DAWN-FC

DAWN - Framing Camera

Framing Camera ICO Report

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		7	Distortion figure replaced

Distribution Record

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1 General aspects

1.1 Scope

This document is the compiled final ICO report of the Dawn Framing Cameras FC1 and FC2.

1.2 Introduction

Camera functionality and performance/calibration tests were run in the context of Dawn ICO. We provide an overview of the tests as ran and walk thru data analysis as exits today. The attachment is the container for all short reports forwarded to the teams at end of session.

1.3 Applicable Documents

no.	document name	document number, Iss./Rev.

1.4 Reference Documents

no.	document name	document number, Iss./Rev.

2 ICO Overview

The ICO was performed in 7 slots, 4 for FC1 and 3 for FC2.

Camera	Slot	Date
FC1	Functional	10-12-2007
	CCD Mini-cal	12-12-2007
	Performance	21-02-2008
	Calibration	22-02-2008
FC2	Functional	18-10-2007
	Performance	03-12-2007
	Calibration	13-12-2007

Technically, FC1 Performance and Calibration were executed outside of the nominal ICO period, but the results are included in this report for consistency.

Detailed reports for each of the test slots are attached at the end of the report, including a textual description and any other feature worth mentioning.

3 Functional and Operations

3.1 Camera functionality

From the functional point of view, both cameras performed nominally during ICO. 584 (FC1) and 573 (FC2) images were acquired and transmitted to ground. Both the LLSW and the UDP library ran uneventfully on both cameras without a single deviation from the expected behavior. The performance of the compression algorithm is good, providing compression factors over 1:2 (lossless) consistently through all this phase. A preliminary set of Level 1a images has been delivered to DSC. The table below summarizes data volumes.

Camera	Slot	Images acquired	Tx Data volume [MiB]	L1a data volume [MiB]
FC1	Functional	102	52	212
	CCD Mini-cal	72	34	125
	Performance	220	69	265
	Calibration	190	86	340
FC2	Functional	102	50	212
	Performance	215	75	262
	Calibration	256	78	364

On the spacecraft side, the flight software repeatedly showed an unexpected behavior when pausing and resuming data playback. During the FC1 and FC2 performance blocks one image was initially found corrupted per test. Under closer scrutiny, image corruption was found to happen twice per test slot, every time the data playback was paused. An ISA has been filed on this issue

3.2 Operations

On the operational side, all the teams (MPS, JPL, DSC) are well trained, but there is still some work to do before we are really ready for science planning.

3.3 Thermal performance

With respect to the spacecraft, the thermal performance matches the predictions from the TVAC test, with a baseplate temperature rising from 273 to 283 K with one camera in operation. The steady-state temperature of the CCD in these conditions is around 220 K. The performance of the CCD could be improved by reducing the interface temperature to the lower AFT (253 K).

4 Camera performance

4.1 Bias

The bias level of an image was calculated on-board as the average of the leftmost 12 columns of the CCD, and returned as an integer during ICO. The associated uncertainty is not known exactly, but estimated to be in the order of 1 DN. The bias was found to have similar values compared to ground tests, unaltered through the launch event and mission so far.

In the future the bias will be returned as a floating point for higher accuracy.

4.2 Dark current

In every block of the ICO campaign dark current exposures were acquired for at least two exposure times: 30 and 300 s (sometimes also 1 and 3). An analysis of the FC2 performance block exposures reveals the dark current of a typical pixel to be 0.03 DN/sec at a CCD temperature of 219 K. 1150 pixels (0.11%) have a dark current at least three times this value Figure 1). Of these, 11 pixels are ‘very hot’ (dark current exceeding 3 DN/sec). The dark current of hot pixels is found to increase approximately linear with exposure time (Figure 2). Analysis of the dark current data is ongoing. Plans include a comparison with pre-launch values, an analysis of FC1 dark current, and an assessment of the dark current behavior over time.

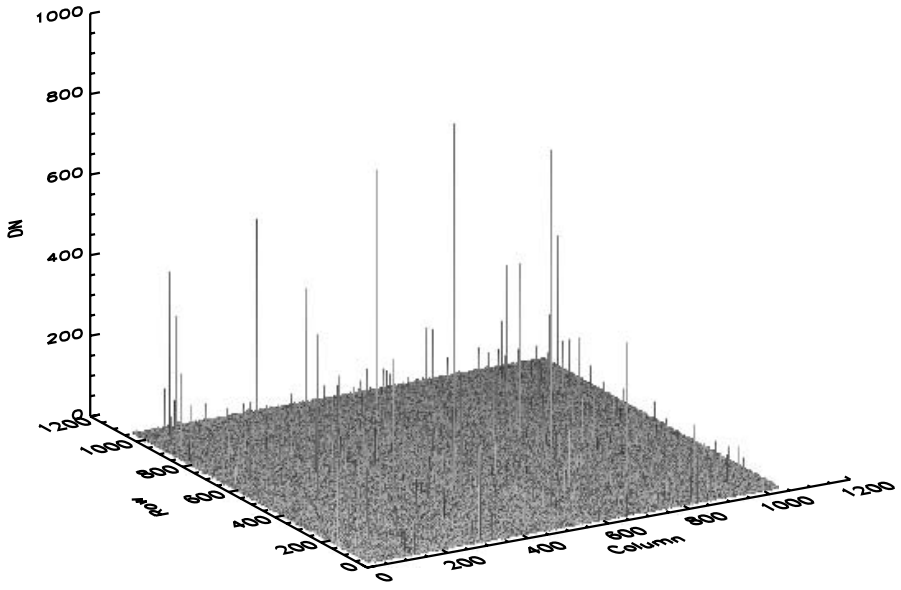


Figure 1. Dark current accumulated by the FC2 CCD in 300 sec (Performance block). The figure has been capped at 1000 DN, but there are 10 pixels exceeding this value.

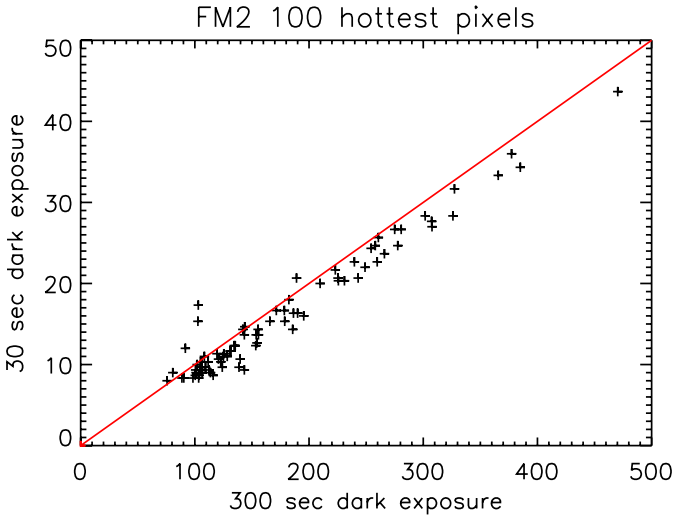


Figure 2. Dark current of the FC2 (FM2) CCD from the Calibration block data. We compare the charge acquired by the 100 hottest pixels in the active area in 300 sec to that in 30 sec. The dark current increases approximately linear with time, within the uncertainty imposed by the bias (~1 DN).

4.3 Point spread function

The point spread function (PSF) of both FCs reconstructed from ground observations was compared to in-flight observations of Vega and Saturn during ICO.

FC2. The full width at half maximum (FWHM) of the PSF measured pre-launch was in the order of 1 pixel, and wider in the vertical direction due to the asymmetric distribution of the sensitive area on each pixel. This shape was compared to the PSF of Vega. The FWHM was derived from a 2-dimensional Gaussian fit to the Vega profile. The results in Table 1 and Table 2 need to be regarded with caution because of aliasing effects created by the small CCD fill factor (only 40%). During the Vega slew a larger number of measurements was made (n = 10 for each filter). The FWHM values derived from the slew are slightly larger that those from derived from pointed measurements because the former are elongated by the S/C slewing, especially for the long exposure (F4, F5 and F8). Additional PSF measurements where made with Saturn as light source. Whereas Vega can be considerer a point source, Saturn is a slightly extended object (diameter around 1.4 pixels). This is already enough to see a difference in the PSF (see Figure 3).

FC1. The Vega measurements were repeated with FC1. Unfortunately Saturn could not be observed because of the flight rules. Both cameras show the same good optical quality. There is no systematic difference between the PSF derived from long and short exposure times, suggesting more stable pointing (see also § 4.5). The FC1 Vega slew employed the same exposure times and slew rate as FC2. Again, the PSF is similar for dedicated pointing and slew, with its FWHM increased for filters that required longer exposure time.

Table 1. FWHM of the FC2 PSF (in pixels) for Vega dedicated pointing and slew, and Saturn pointing.

Object	**Vega**				**Saturn**	
Mode	**Pointing**		**Slew**		**Pointing**	
Filter	**fwhm x**	**fwhm y**	**fwhm x**	**fwhm y**	**fwhm x**	**fwhm y**
F1	1.16	1.24	1.37	1.39	1.37	1.36
F2	1.14	1.23	1.13	1.22	1.40	1.37
F3	1.20	1.40	1.35	1.47	1.54	1.66
F4	1.39	1.65	1.35	1.43	1.62	1.66
F5	1.35	1.59	1.47	1.49	1.61	1.51
F6	1.30	1.42	1.28	1.40	1.50	1.61
F7	1.17	1.37	1.24	1.38	1.46	1.52
F8	1.24	1.35	1.48	1.40	1.56	1.49
Average	**1.24**	**1.40**	**1.33**	**1.40**	**1.51**	**1.52**

Table 2. FWHM of the FC1 PSF (in pixels) for Vega dedicated pointing and slew.

Mode	**Pointing**		**Slew**	
Filter	**fwhm x**	**fwhm y**	**fwhm x**	**fwhm y**
F1	1.14	1.38	1.18	1.22
F2	0.96	1.05	1.00	1.11
F3	1.13	1.39	1.16	1.32
F4	1.35	1.58	1.62	1.59
F5	1.35	1.51	1.54	1.62
F6	1.11	1.23	1.34	1.41
F7	1.10	1.23	1.04	1.18
F8	1.31	1.25	1.54	1.52
Average	**1.18**	**1.33**	**1.30**	**1.37**

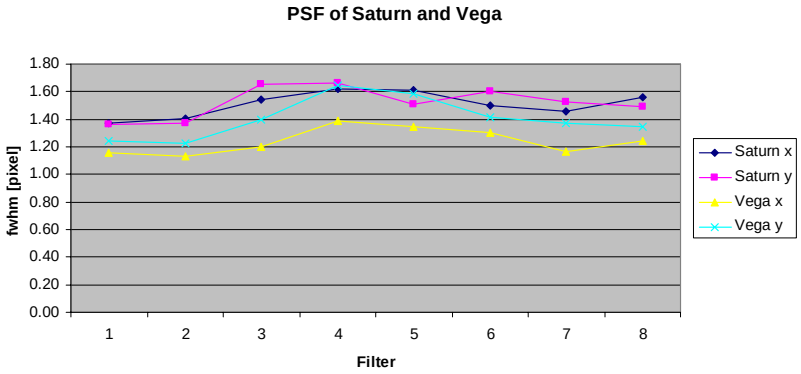


Figure 3. PSF derived from FC2 Saturn and Vega observations compared.

The optical quality of both cameras, in terms of their PSF, is good. The determined PSF contains both the optical performance of the camera and the jitter of the S/C. It will be interesting to see how the PSF changes in case of more accurate S/C pointing. This would allow us to determine if the FWHM differences are truly associated with the different filters or are caused by a jittering S/C. We noticed strong deviations of a few pixels from the expected pointing in some images during the Vega slew (see Figure 4). It has to be checked if those appeared simultaneously with a realignment of the solar array panels.

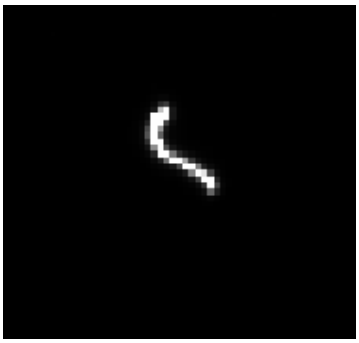


Figure 4. S/C jitter during Vega slew (60sec exposure time).

