Technical Instrument Report ACS 2006-02

The ACS Side-2 Switch: An Opportunity to Adjust the WFC CCD Temperature Setpoint

M. Sirianni, R. Gilliland, & K. Sembach
September 06, 2006

ABSTRACT

The switchover of the Advanced Camera for Surveys to its Side-2 electronics in July 2006 presented an opportunity to combine calibration activities for the electronics switch with those needed for a lowering of the Wide Field Channel CCD detector temperature setpoint from -77 ˚C to -81 ˚C. This document, which was originally released as an internal white paper to the HST Mission Office in June 2006, describes the rationale for the temperature setpoint change. Future documentation will describe the implementation and results of the calibration activities required to support the electronics switch and temperature setpoint change.

1. Introduction.

We propose to use the ACS Side-2 switch as an opportunity to optimize the scientific return of the Wide Field Camera of ACS by lowering the temperature setpoint from -77 °C to -81 °C. Some degree of re-calibration is required anyway as a result of switching from Side-1 to Side-2 electronics. We have estimated that changing the operating temperature from -77 to -81 °C would benefit survey programs with WFC and would

reduce the overhead associated with the hot pixel contamination. Changing the temperature setpoint would require only a modest increase in the re-calibration effort.
Sections 2 and 3 cover the changes in instrument characteristics, science impact, and calibrations required following the electronics switch. Sections 4, 5, and 6 discuss the benefits, calibrations, and proposed plan that would follow from adopting an explicit lowering (by 4 degrees) of the WFC temperature setpoint.

2. Side 1 – Side 2 expected differences.

With the proposed switch to the Side-2 ACS electronics, we expect some differences in the performance of the CCDs due to different electrical components and different sensors[1]. The main variations expected are bias level and read noise changes, as well as small (<1 °C) changes in the operating temperature.

During pre-flight testing, a considerable amount of data were taken with the Side-2 electronics. According to the results of these tests, the variations in bias level and readout noise expected under Side-2 operations should have little impact on science. As mentioned above we may also expect a difference in temperature. While the TEC Side-1 electronics are designed to be identical for both Side-1 and Side-2, some differences are expected because of different temperature sensors and because of different associated control law electronics. This difference is likely to be small and is limited by the precision of the sensor reading (~0.7 °C).

A variation in temperature will affect not only the dark current and hot pixel contamination but may also influence the quantum efficiency (QE), the flat field, and the charge transfer efficiency (CTE). Table 1 summarizes the expected changes, the impact on the scientific performance and the required calibration.

3. Expected temperature variation with Side-2 operations.

The different temperature sensors of Side-2 and their associated control law electronics may drive a different temperature at the CCD for the same commanded temperature of Side-1. In order to quantify the expected temperature difference, we compared pre-flight dark current frames obtained with the flight detector using both sets of electronics. Ideally, for the same temperature, the dark current expressed in e-/sec/pix ought be the same, independent of the electronics. Given that the gain conversion for Side-2 is not known, we calculate the ratio of the count rate (DN/sec) for the two sides as a proxy for knowing the gains; for two frames taken at the same temperature this ratio should be consistent with the ratio between the gains. We performed three different comparisons for temperatures of -74 and -77 °C and different amplifiers. We find a ratio between 0.9 and 1.1 in all cases, which is compatible with the expected gain ratio.

A temperature variation of one degree Celsius would produce a 15-20% variation in the dark current at -77 °C and 40-60% at -74 °C. We expect the temperature for Side-2 operations to be within 1°C of the current Side-1 value.

