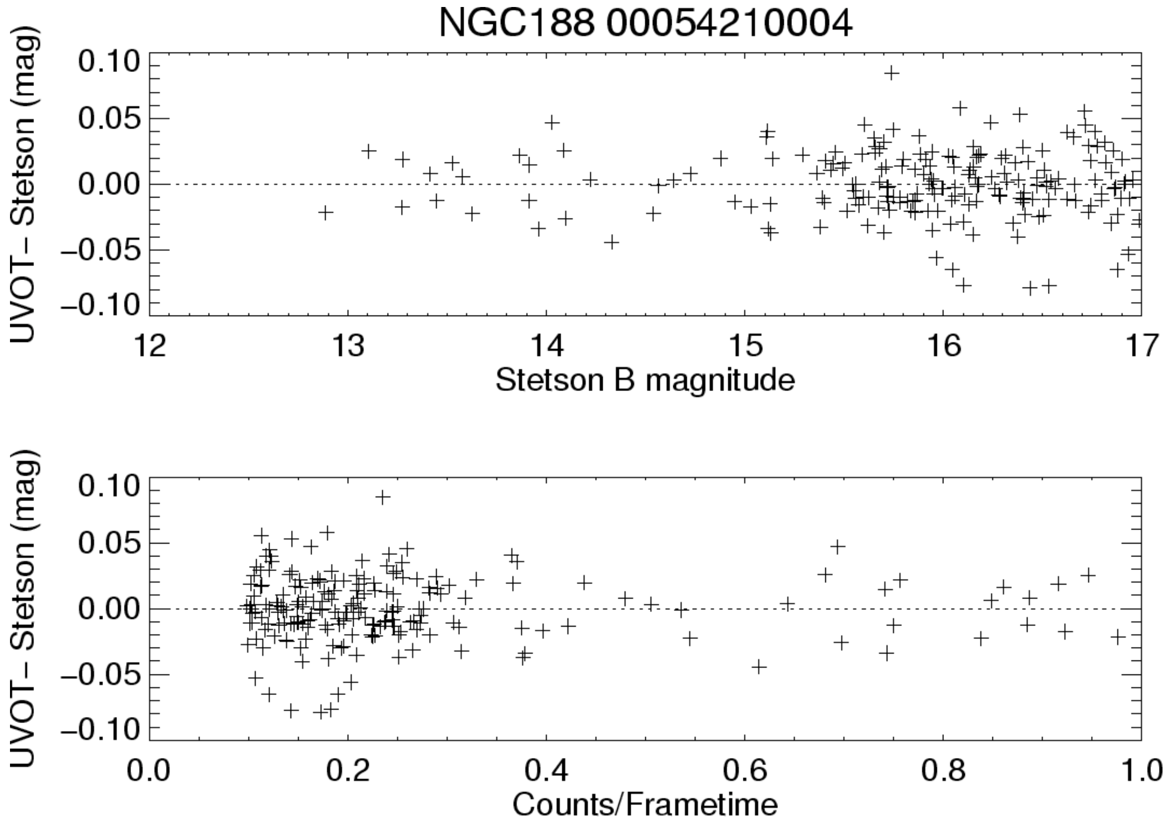
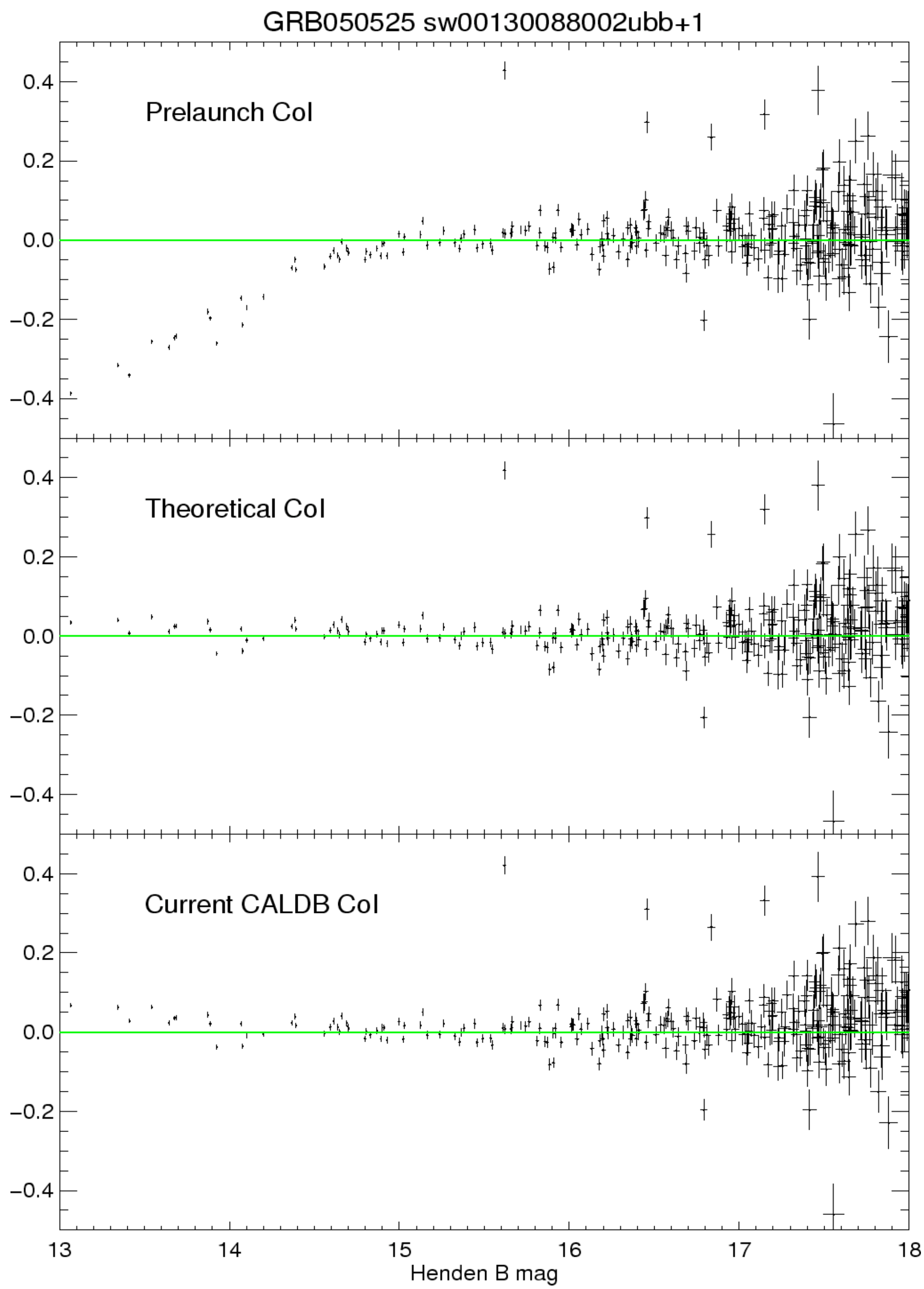