4.4 Geometric distortion

We determined the degree of geometric distortion affecting the FC optics by analyzing images from the Performance and Calibration blocks, which had the FC point at starfield targets. To this end we have developed a tool to compare the expected position of stars to that observed, and output the corrected images at any desired resolution and pointing to enable the creation of image mosaics (see §5). We use a four-parameter model for radial image distortion: the magnification in the (horizontal) x-direction m_x, the magnification in the (vertical) y-direction m_y, and distortion parameters k_1 and k_2. The horizontal distance from the center x (in pixels) depends on the angular distance to the center δ as

$$x = m_x(1 + k_1\delta^2 + k_2\delta^4),$$

with an identical expression for y. We determined the center for geometric distortion to approximately coincide (within ~10 pixels) with the center of the image. For each starfield we retrieved the sky coordinates (in R.A. and Dec.) of ~50 stars in the SIMBAD database[1], and fitted our model to their positions as observed by the FC, determined as the center of a 2D Gaussian fit to the stellar brightness profile.

The FC2 suffers from minor pincushion distortion ($k_1 > 0$), typically, $0.2 < k_1 < 0.5$, depending on the filter. Having a non-zero k_2 often does not significantly improve the fit to the observations. The residuals are generally less than a third of a pixel (Figure 5) and randomly orientated, an indication that the radial distortion model is a good one for the FC. The magnification in the x-direction is typically $m_x = 10720$, again depending on filter, with m_y slightly larger (0.06%) than m_x. The Field-of-view (FOV) of FC2 is approximately 5.46° on each

[1] `http://simbad.u-strasbg.fr/simbad/`

side. The geometric distortion of FC1 is similar to that of FC2, but remains to be investigated in detail. In all, the degree of geometric distortion of the FC is very small, in the order of one pixel in the corners (Figure 6), in compliance with the requirements. However, it is important to correct for this distortion, especially when creating color images of stars, to avoid color separation (Figure 7).

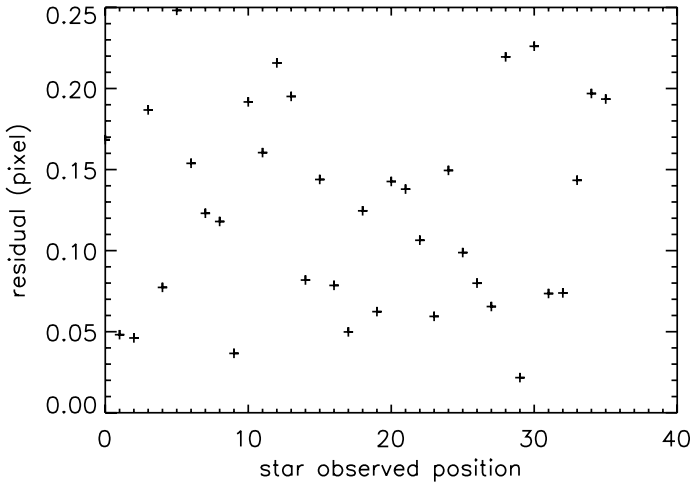


Figure 5. Typical residuals of the FC radial distortion model, i.e. the difference of a star's observed position in the geometrically corrected image (estimated from a 2D Gaussian fit to the brightness profile) and that expected from its sky coordinates (n = 36).

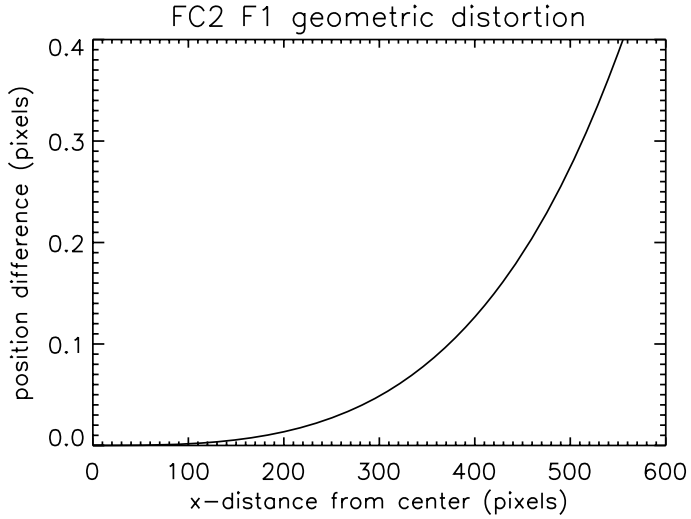


Figure 6. Geometric distortion of images taken through the clear filter (F1) of FC2 as determined from a fit of the radial distortion model to 36 star positions.

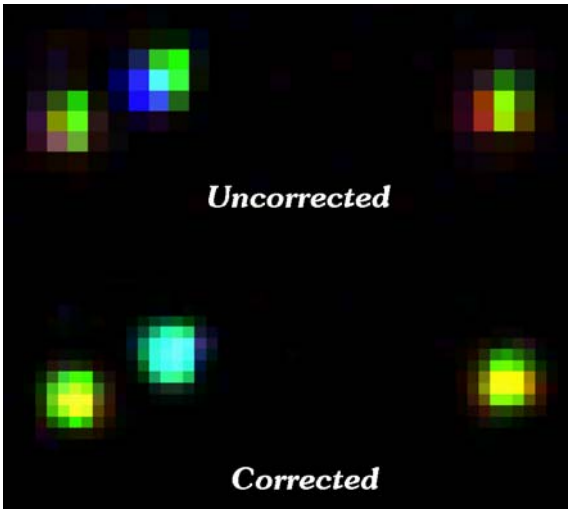


Figure 7. Star images taken through the different color filters need to be corrected for geometric distortion before combining them into a single color image. Here, both frames show a color composite of the same three stars, with (bottom) and without (top) prior geometric correction.

4.5 Absolute calibration

Prior to launch the absolute responsivity of the FCs was determined for all filters by means of a monochrometer, diffuser, and collimator. The results are shown in Figure 8. During the Performance and Calibration blocks several stars were observed to verify the lab responsivity. Vega was observed by both cameras in the Performance block (both with dedicated pointing and slewed), while in the Calibration block FC1 observed 73 Ceti, and FC2 observed 42 Pegasi. All these are considered photometric standard stars by the European Southern Observatory[2] (spectra shown in Figure 9). The star images were corrected for bias, dark charge was subtracted, and the result was divided by the flatfield. The observed stellar flux was then calculated as the total charge of a 14×14 pixel sized area centered on the star (as determined from a 2D Gaussian fit), corrected for background intensity (estimated as the median value of a 100×100 pixel sized area around the star). The expected flux for each filter was obtained by integrating the product of the appropriate spectrum in Figure 9 with the responsivity curves in Figure 8.

We found the observed flux to depend strongly on the position of the center of the PSF with respect to the center of the pixel, being highest when both coincide (Figure 10). It is most sensitive to the distance to the center in the horizontal direction due to the presence of the anti-blooming gates running top-to-bottom. To enable a comparison with the lab data we need to take the average of a representative sample of observations through each filter. Such a sample is available for Vega (n = ~10), whereas 42 Peg and 73 Cet were observed twice per filter. Figure 11 shows how the stellar flux observed by FC1 is significantly higher that that expected from the lab calibration. The results for FC2 are very similar (Figure 12), albeit with smaller standard deviations (indicating more stable pointing for FC1, see also §4.3). The average ratio of observed and expected flux in the clear filter (F1) is 1.22 for both models, an indication that their overall responsivity is the same. This ratio is around 1.2 for all color filters except F8 (which has the lowest responsivity, and a ratio of 1.5-1.6). The ratios in the filters F4 and F5 are derived

[2] `http://www.eso.org/sci/observing/tools/standards/spectra/`

consistently (i.e. for both models) higher from 73 Cet/42 Peg than from Vega. The spectral type of 73 Cet is virtually identical to that of 42 Peg, but significantly different from that of Vega in exactly the wavelength range of F4 and F5 (see Figure 11 and Figure 12). This suggests the problem lies with the standard star spectra, and not with the FC filters. These results indicate that first, the responsivity of both cameras is the same, and second, that it is equal to that determined in the laboratory multiplied by a factor 1.2 for all color filters, except F8. Analysis is continuing, and the FC2 lab calibration remains to be worked out.

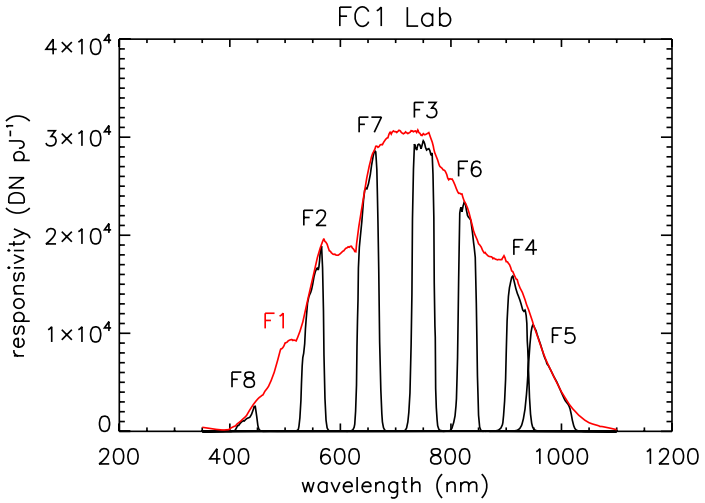


Figure 8. The absolute responsivity of the FC1 through the different color filters as determined from the lab calibration. Note that the responsivity determined from flight data is larger!

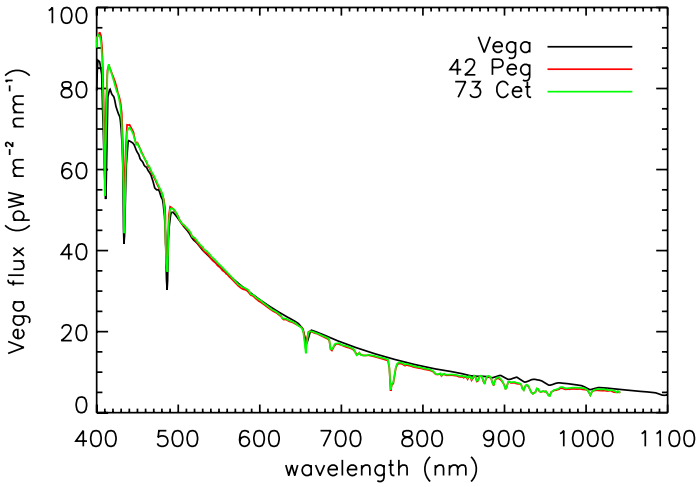


Figure 9. The spectrum of the three stars that were observed during ICO. The fluxes of 73 Cet and 42 Peg were equalized to that of Vega at 500 nm (by multiplying by 51.06 and 22.93, respectively). Spectral types are Vega: A0V, 73 Cet: B9III, and 42 Peg: B8V.

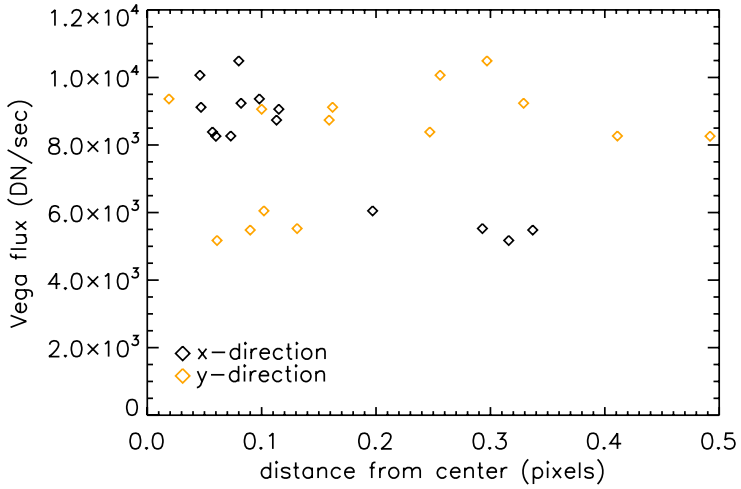


Figure 10. The measured stellar flux depends strongly on the position of the PSF on the pixel, especially in *x*-direction because of the presence of anti-blooming gates. The *x*-axis denotes the distance of the center of the PSF to the center of a pixel, as determined by a 2D Gaussian fit.