Table 1. Side-2 switch: impact on science and calibration

CCD Parameter	Expected changes with Side-2 electronics	Impact on Science	Calibration Required
Bias Level	Bias level on Side-2 is known to be different from Side-1	None	Collection of reference files will proceed as normal.
Read Noise	Expected variations (ground testing) are of the order of a few percent.	Very little	We need to reassess the default gains for science operations.
Temperature	Different sensors will are used to determine the CCD temperature. Therefore, the TEC could run at a slightly different temperature.	Depends on the degree of the variation. If the variation is of the order of 0.5-1 °C, there is no significant impact.	See specific sub-items below.
Dark Current	Dark current is strongly dependent on T. For WFC, a variation of +1 or -1 °C will result in variations of +20% and -15% in dark current, respectively.	Little: most of the science with ACS is either sky- or read noise limited.	Collection of reference files will proceed as normal.
Hot Pixels	Strong dependence on T. A variation of +1 or -1 °C will induce variations of +30 and -15 % in the current level of hot pixel contamination.	Moderate. Hot pixel mitigation requires monthly anneals, additional readouts, and dithering of the observations. CTE tails of hot pixels increase the noise.	If hot pixel contamination is reduced, the amount of overheads can be reduced.
CTE	While the overall CTE loss will not be affected, a small variation in the temperature may influence the shape and intensity of the CTE tails.	Moderate. Variation of the shape and intensities of the CTE tails will improve the noise of the image [2]. Survey programs will have better detection thresholds.	Data analysis that requires an accurate characterization of the PSF will be needed.
QE	Small QE variations are seen when the temperature is changed by few °C[3]. A lower/higher temperature would reduce/increase the QE.	If the change in temperature is ~1°C, the WFC QE will change by less than 0.5% across the entire wavelength range. The HRC QE will show more variations in the near-UV and in the near-IR.	New determination of the zeropoints may be required for variation in sensitivity greater than 0.5%.
Flat Field	Variation in the large-scale structure of the flat field are seen when the temperature is changed by a few °C.	If the change in temperature is less than 1 °C, the variations of the large-scale structure of the flat field are expected to be less than 0.5%.	Recalibration of flat fields (low frequency and pixel-to-pixel) may be needed to maintain the current level of accuracy.

The overall changes expected as a result of "just" a side switch are minor in terms of altered characteristics, science impact, and required calibrations. The existing orbital verification calibration plan to support the side switch requires 43 internal orbits, and 6 external orbits. These observations mostly represent well-planned contingencies and/or minor modifications to the structure and scheduling of already existing calibrations. The analysis of this set of calibrations should be a relatively minor work load for the ACS Team. These tests may in some cases indicate that further calibrations will be required in order to maintain currently advertised calibration accuracies that were achievable on Side-1. There is a non-negligible chance that the results of the orbital verification for the Side-1 to Side-2 switch will indicate that a more extended set of calibrations is necessary.

Therefore, it is prudent to consider whether we should perform a more extended set of calibrations in conjunction with a temperature setpoint change for the WFC, and hence avoid the need to perform another complete set of recalibration activities that would likely be required by an expected (and desirable) temperature setpoint change in a 12-24 month timeframe.

4. The benefits of a colder temperature setpoint.

In late 2005, as part of the investigation of the potential benefits associated with the installation of the Aft Shroud Cooling System[2,3], we analyzed the advantages and disadvantages of changing the operating temperature of the ACS CCDs. The results of this investigation indicated that, although the improvement in performance was not so dramatic to justify the risks associated with the installation of the ASCS during SM4, running the WFC CCDs at -81 °C would be beneficial in several aspects.

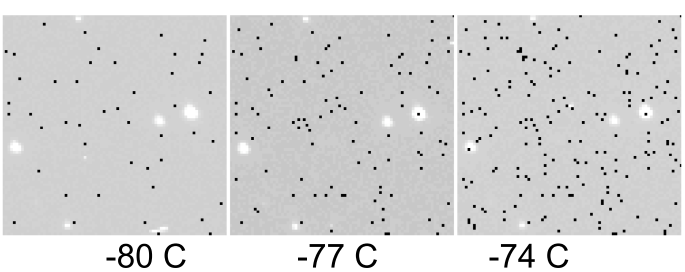
- The current dark current would be reduced by more than 50% and would return to its pre-launch level.

- The hot pixel contamination would be reduced by 50%, bringing it back to the level it was after ~ 4 months on-orbit. A lower level of contamination would require fewer readouts during science observations. Moreover, at the colder temperature only the brightest hot pixels would still be considered "hot" and, given that the hot pixel growth is inversely proportional to the dark current, new hot pixels would be generated at a much lower pace. Anneals would be required less often [2].

- Charge transfer efficiency (CTE) tails would be longer but fainter. Given that the deferred charge will be distributed in more pixels, and that the number of hot pixels (and therefore CTE tails) is greatly reduced, the image noise is also reduced.† We estimate a gain of ~ 0.1 magnitudes in detection limits for faint sources [3]. The same gain could be realized with an increase of ~20% in the exposure time.

Figure 1: WFC hot pixel contamination.

(Hot pixels indicated with a black dot)



WFC CCD Temperature (°C)	Hot pixel[a] contamination (%)
-74	**2.6**[b]
-76	1.6
-77	**1.2**
-78	1.0
-80	**0.6**
-81	0.4

[a] > 0.08 e-/pix/sec.