Figure 3: Linearity vs. Counts/Frametime

GRB050525

To test whether the coincidence loss correction derived from the NGC 188 data applies to other UVOT images, we performed a similar test with a B image (00130088002) of the field of GRB050525. This field has BV photometry available from Arne Henden (ftp://ftp.aavso.org/public/grb/)for comparison. Figure 4 compares the UVOT photometry with the Henden photometry using the pre-launch coincidence loss correction, the theoretical correction, and the theoretical plus current CALDB empirical correction. Again, the pre-launch polynomial strongly overcorrects at high count rates, but here the theoretical relation actually performs slightly better than the



current CALDB.

Figure 4: Coincidence loss correction for GRB050525

Tests with different frame rates

A different type of test of the coincidence loss polynomial can be performed using images of standards taken with different hardware windows (and hence different frame rates). We used the data of standard stars Hz2 and GD128 taken with three different hardware windows (and hence different frame rates). Since the count rate of the source is constant we should get the same answer regardless of frame rate. Three different frame rates were used, so we were effectively sampling the co-incidence correction at three points in count-to-frame rate space, per filter. A radius of 12 and more recently 10 pixels was used for all measurements, to bring the data analysis in line with the optimum aperture photometry work.

This test also shows that the pre-launch correction is very poor - at least it seems to work at the lowest count rate, but somewhere around 50c/s it stops being effective. The new post-launch formula and the theoretical formula both work reasonably well. If error is defined as the difference between the three measurements, then Table 2 demonstrates the accuracy of the theoretical relation and the current CALDB polynomial correction.

Table 2:

Filter	**full frame count rate**		**Error (CALDB) (%)**	**error(theoretical) (%)**
	no bkgnd	including bkgnd		
V	33.09	33.87	0.83	1.48
UVM2	70.36	70.50	1.58	0.52
B	67.11	70.96	2.19	2.12
Wh	69.50	76.36	4.56	4.43
UVW1	77.55	77.93	1.47	3.29
U	80.11	81.59	5.06	2.64
UVW2	85.17	85.43	3.66	1.03

Apart from the white filter data which has been shown recently to have exposure time problems, both the post-launch and the theoretical formula achieve better than 3% up to a measured (output) count rate of 78 c/s. The theoretical formula achieves slightly better results at higher count rates. Further framerate tests and photometric tests will be needed if better than 3% linearity is required.