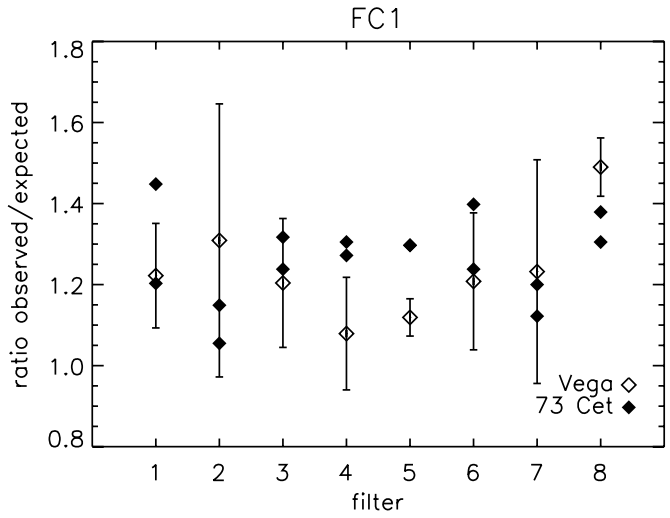


Figure 11. The stellar flux observed by FC1 in the different filters compared to that expected from the laboratory calibration. The Vega data are mean and standard deviation of ~10 observations. The 73 Cet data are two single observations per filter.

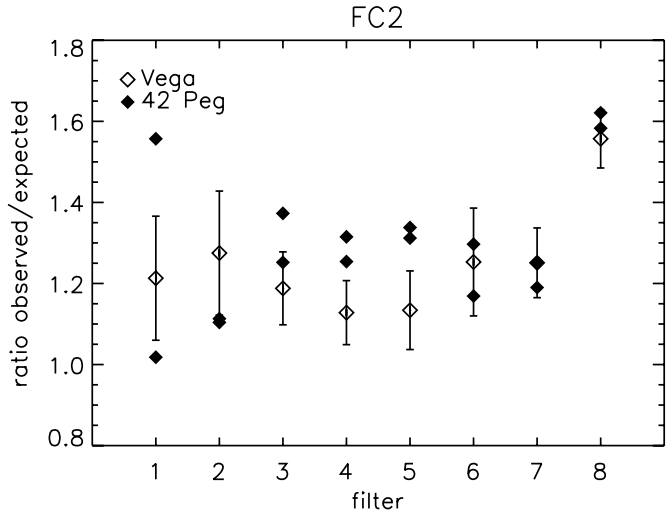


Figure 12. The stellar flux observed by FC2 in the different filters compared to that expected from the laboratory calibration of FC1. The Vega data are mean and standard deviation of ~10 observations. The 42 Peg data are two single observations per filter.

4.6 Charge blooming

Despite the presence of anti-blooming gates, the CCDs of both cameras exhibit what we believe is blooming in columns in which overexposed pixels are present (although it may also be a charge transfer issue). Figure 13 shows an example for FC2. This blooming appears to be exclusively upward (i.e. towards the top of the CCD). We are in the process of understanding this phenomenon, but note that dedicated observations are required to fully quantify it.

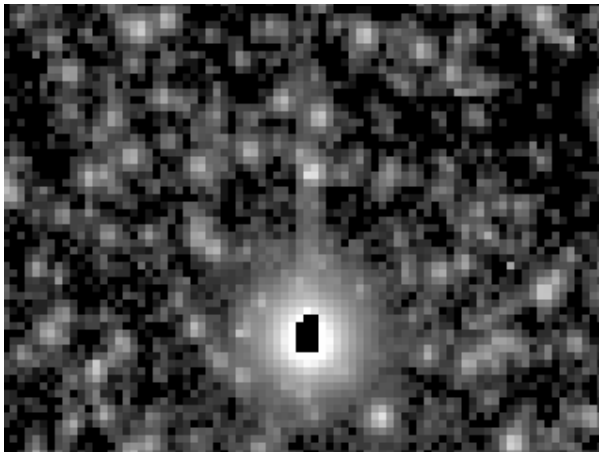


Figure 13. Charge blooming upward of an overexposed star in the 20 Cep starfield (from a FC2 600 sec clear filter exposure in the Performance block). The overexposed pixels at the center of the stars are marked in black.

4.7 Residual charge

From pre-launch flatfield measurements we learned that the FC1 CCD is not completely cleared prior to image acquisition. This charge, being present on the CCD at the beginning of the exposure, we call 'extra charge' or 'residual charge'. We subsequently found this undesirable behavior in other camera models as well. Apart from FC1, QM1 and FM1 are also affected. So far, this problem has not been found for FC2. The ICO offered an opportunity to learn more about the extra charge behavior in-flight. We now give a brief overview of the lessons learned for each model.

QM1

On ground we worked out a strategy with QM1 on how to determine the magnitude and the charging behavior of the extra charge using the calibration lamp internal to the FC ('callamp'). In these experiments we left the callamp continuously switched on. At t = 0 msec an image was acquired to clear the CCD. After a 'pre-illumination time' the image was read out with a 0 msec exposure time from which the extra charge could be determined by removing the frame transfer smear. Because we had found that pre-illuminating for longer than 20 sec does not create additional extra charge we made measurements with a pre-illumination time of 1, 2, 3, 5, 10, 15 and 60 sec. The results are shown in Figure 14.

FC1

(a) CCDcal (minical) block measurements: The first in-flight measurements of extra charge on the FC1 CCD were made during the ICO CCDcal test sequence. The distribution of extra charge is shown in Figure 15. The column worst affected is 1024 (out of 1024) where the callamp intensity is highest. The magnitude of the extra charge for individual pixels in this column as a function of pre-illumination time is plotted in Figure 16. Values in excess of 300 DN were reached at a flux between 12.5 (column 1024) and 8.0 kDN/sec (column 0). The CCD temperature during the CCDcal sequence in ICO was 219 K.

(b) Calibration block measurements: The second measurements of the FC1 extra charge were made during the Calibration block, and the data show basically the same behavior (see Figure 17). The main difference between this and the previous block is the 2 K higher CCD temperature (now 221 K). It was already known form lab measurements with FM1 and QM1 that the CCD temperature has a strong effect on the extra charge. Hence, we found the average extra charge in column 1024 about 10 DN lower. The spatial profile of the extra charge was the same in both tests, which implies that we may be able to devise a correction for extra charge, depending only on the light flux and CCD temperature.

FC2

No traces of extra charge were found on the FC2 CCD, neither in lab measurements with different low-intensity light sources, nor during flight with the same test done with the minical sequence.

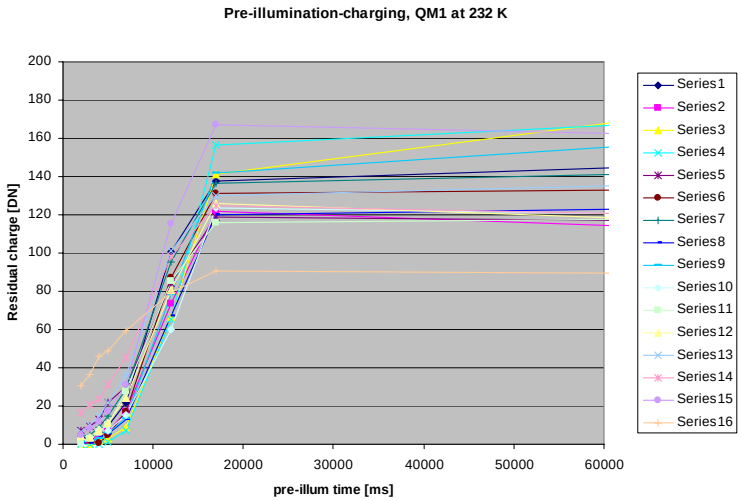


Figure 14. Extra charge on the QM1 CCD. Shown are the 16 most affected pixels per column at 232 K.

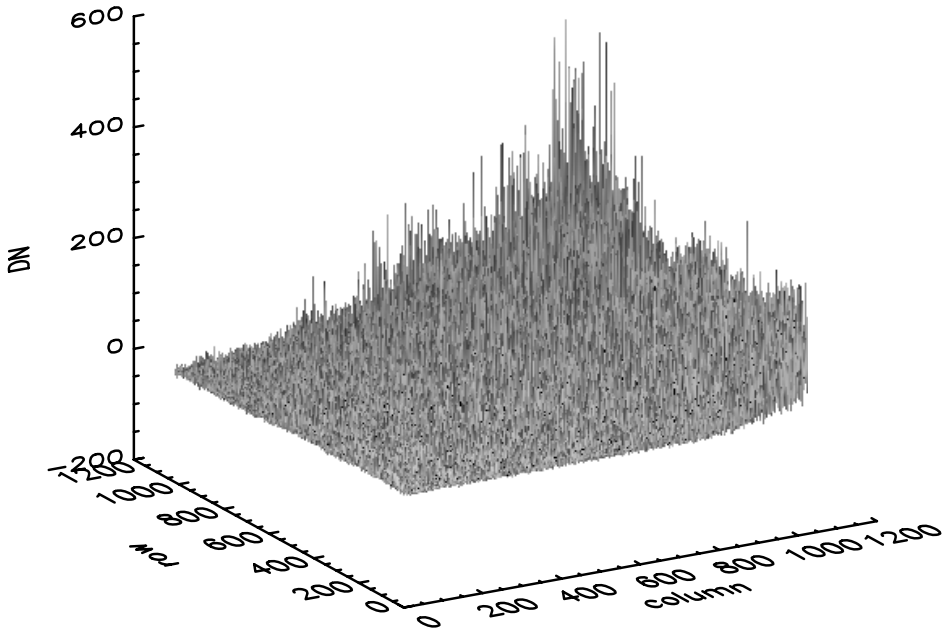


Figure 15. Typical extra charge profile of the FC1 CCD.

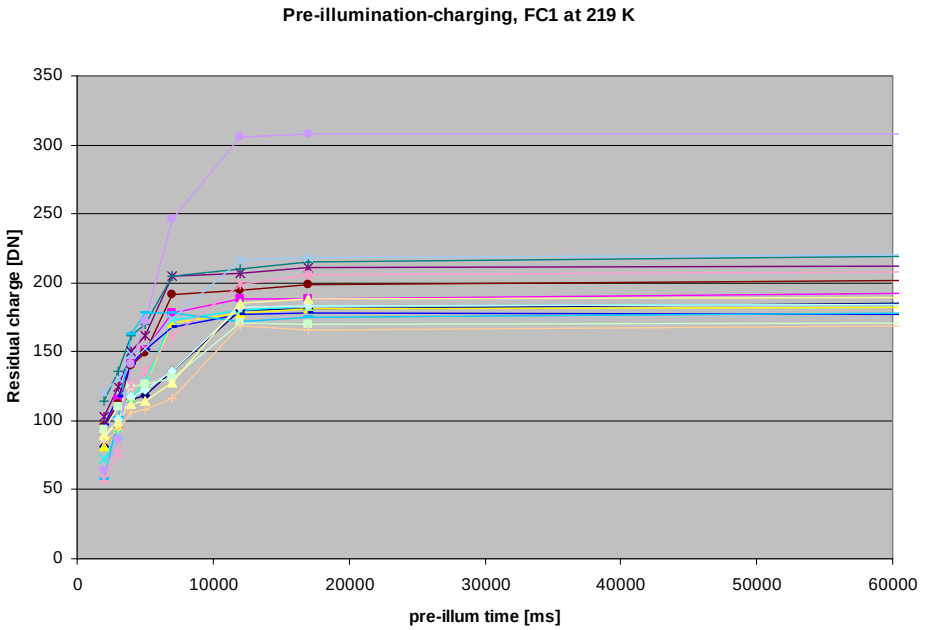


Figure 16. Extra charge on the FC1 CCD during ICO CCDcal at 219 K (16 highest pixels of column 1024).