[b]Measured values are highlighted

† This sentence has been updated. The original wording in the white paper was incorrect.

5. Calibration required for a change in temperature.

Changing the WFC temperature setpoint to -81 ˚C will result in the need to update calibrations related to both the flat fields and quantum efficiency estimates for the CCD. On orbit tests have shown that at -81 ˚C the quantum efficiency would decrease by 1-1.5% across the sensitivity range of WFC[3] and that the large-scale structure in flat fields would also show variations of the order of 1-2%[2]. Many ACS programs require high photometric precision (~1%), and new calibration of the flat fields and quantum efficiency are needed to support these programs.

We estimate that both the pixel-to-pixel sensitivity and the large-scale flat fields (L-flats) would change by an amount greater than our current pipeline accuracy of 1% for a temperature change of -4 ˚C. Correction for this would represent a new calibration activity for ACS. Although we have previously monitored changes to pixel-to-pixel response through internal (lamp and Earth) flat fields, we have not altered these for the WFC optical filters, which still carry ground test heritage. To conduct the flat field calibrations, we would adopt the previous approach used during the initial ACS SMOV.

The quantum efficiency calibration needed could be accomplished using techniques that we have used in the past to establish the photometric zero point. This would entail observations of both spectrophotometric standards to account for non-constant throughput change over the bandpass, as well as observations of a rich well-studied globular cluster in different filters to reference the zero point using stellar model atmospheres and previous observations on Side-1. Additional tests to monitor the ultraviolet sensitivity and to update the sensitivity estimates at wavelengths longward of 9000 Angstroms would also be needed.

The total additional work effort involved from a change in the WFC setpoint temperature is of the order of 1.1-1.5 FTE above and beyond the current ACS calibration effort anticipated for Cycle 15 in the absence of such a change. However, we note that such an effort would likely need to be expended at some point in the next few years as ACS ages anyway. The increase in the number of calibration orbits required is also modest. We estimate that roughly 30-40 additional internal orbits and 25-30 external orbits would be required.

6. Proposed Plan

We suggest changing only the WFC temperature setpoint to -81 °C. We do not recommend changing the HRC setpoint at this time for several reasons.

- Lowering the temperature on both CCDs may raise power concerns in the post-SM4 era. A setpoint of -81 °C for the WFC should leave ample power margin to compensate for increases in the temperature aft-shroud after SM4. This margin would be reduced if the HRC setpoint was also lowered.
- The HRC accounts for only a modest fraction of the total ACS time. The most significant science gains that would be realized by changing the temperature setpoint are for surveys programs that make use of the WFC, not the HRC.
- Fully recalibrating the HRC would be a substantial additional effort that would

also entail redoing some recently completed spectroscopic calibrations that the ACS Team would prefer not to have rework in the near-term future. It is however possible that the different temperature sensor and control law electronics of HRC may also require an increased calibration effort for the HRC. In such a scenario, priority would be given to the calibration of WFC and the most used modes of HRC.

We propose to perform a mini functional test (several bias and dark exposures obtained over 2-3 orbits) at the nominal temperature setpoint after switching to Side-2 but before lowering the WFC setpoint from -77 °C to -81 °C. After lowering the setpoint, we would proceed with our full Side-2 calibration. Science observations could be interleaved with the calibration exposures beginning immediately after the setpoint change. Having a short functional test before lowering the temperature serves the dual purpose of:

- Allowing us to check whether any anomalies seen after the temperature is lowered are due to the electronics switch or the temperature change.
- Serving as a baseline for future Side-2 CCD performance as the aft shroud warms with time.

Performing the temperature setpoint change before science observations are resumed ensures that all science observations on Side-2 will benefit from the full calibrations that will be performed as part of the post-setpoint characterization of the instrument.

References

1. **Cox, C. et al. 2005: "Switching ACS from Side 1 to Side 2 electronics", ISR-ACS 05-01**
   http://www.stsci.edu/hst/acs/documents/isrs/isr0501.pdf
2. **Sirianni, M. et al. 2005 : "Temperature change for ACS CCDs: Initial Study on scientific performance"**
   http://www-int.stsci.edu/~sirianni/PRESENTATIONS/ASCS_ACSstudy_GSFC.ppt
3. **Sirianni, M. et al. 2005 : "Temperature change for ACS CCDs: study on scientific performance"**
   http://www-int.stsci.edu/~sirianni/PRESENTATIONS/ASCS_ACSstudy_GSFC_part2.ppt