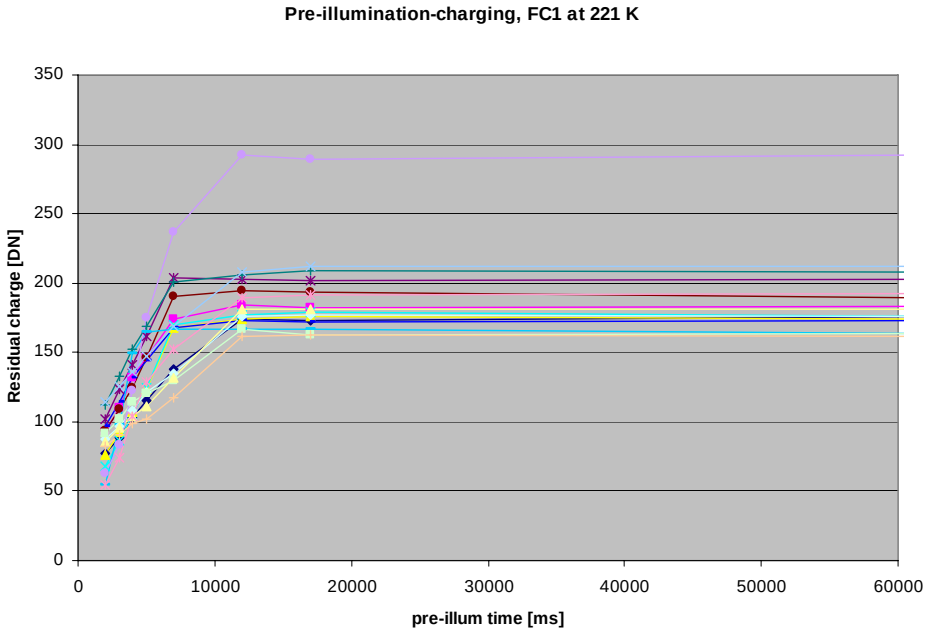


Figure 17. Extra charge on the FC1 CCD during ICO Calibration at 221 K (16 highest pixels of column 1024).

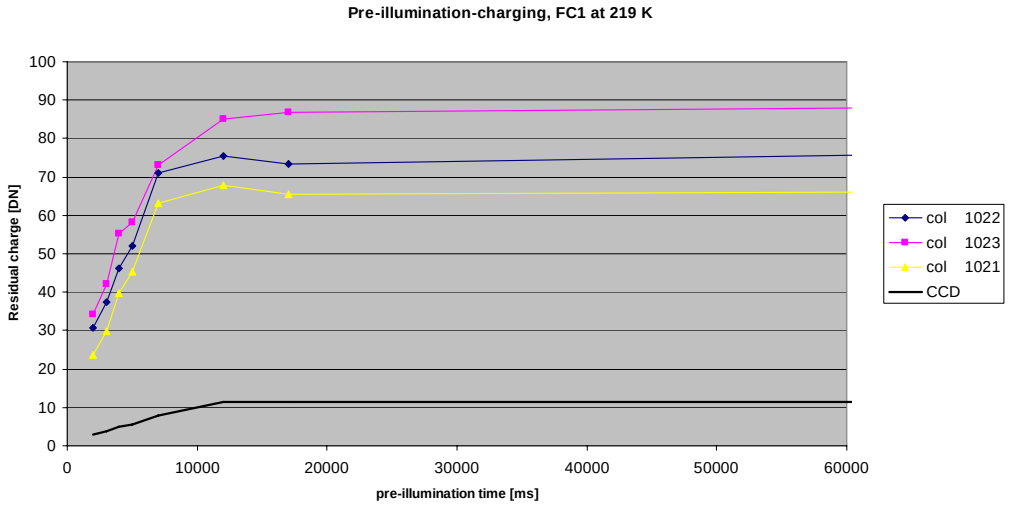


Figure 18: Average extra charge (columns and whole CCD) for FC1 during ICO CCDcal at 219 K.

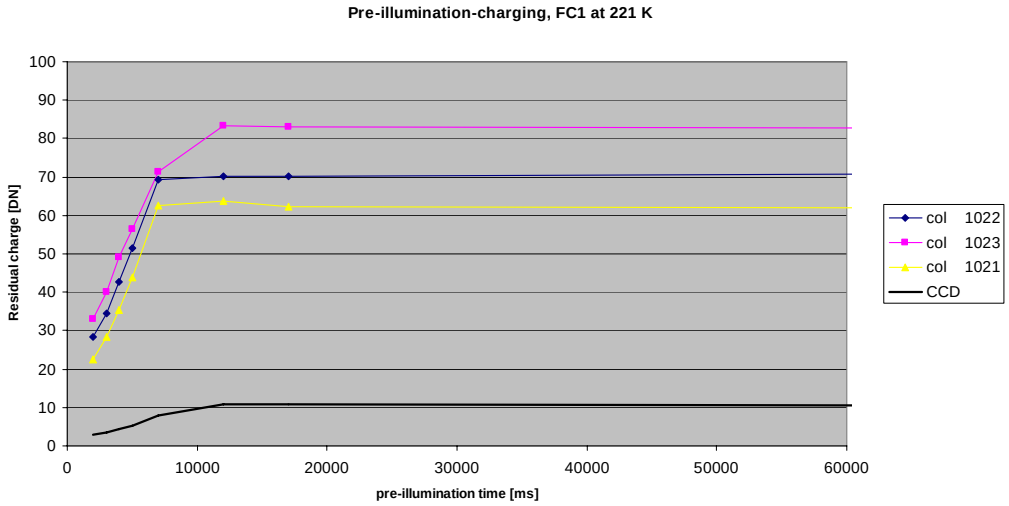


Figure 19. Average extra charge (columns and whole CCD) for FC1 during ICO Calibration at 221 K.

4.8 Interference

Interference pattern were found in both camera image data, in dark and open door images as well as in serial readouts (see appendixes). Dominant frequencies are 5Hz, a triplet at 45/50/55 Hz, but higher frequencies in some hundred to few kHz range are also present. The amplitude of disturbance is in the range of 1-2 DN.

The Mil-Bus is believed as main source of interference (diagnostic is the timing), external and internal contribution to be determined in follow-up tests.

5 Image mosaics

The tool we developed to correct for image geometric distortion (see §4.4) enables us to accurately find the position of the FC FOV on the celestial sphere. This is how we first noticed (in the FC2 Performance block) the discrepancy between the commanded and achieved FC pointing. The tool can output images at any desired resolution and pointing. These registered images can be combined into a color image or mosaic, as the example in Figure 20 shows, to enlarge the FOV and improve the signal-to-noise. Note that our tool only works for star fields as it depends on the known position of the observed stars.

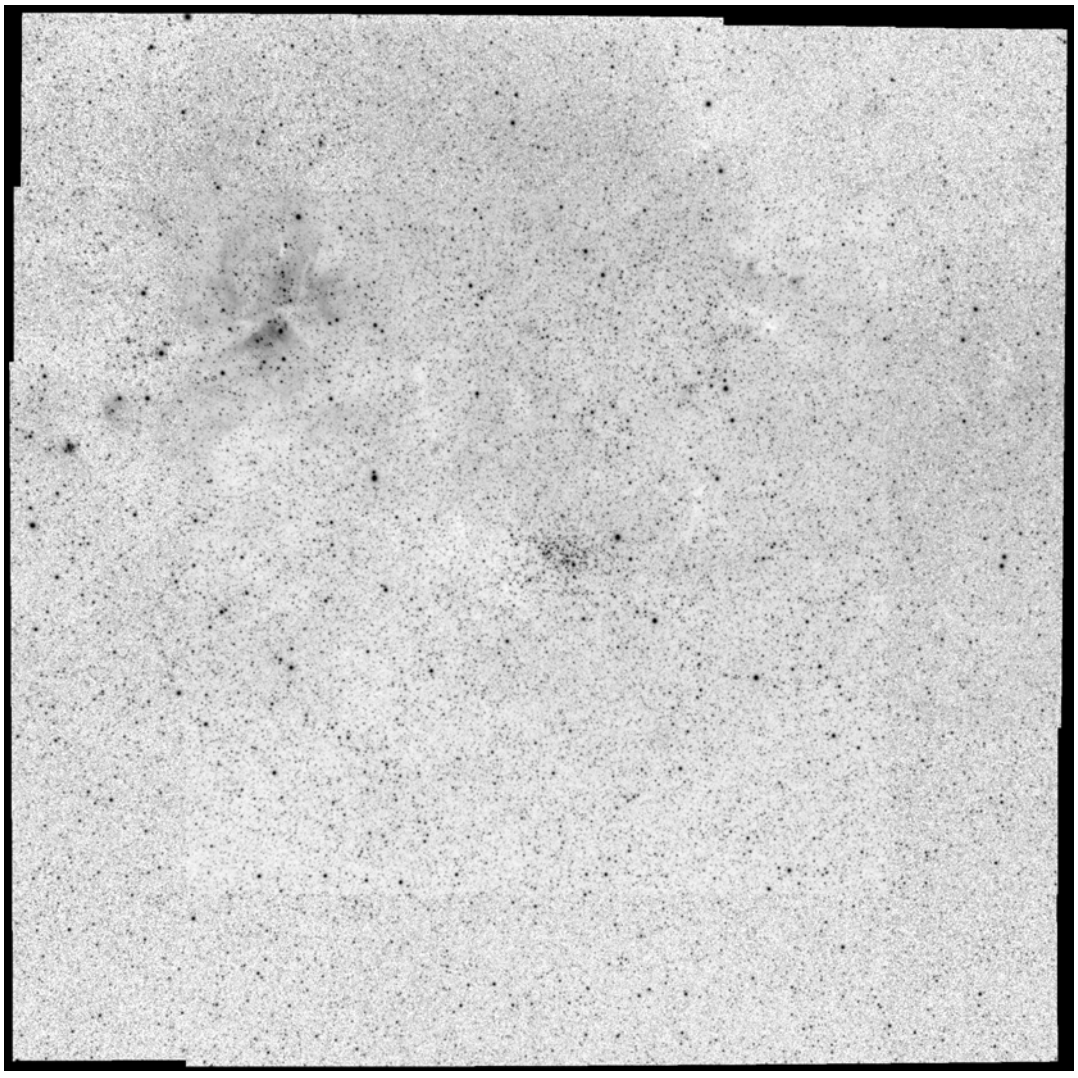


Figure 20. Mosaic of 9 clear filter (F1) FC2 images of the NGC 3532 star cluster (visible in the center, with the Eta Carinae nebula in the upper left corner), obtained as part of the Calibration block. Each image is a combination of two exposures. The mosaic is displayed negative in a logarithmic brightness scale. The original is sized 4000×4000 pixels.

6 HK data analysis

6.1 Operational key parameters

An operational key parameter is constructed of a combination of FC HK status and mode flags. HK flags take, or are forced to take, the values 0 (=OFF) and 1 (=ON). The key is then built as a base 2 integer.

6.1.1 Selection of key as combined mode value

A preliminary choice of status flags is listed in Table 3. The key is then the sum of these parameters, with possible values between 0 (every sub-unit OFF) and 127 (all sub-units ON, Door and FW active and both heaters ON).

Table 3 Preliminary parameter choice

N	Parameter	Function	ON value	OFF value
1	MCUCTRLswitch	MCU ON	1	0
2	MCUPOWswitch	MCU power ON	2	0
3	1 – FEE IF status	FEE ON	4	0
4	Door active	door open/close	8	0
5	FW active	FW op	16	0
6	HEAT1 switch	Baffle heater ON	32	0
7	HEAT0 switch	CH heater ON	64	0

Using the HK parameter names, the key value is calculated as

Key = MCUCTRLswitch + 2 * (MCUPOWswitch +
2 * (1-FEE IF status +
2 * (Door active +
2 * (FW active +
2 * (HEAT1 switch + 2 * HEAT0 switch))))).

6.1.2 Results for FC1 Functional test, 10 Dec 2007

The key value described and illustrated in §6.1.1 for the Functional tests can be applied to the FC1 Functional test. This provides a further example of the application of a combined key value, and will indicate to what extent the key value indexed HK data from the two tests can be used to compare FC1 and FC2 currents and temperatures. It is the objective to use the HK data sorted on key value to compare comparable operational modes of the two cameras in these and future tests.

A set of graphs and tables has been prepared for the FC datasets and are presented below. Figure 21 shows a similar course of the functional test as for FC2, and from Table 4 it is clear that the major operational modes are for combinations of MCU ON, FEE ON and one or the other, neither or both heaters on. The ratio of heaters ON:OFF is 11:10, approximately.

Table 5 summarises the key sorted input current statistics for these main modes.

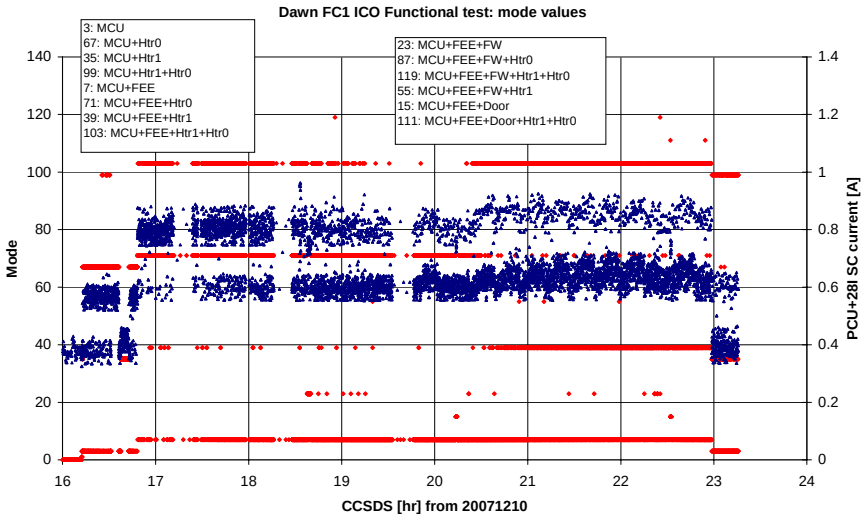


Figure 21 Variation of key value and input current for FC1 ICO Functional test

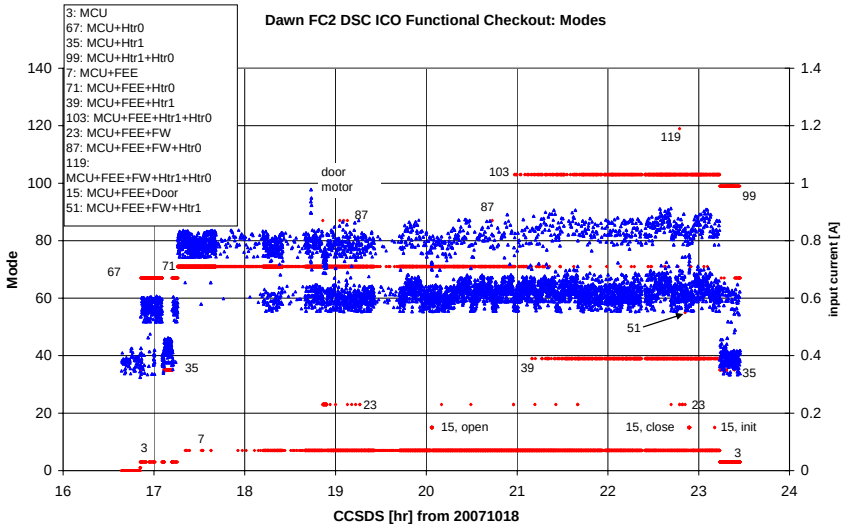


Figure 22 Variation of key value and input current for FC2 ICO Functional test

Table 4 Occurrence of parameter combinations of provisional key in FC1 ICO Functional Test

N	Key Value	Parameter combination	Meaning	HK Count	HK %
1	0	none	FC2 on, but no MCU or FEE	75	0.65
2	1	1	MCU CTRL ON	4	0.03
3	3	1, 2	MCU POW & CTRL ON	560	4.85
4	7	1, 2, 3	MCU + FEE ON	4673	40.47
5	15	1, 2, 3, 4	MCU + FEE + Door	36	0.31
6	23	1, 2, 3, 5	MCU + FEE + FW	72	0.62
7	35	1, 2, 6	MCU + Baffle heater	259	2.24
8	39	1, 2, 3, 6	MCU+FEE+ Baffle heater	1734	15.02
9	55	1, 2, 3, 5, 6	MCU+FEE+FW+ Baffle heater	4	0.03
10	67	1, 2, 7	MCU + CH heater	633	5.48
11	71	1, 2, 3, 7	MCU + FEE + CH heater	1981	17.16
12	87	1, 2, 3, 5, 7	MCU + FEE + FW + CH heater	none	
13	99	1, 2, 6, 7	MCU + CH & Baffle heaters	135	1.17
14	103	1, 2, 3, 6, 7	MCU + FEE + CH & Baffle heaters	1375	11.91
15	111	1, 2, 3, 4, 6, 7	MCU + FEE + Door + CH & Baffle heaters	2	0.02
16	119	1, 2, 3, 5, 6, 7	MCU + FEE + FW + CH & Baffle heaters	3	0.03

Table 5 Statistics of FC1 PCU +28I SC, key values illustrated in Figure 23

Key value	FC1 PCU +28I SC average [A] (half range [A]) *key value*			
	No heaters	**Baffle Heater**	**CH heater**	**Both heaters**
FEE OFF	0.428 (0.158) *3*	0.440 (0.157) *35*	0.538 (0.155) *67*	0.488 (0.150) *99*
FEE ON	0.658 (0.204) *7*	0.685 (0.185) *39*	0.746 (0.203) *71*	0.720 (0.198) *103*
FEE + door	0.725 (0.107) *15*			
FEE + FW	0.707 (0.138) *23*			

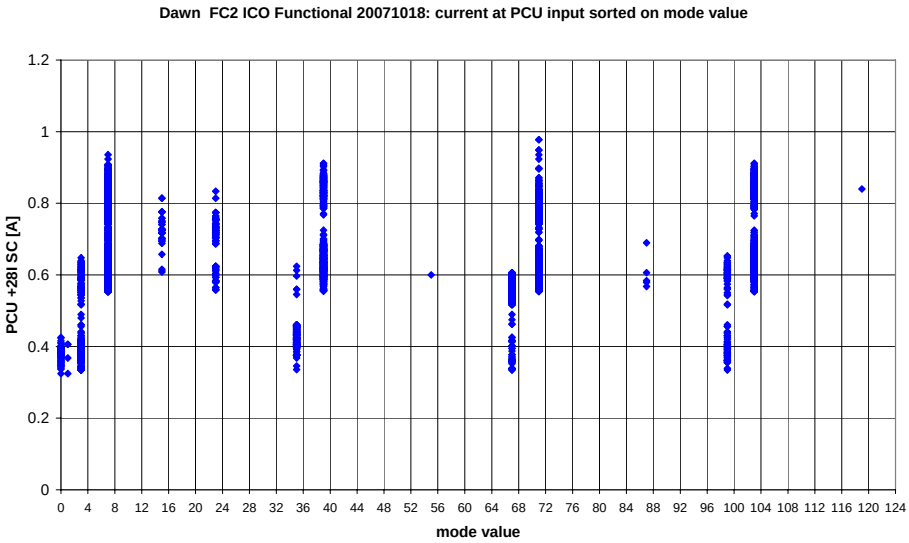


Figure 23 FC1 PCU input current as function of key value

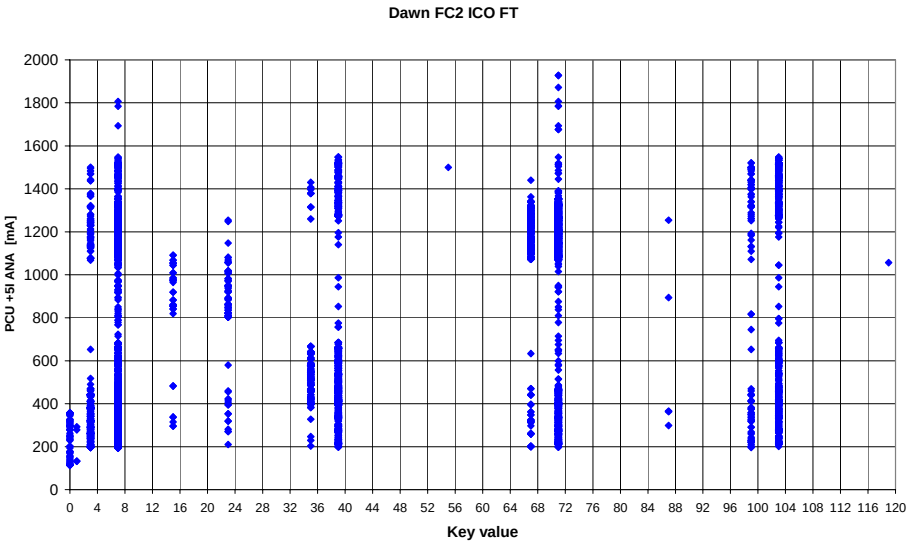


Figure 24 Dawn FC2 ICO FT PCU +5I ANA vs Key

The variation of PCU +5I ANA parameter with key shown in Figure 24 is similar to the variation of input current. However, there is not the large difference between FEE ON and FEE OFF. The statistics are summarized later.

One aspect of the variation is a bimodal distribution which is not separated by the key sorting trick. Plots of the currents against the time show a correlation of the bimodal distribution with imaging. It is not clear which HK status flag should be added to the key in order to separate the two modes. The bimodal distribution is like a switching and depends on imaging, as will be

shown in a later section for FEE current supply. The solution can be shown to be partly H/W; augmenting the key by a true/false flag improvised on PCU -5I FEE >/< -80mA separates the distribution, but not completely.

Sampling noise and stale HK data

The points lying between the obvious groupings in the corners were called noise. That was with reference to what are assumed to be stable states, two or four as the case may be. The in between data are probably real, sampled in the transition.

A more serious difficulty for the key sorting method is the occurrence of apparently stale data, that is, HK currents and voltages that were sampled at an earlier time than the status and flag parameters in a given HK packet. For example, checking MAX/MIN statistics of key sorted data shows occasional non-zero FEE voltages and currents when FEE status is OFF, and vice versa. That type of sorting error can be corrected, but if as one supposes the same sampling of stale values is going on during the frequent heater switching then those sorting errors cannot be systematically corrected and the resulting sorting statistics are biased or mixed depending on viewpoint.

This is not seen as too serious a problem for the current purpose of comparing the two cameras during similar FT operations. In the statistics tabulated later the bimodal distributions are split in a second sorting and statistics built on the separate data groups.

The techniques used in this section have been followed for FC1 ICO FT data, which are presented next for electrical HK data.

6.2 Comparison of FC1 and FC2 currents during ICO FT

The provisional key value has been used to compare average and range of current for the two cameras, as observed during ICO functional tests. Details are not in the scope of this document. The first table gives the results for input current (PCU +28I SC) and the analog power supplies (PCU +5I ANA). Following in Table 7 are DPU supply currents (PCU +3.3I DPU, and PCU +2.5I DPU), then the FEE supplies in Table 8 (PCU +12I FEE), Table 9 (PCU +15I FEE),

Table 10 (PCU +5I FEE), and Table 11 (PCU -5I FEE).

Table 6 Summary of FC2-FC1 differences for input current and +5I ANA supply currents during ICO functional tests

		PCU +28I SC [A]							PCU +5I ANA [mA]						
		FC1			FC2			D	FC1			FC2			D
	key	AVG	HR	N	AVG	HR	N	%	AVG	HR	N	AVG	HR	N	%
No MCU or FEE	0	0.376	0.052	75	0.378	0.050	75	0.7	218.3	125.5	75	229.6	122.3	75	4.9
MCU Power ON	1	0.370	0.034	4	0.376	0.041	4	1.6	240.9	103.9	4	209.0	80.2	4	-15.3
MCU Pow & Ctrl ON	3	0.428	0.158	560	0.426	0.157	409	-0.4	480.4	663.9	560	487.0	652.2	409	1.4
MCU and FEE ON	7	0.658	0.204	4673	0.647	0.191	5377	-1.7	491.9	674.6	4673	451.0	806.6	5377	-9.1

MCU + FEE + Door	15	0.725	0.107	36	0.723	0.103	38	-0.3	846.6	422.9	36	847.8	397.8	38	0.1
MCU + FEE + FW	23	0.707	0.138	72	0.690	0.138	78	-2.5	776.4	555.9	72	814.0	521.8	78	4.6
MCU + Baffle heater	35	0.440	0.157	259	0.427	0.144	170	-2.9	601.8	648.6	259	554.5	613.5	170	-8.5
MCU + FEE + Baffle heater	39	0.685	0.185	1734	0.690	0.178	623	0.7	612.1	671.8	1734	701.3	675.3	623	12.7
MCU + CH heater	67	0.538	0.155	633	0.549	0.136	465	2.1	1105.9	649.4	633	1139.1	620.3	465	2.9
MCU + FEE + CH heater	71	0.746	0.203	1981	0.737	0.212	2082	-1.2	1082.3	860.2	1981	1021.2	864.7	2082	-6.0
MCU + Baffle & CH heaters	99	0.488	0.150	135	0.500	0.159	98	2.5	817.1	663.1	135	857.2	662.0	98	4.7
MCU + FEE + Baffle & CH heaters	103	0.720	0.198	1375	0.711	0.179	706	-1.3	921.3	920.2	1375	918.1	673.8	706	-0.3

Note: AVG = average; HR = half range; N = count; D = 100 (FC2-FC1)/FC2.

The key definition in terms of units ON has been included in the tables, and the counts, average and half range for FC2 and FC1, and the percent difference between FC2 and FC1 averages for each key. Half range has been used so that average + half range could be used for an upper limit, but this is not correct. Note also that average - half range can be negative. This is because average does not represent a central value for range as an estimate of spread.

These tables must be redone with average and standard deviation as statistical measures.

Table 7 Summary of FC2-FC1 differences for +2.5I and +3.3I DPU supply currents during ICO functional tests

		PCU +2.5I DPU [mA]							PCU +3.3I DPU [mA]						
		FC1			FC2			D	FC1			FC2			D
	key	AVG	HR	N	AVG	HR	N	%	AVG	HR	N	AVG	HR	N	%
No MCU or FEE	0	746.3	155.0	75	741.1	146.7	75	-0.7	321.5	79.0	75	318.4	81.0	75	-1.0
MCU Power ON	1	776.3	12.3	4	770.0	11.0	4	-0.8	234.9	5.2	4	232.9	5.3	4	-0.9
MCU Pow & Ctrl ON	3	749.5	108.5	560	744.8	115.9	409	-0.6	236.3	53.0	560	234.2	52.7	409	-0.9
MCU and FEE ON	7	718.3	140.3	4673	710.9	135.6	5377	-1.0	246.9	68.0	4673	245.1	70.7	5377	-0.7
MCU + FEE + Door	15	727.8	95.1	36	684.6	103.5	38	-6.3	237.7	50.1	36	246.9	49.9	38	3.7
MCU + FEE + FW	23	719.3	101.2	72	700.7	128.6	78	-2.6	241.1	53.3	72	242.4	53.0	78	0.5
MCU + Baffle heater	35	753.9	105.2	259	742.8	100.5	170	-1.5	233.1	5.6	259	231.2	50.0	170	-0.8
MCU + FEE + Baffle heater	39	710.8	140.6	1734	705.0	125.3	623	-0.8	249.1	63.8	1734	243.3	63.9	623	-2.4
MCU + CH heater	67	743.6	105.9	633	742.3	112.7	465	-0.2	232.4	49.0	633	230.1	49.4	465	-1.0
MCU + FEE +	71	714.5	130.9	1981	700.3	130.7	2082	-2.0	244.7	65.1	1981	244.1	66.8	2082	-0.2

CH heater															
MCU + Baffle & CH heaters	99	766.3	102.5	135	740.8	99.0	98	-3.4	233.1	10.4	135	231.4	5.6	98	-0.7
MCU + FEE + Baffle & CH heaters	103	711.7	139.8	1375	708.2	117.3	706	-0.5	245.9	63.2	1375	242.1	62.5	706	-1.6

Note: AVG = average; HR = half range; N = count; D = 100 (FC2-FC1)/FC2.

Table 8 Summary of FC2-FC1 differences for +15I FEE supply currents during ICO functional tests

		PCU +15I FEE <47mA [mA]							PCU +15I FEE >47mA [mA]						
		FC1			FC2			D	FC1			FC2			D
	key	AVG	HR	N	AVG	HR	N	%	AVG	HR	N	AVG	HR	N	%
MCU +FEE	**7**	32.4	7.2	3062	36.0	4.6	2950	**10.0**	61.6	7.5	1611	59.0	4.1	2427	**-4.3**
MCU + FEE + Door	**15**	33.0	0.6	36	36.5	0.6	38	**9.6**			0			0	
MCU + FEE + FW	**23**	32.9	0.9	72	36.4	0.7	78	**9.7**			0			0	
MCU + FEE + Baffle heater	**39**	32.4	3.4	733	36.2	0.8	389	**10.3**	61.7	6.6	1001	59.2	0.8	234	**-4.2**
MCU + FEE + CH heater	**71**	33.0	2.1	1840	36.4	5.1	1793	**9.5**	61.9	1.2	140	59.1	3.1	289	**-4.7**
MCU + FEE + Baffle & CH heaters	**103**	32.8	1.8	890	36.2	2.9	412	**9.3**	61.8	1.2	485	59.3	4.1	294	**-4.2**

Note: AVG = average; HR = half range; N = count; D = 100 (FC2-FC1)/FC2.

Table 9 Summary of FC2-FC1 differences for +12I FEE supply currents during ICO functional tests

		PCU +12I FEE <75mA [mA]							PCU +12I FEE <75mA [mA]						
		FC1			FC2			D	FC1			FC2			D
	key	AVG	HR	N	AVG	HR	N	%	AVG	HR	N	AVG	HR	N	%
MCU +FEE	**7**	65.3	3.9	3086	64.3	4.3	2988	**-1.6**	84.4	4.2	1587	83.3	8.3	2389	**-1.3**
MCU + FEE + Door	**15**	65.2	0.0	36	64.2	0.1	38	**-1.6**			0			0	
MCU + FEE + FW	**23**	65.2	0.1	72	64.2	0.1	78	**-1.6**			0			0	
MCU + FEE + Baffle heater	**39**	65.4	3.6	743	64.2	3.4	395	**-1.8**	84.4	4.5	990	83.2	0.3	228	**-1.4**
MCU + FEE + CH heater	**71**	65.0	5.2	1850	63.9	4.3	1810	**-1.8**	84.4	0.5	130	83.3	1.7	272	**-1.3**
MCU + FEE + Baffle & CH heaters	**103**	65.2	3.8	903	64.2	3.5	414	**-1.5**	84.4	4.1	472	83.2	0.6	292	**-1.5**

Note: AVG = average; HR = half range; N = count; D = 100 (FC2-FC1)/FC2.

Table 10 Summary of FC2-FC1 differences for +5I FEE supply currents during ICO functional tests

		PCU +5I FEE [mA] (<285mA)							PCU +5I FEE [mA] (>285mA)						
		FC1			FC2			D	FC1			FC2			D
	key	AVG	HR	N	AVG	HR	N	%	AVG	HR	N	AVG	HR	N	%
MCU +FEE	**7**	266.3	7.0	3059	269.0	3.3	2953	**1.0**	297.5	0.8	1614	300.4	5.6	2424	**1.0**
MCU + FEE + Door	**15**	265.9	0.4	36	268.7	0.3	38	**1.0**			0			0	
MCU + FEE + FW	**23**	266.0	0.5	72	268.8	0.3	78	**1.0**			0			0	
MCU + FEE + Baffle heater	**39**	266.0	7.0	736	269.0	0.6	389	**1.1**	297.4	0.8	998	300.4	1.3	234	**1.0**
MCU + FEE + CH heater	**71**	266.9	2.4	1841	269.8	2.5	1780	**1.1**	297.6	1.6	139	300.3	8.7	301	**0.9**
MCU + FEE + Baffle & CH heaters	**103**	266.5	2.5	898	268.9	0.7	411	**0.9**	297.4	0.8	477	300.4	5.6	295	**1.0**

Note: AVG = average; HR = half range; N = count; D = 100 (FC2-FC1)/FC2.

Table 11 Summary of FC2-FC1 differences for -5I FEE supply currents during ICO functional tests

		PCU -5I FEE (<-80mA) [mA]							PCU -5I FEE (>-80mA) [mA]						
		FC1			FC2			*D*	FC1			FC2			*D*
	key	A	HR	N	A	HR	N	%	A	HR	N	A	HR	N	%
MCU +FEE	**7**	-87.7	1.5	1619	-88.7	2.7	2417	***1.1***	-74.3	2.3	3054	-74.8	2.5	2960	***0.8***
MCU + FEE + Door	**15**	na	na	0	na	na	0		-74.2	0.0	36	-74.8	0.1	38	***0.8***
MCU + FEE + FW	**23**	na	na	0	na	na	0		-74.2	0.0	72	-74.8	0.1	78	***0.8***
MCU + FEE + Baffle heater	**39**	-87.7	0.4	1002	-88.7	0.3	231	***1.2***	-74.2	0.2	731	-74.9	0.2	392	***0.9***
MCU + FEE + CH heater	**71**	-87.8	1.7	141	-88.7	3.8	296	***1.1***	-74.4	0.3	1839	-75.1	2.5	1785	***0.9***
MCU + FEE + Baffle & CH heaters	**103**	-87.7	0.4	476	-88.7	0.2	294	***1.2***	-74.3	0.3	899	-74.8	0.2	412	***0.7***

Note: A = average; HR = half range; N = count; D = 100 (FC2-FC1)/FC2.

7 Image streaks

In some images acquired by both FC1 and FC2 during ICO we find objects moving through the FOV. We have come to conclude that these are truly objects moving in front of the camera, and not effects created by the FC itself. Of the 731 images taken with open front cover, 15 show evidence for moving objects (FC2: 6, FC1: 9). These images were taken at four different S/C attitudes: the 'background' attitudes during the Functional block (both cameras), pointing to 20 Cep (Performance block), and pointing to NGC 3532 (Calibration block). All attitudes have the positive *x*-axis of the S/C aligned to the Sun between –17.5° and +10.0° (see Figure 25,

Figure 26, Figure 27 and Figure 28). Figure 29 shows the definition of the S/C coordinate system.

In all the images listed in Table 12 and Table 13 the streaks are aligned (more or less) horizontally from right to left (from $+x$ to $-x$ in S/C-coordinates), except for image 455. Possibly, the streaks are caused by small particles apparently coming loose from the spacecraft and being forced by radiation pressure and/or solar wind from the Sun through the FOV. This would explain both the main orientation (x-z-plane) and direction ($-x$) of the streaks in the images taken during 'ICO background attitude 2' (Figure 26) and for the images 436 and 437 taken during 20 Cep pointing (Figure 27).

Two streak examples are show in Figure 30 and Figure 31. They are associated with particles moving into $-x$-direction in the S/C coordinate system. Figure 32 shows a very faint and thin streak in the lower left corner. Unlike other streaks it is not blurred and only about one pixel wide. The apparent size for a point source blurred by defocusing is shown in

Table 14. Calculations show that it has to be at least 200 m away from the S/C to be in focus. The widest streak was found in image 762 (Figure 33). Due to its varying width it was possible to calculate the distance of the associated particle to the S/C at the beginning and end of its crossing the FOV, and to determine the angle of its path relative to the S/C. The streak is narrowing from 49 pixels at the right edge to 37 pixels where it ends in the image. The corresponding distances to the S/C are 4.6 m and 6.0 m. With a length of 810 pixels, we find that the path is 74° inclined to the x-y-plane. Assuming a linear motion of the object, it intersects with the z-deck at a distance of around 1.5 m from the optical axis of the camera.

Table 12. Images with streaks in the FC2 Functional and Performance block.

camera	FC2	FC2	FC2	FC2	FC2	FC2	FC2
test	Func.	Func.	Func.	Func.	Perf.	Perf.	Perf.
attitude	ICO1	ICO1	ICO1	ICO1	20Cep	20Cep	20Cep
img-ID	295	296	297	298	436	437	455
exp-time	3s	3s	30s	30s	15s	15s	600s

Table 13. Images with streaks in the FC1 Functional, CCDcal, and Calibration block.

camera	FC1	FC1	FC1	FC1	FC1	FC1	FC1	FC1
test	Func.	Func.	Func.	Func.	Func.	Func.	CCDcal	CCDcal
attitude	ICO2	ICO2	ICO2	ICO2	ICO2	ICO2	ICO2	ICO2
img-ID	295	296	297	298	299	300	417	418
exp-time	0.3s	0.3s	3s	3s	30s	30s	30s	30s

camera	FC1	FC1	FC1	FC1
test	Calib.	Calib.	Calib.	Calib.
attitude	20Cep	20Cep	20Cep	NGC
img-ID	512	513	521	762
exp-time	3.7s	3.7s	160s	45s

Table 14. Blur size of a point source at a finite distance.

Distance (m)	Blur size (px)
0.5	445.7
1	222.9
2	111.4
3	74.3
4	55.7
5	44.6
6	37.1
7	31.8
8	27.9
9	24.8
10	22.3
15	14.9
20	11.1
50	4.5
100	2.2
200	1.1

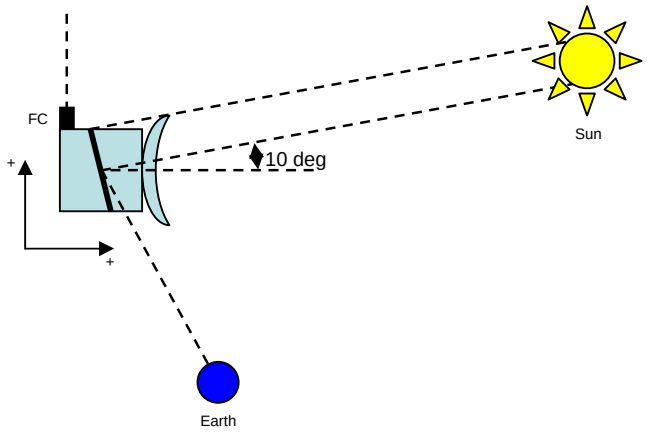


Figure 25. ICO background attitude 1, 2007 Oct 18 (ICO1).

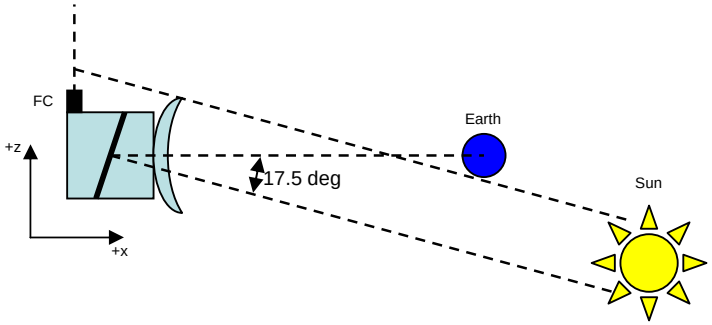


Figure 26. ICO background attitude 2, 2007 Dec 04 (ICO2).

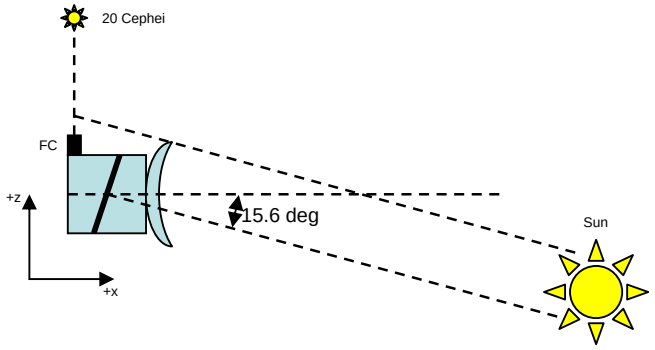


Figure 27: 20 Cep pointing, 2007 Dec 04 (20Cep).

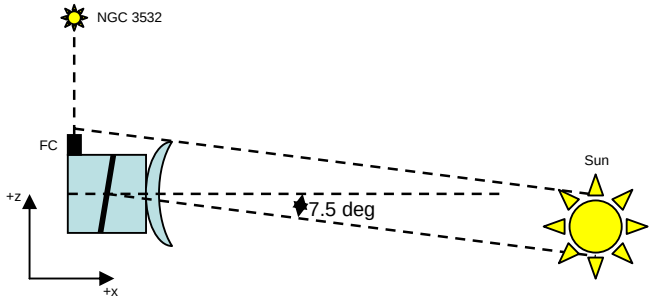


Figure 28: NGC 3532 pointing, 2008 Feb 21 (NGC).

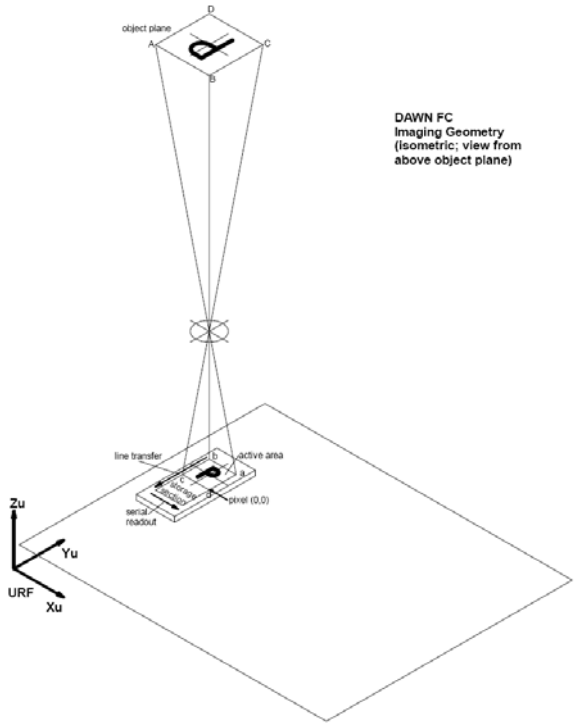


Figure 29. FC imaging geometry and coordinate system.

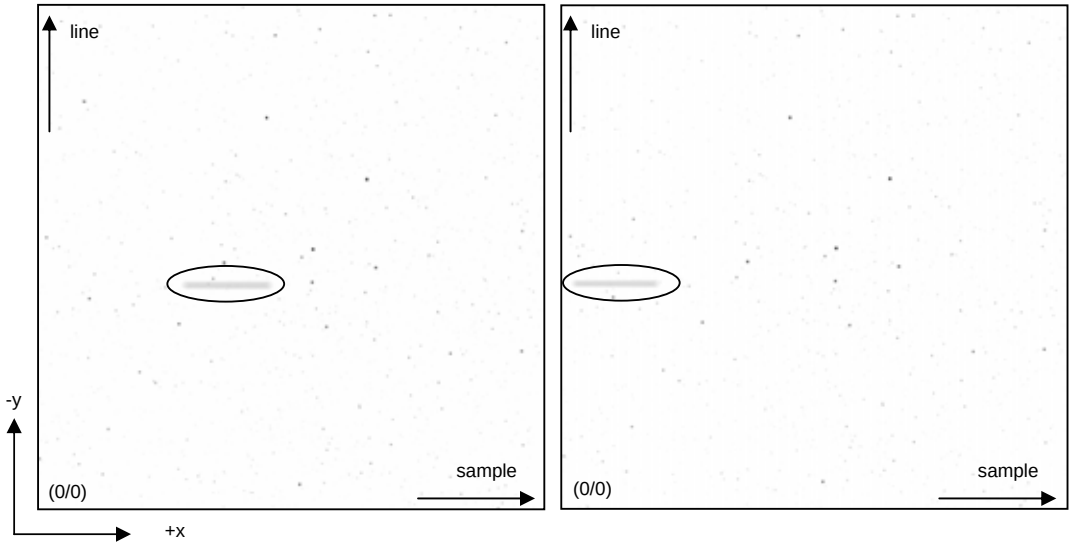


Figure 30. Moving streak in images FC2_2007-12-04T04.57.15.436Z_ID10_0000000436_F1.img and FC2_2007-12-04T04.57.39.396Z_ID10_0000000437_F1.img.

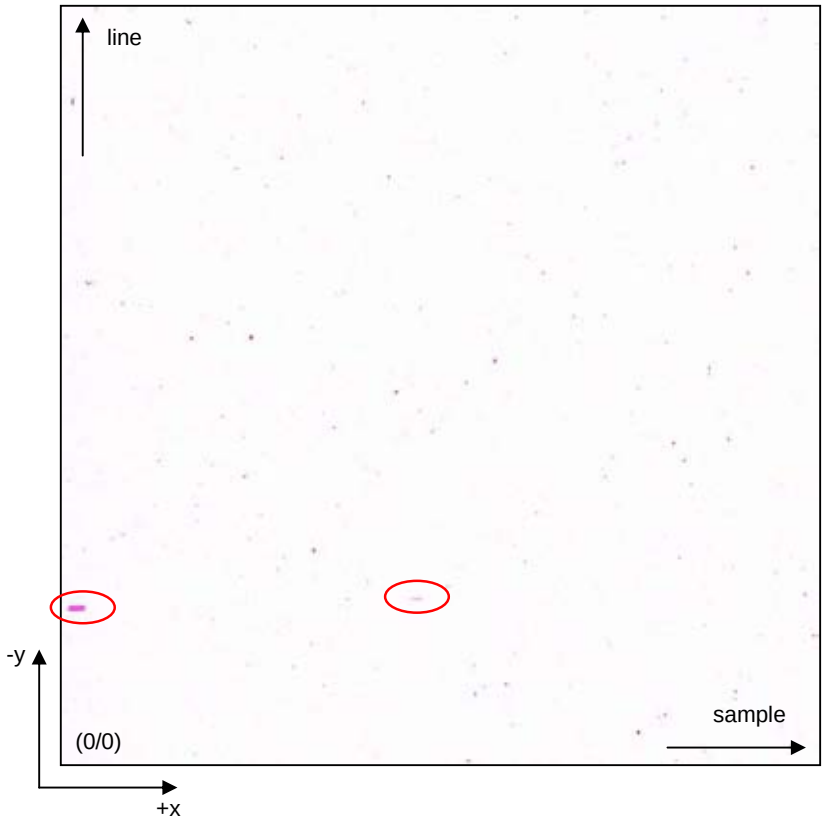


Figure 31. Two streaks in image FC1_2007-12-10T20.19.15.883Z_ID10_0000000297_F1.img.

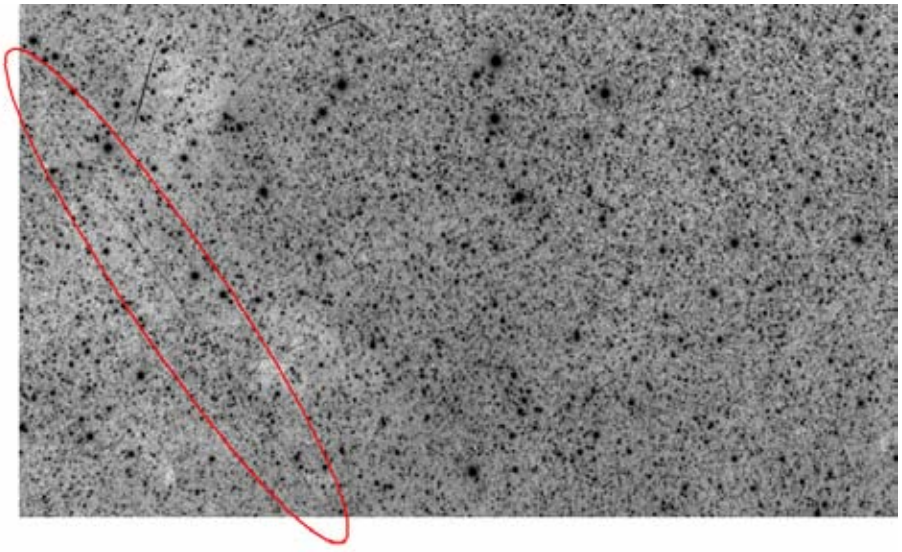


Figure 32. Lower part of image FC2_2007-12-04T05.39.36.000Z_ID10_0000000455_F1.img: a faint and thin streak in lower left corner.

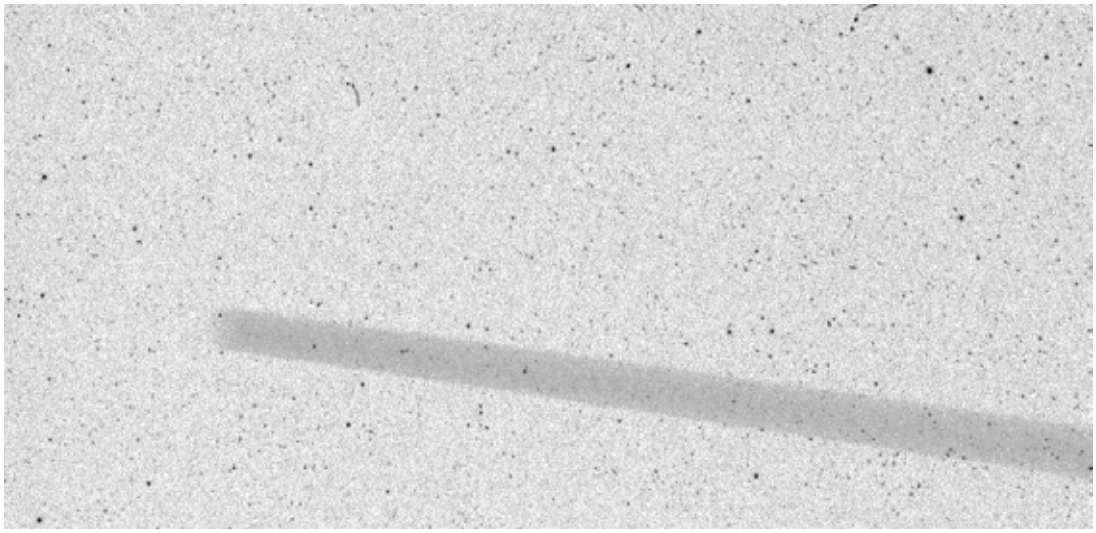


Figure 33: Lower part of image FC1_2008-02-22T06.55.21.123Z_ID10_0000000762_F3.img: a streak with varying width.

8 Conclusions

Commissioning of the Dawn Framing Cameras was performed in 7 slots, 4 on FC1 and 3 on FC2. Both cameras were found fully functional, unaltered by the launch event and performing as designed in zero-g, vacuum and mission thermal environment.

Total of 1157 images were acquired. Front doors were opened and closed, filter wheels turned one-by-one and multiple filters, cal lamps used for optical stimulation. Operational heaters stabilized the FCs right at the target temperatures of camera head and baffle with good power margins.

A few images were corrupted when received on ground. Further investigation pointed at an issue in the spacecraft virtual recorders. An ISA has been filed but no action is required on the FC side.

Flight software performed well, camera internal communication was checked by checksum check and found ok. Image compression works well. Engineering housekeeping was verified and found in expected ranges.

Thermal performance of both cameras is inline with s/c TVac based predictions. CCDs ran at about -52degC for FC2, FC1 about 2deg warmer at -50degC. There is room for improvement by lowering deck temperature by -20degC, aiming for CCD target temperature of -60degC.

Camera performance was verified concerning bias, dark current, PSF, and geometric distortion, all nominal as expected from ground tests. S/C jitter was seen in long exposures adding to the PSF and providing upper limits for exposure times.

Absolute calibration was found approx. 20% offset compared to ground tests, very similar for both cameras indicating mismatch of ground facilities (under review).

The CCDs were found with slight charge blooming column-up of strongly over exposed pixels (which can be interpreted as insufficient CTE). However, CCD anti-blooming gate is efficiently removing charges as no column crossings were found.

Residual charge by incomplete clearing prior to exposure was found as seen on ground in FC1 cal lamp images, and verified absent in FC2 frames. A software patch will be uploaded in April to mitigate FC1 residual charge in most color filters, but not in FC1 clear filter at Vesta flux.

Streaks were seen in 19 images, the blur size indicates source of streaks may be in only a few to a few tens of meters distance, moving at low velocities. One streak is only 1 pixel wide, thus source at least 200m away.

9 Appendixes

9.1 FC1 Functional test report

Dawn FC1 ICO Functional Test Block; DSC/UCLA
10 Dec 2007 (H Sierks, M Aye, S Schroeder, H U Keller, S Mottola at DSC; P Gutierrez, T Maue, M Richards at MPS)

- ccd temperature was found in steady state with rampage readings of -63.7C and camera head at -18.9C at bit below 50% duty cycle; pt2000 final calibration tunes not applied yet; deck temperature is -2.7C with unit off
- all times herein are DSC local time/PST

07:00 voca check ok
07:02 checked space weather on noaa, sun is quiet, no solar event ongoing
07:36 engineering playback finished
07:50 FC1 thermal data is ok to proceed
07:52 4h life boat sent (ends 11:22 with 30min margin)
07:57 FC1 power on radiated
08:03 power on ok, memory check running, ch temperature drops as thermal control demon is not yet up and running
08:13 mass mem check ok, mcu turned on, hk & temps ok, power on htr test ok
08:16 all hk fine :-)
08:18 camera is on, boot was nominal, CCD at -63.43C, radiator -78.75C, camera head at -25.89C, thermal control catching up at 63% duty cycle and raising
08:28 radiated extended heater test cmds
08:32 thermal control stopped, ch htr turned on for 5min
08:37 ch htr turned off, ok
08:38 table patch sent and verified: 125 steps to open door (flight config)
08:39 turned baffle htr on for 5min
08:44 ok, htr tests went fine
08:46 sent fee switch on
08:49 all hk fine, ok
08:55 sent cmd acquisition of 'ten basics'
09:09 radiate playback for 8 min, all images
09:12 temperature snap shot: CCD -57.27, camera head -23.89, radiator -77.75 baffle -30.87, i/f 3.6
09:15 first test pattern streaming down, ok
09:20 all 10 images down and look fine, checking, see cosmics, images are ok; serial images show peaks at frequencies comparable to FC2, level is elevated by approx. 15%, a broad peak at higher frequencies is visible
09:22 back to real time tlm, gap check revealed no gap, wait for station handover
10:00 back to cmding after station handover
10:01 radiated cal lamp imaging sequence
10:02 temperature snap shot: CCD -52.91, camera head -18.9, radiator -72.76 baffle -30.87, i/f 6.1
10:04 cal lamp is on
10:08 6 images taken, processing,, done
10:14 radiated p/b cmd to download image data
10:15 note encoder values are #36 for filter wheel (F1), #35 for door (closed)
10:24 images are fine so far, cal lamps are operative, ccd sensitive, optics transmissive, door still close :-)
10:28 zero gaps in playback reported
10:29 radiated heat pulse sequence
10:33 test UDP on board
10:35 received hk alarm on 5V current as seen with fc1 when motor is powered on top of thermal control turning htr on, ok
10:36 radiated fw init cmd
10:41 fw init found residual steps 3, encoder at end of init is 36 at F1
10:43 filter wheel rotated to pos 2, ok, enc 26/2; cal lamp para changed, ok
10:47 2 full frames in F2, move to F3, ok, enc 19/3 with jitter to 20/3
10:52 2 full frames in F3, move to F4, ok, enc 10/4
10:58 2 full frames in F4, move to F5, ok, enc 4/5
11:03 2 full frames in F5, move to F6, ok, enc 58/6
11:12 2 full frames in F6, move to F7, ok, enc 52/7
11:14 2 full frames in F7, move to F8, ok, enc 42/8
11:17 2 full frames in F8, move back to F1, ok, enc 36/1, cal lamp off
11:22 life boat cancelled (radiated)
11:26 go to renew the 4h life boat, radiated (ends 14:56 with 30min margin)
11:28 temperature snap shot: CCD -50.37, camera head -18.9, radiator -70.77 baffle -28.88, i/f 7.1
11:30 start playback of image data in vr8
11:40 all images are down, 0 gaps, analyzing images..
11:44 radiated back to realtime
11:49 radiated sequence to acquire dark images (2x 1sec,300sec,30sec)
11:57 6 darks acquired, streaming out to VR, done
12:03 checked temperatures and hk prior to door opening, ok; door enc reads 35, decoded 'closed'
12:10 radiated door open sequence
12:15 door is open, encoder reads 14/open, yeah
12:16 radiated 3 full frames in F1 (36/1), goto F8, enc @end of sequence: 42/8
12:23 radiated 3 full frames in F8 (42/8), goto F7, enc @end of sequence: 52/7
12:30 checked temperature effect of open door, see baffle temp drop and hot motor from door opening

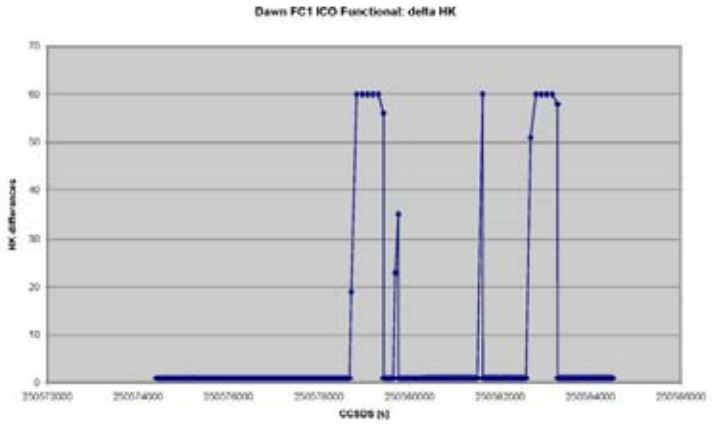
12:40 radiated 3 full frames in F7 (52/7), goto F6, enc @end of sequence: 58/6
12:58 temperature snap shot: radiator -69.8C, cold stack -54.1C (pt2000 corrected), CCD -49.9C; baseplate is at 7.4C; duty cycle ch 19%, baffle 49%
Note: correction of pt2000s is FC1-CCD-A: subtract 2.1C, FC1-CCD-B: subtract 2.0C, FC1-CH-A: subtract 3.1degC, FC1-CH-B: subtract 2.8C
12:56 radiated 3 full frames in F6 (58/6), goto F5, enc @end of sequence: 4/5
13:12 radiated 3 full frames in F5 (4/5), goto F4, enc @end of sequence: 10/4
13:28 radiated 3 full frames in F4 (10/4), goto F3, enc @end of sequence: 19/3
13:44 radiated 3 full frames in F3 (19/3), goto F2, enc @ end of sequence: 26/2
14:01 radiated 3 full frames in F2 (26/2), goto F1, enc @end of sequence: 36/1
14:18 radiated 'random' filter access f1, f4, f7, f1, 2x, 1sec, 30sec, ok
14:29 radiated close door cmd, enc changed from 14/open to 35/closed
14:34 radiated acquisition of darks, running, done, ok
14:52 radiated door init, executed (mcu pwr busy), ok
14:55 temperature snap shot: radiator -69.8C, cold stack -54.6C (pt2000 corrected), CCD -50.3C; baseplate is at 7.7C; duty cycle ch 16%, baffle 53%
14:57 radiated fee pwr off and checked hk, done
15:04 ready for preppowerdown, radiated, done and fine, checked parameter hardware and life time table dumps and ok
15:12 power down fc1, ok
15:17 ccd temp going up by ccd non-op htr, ch htr enabled, thermal handover done successfully
15:20 radiation to kill life boat
15:26 life boat terminated
15:30 starting desat
15:45 temperatures are back to cruise, non-op heaters are operating
16:07 ready for playback, radiated, awaiting first light images
16:10 first light received, nice..
16:56 all images downloaded

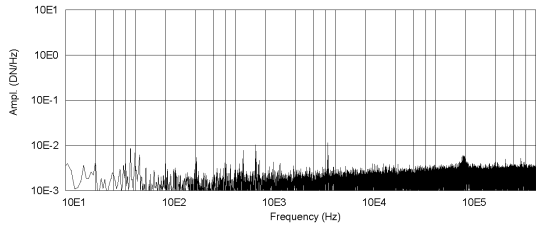
note: - s/c apid forwarding was none functional on fc1 current
- unused thermal sensor 3047 not removed yet (as of fc2 runs)
- tune down of s/c read pt2000 thermistors not performed yet

Summary:
The Dawn Framing Camera FC1 was turned on for slightly more than 7 hours for functional checkout. It received 150 cmds, acquired 102 images, 12776 hk frames, and 12324 events. All radiated sequences ran nominally, the instrument worked fine. All FC1 subsystems were found alive and functionally unaltered by the launch event. The filter wheel initialization found the 3 step off pre-launch configuration. The electronics performed nominally, the CCD and optics performed nominally. Filter wheel mechanism checkout cw and ccw and multiple filter change test were ok, front door operation was nominal, a door init was run to leave the unit in nominal state at power down. A few housekeeping alarms were noted during motor pulse check while thermal control used the heaters. Yellow and even one red limit were triggered, but current delivered to the subsystems was well within the power converter unit capability. This hick-up was seen on FC2 before and is a one time c/o feature only.
The CCD reached steady state at approx. -50.3C with camera head at -20C (16% duty cycle) and deck at +7.2C. There is good potential to get CCD temperature further down by decrease of camera head and deck temperatures. The image data was quicklook analyzed, find samples attached. Optical performance shows good sensitivity and excellent star psf, fwhm 1.23px x 1.18px in 3s exposure @Vmag 6.9, the unit is well in focus. We saw debris again. We saw M51 galaxy clearly. Deeper analysis is to come.
Congratulations again to the Dawn team at JPL, DSC, and home at MPS. We do have 2 science cameras on their way..
H Sierks for the FC Team, 10 Dec 2007

attachments:
- this report of activity
- fft analysis of serial images
- plot of hk ccsds packet deltas on p/b hk periods
- star catalogue FC FoV in ICO pointing
- first clear filter image
- debris image

Attachments:





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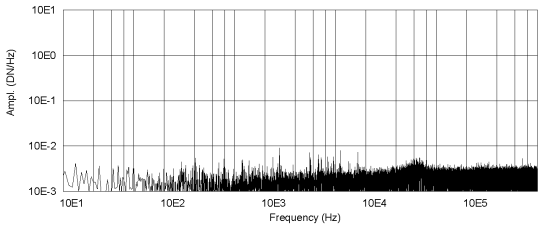
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 271.725DN; RMS= 1.276DN
FFT range (5, 1055)



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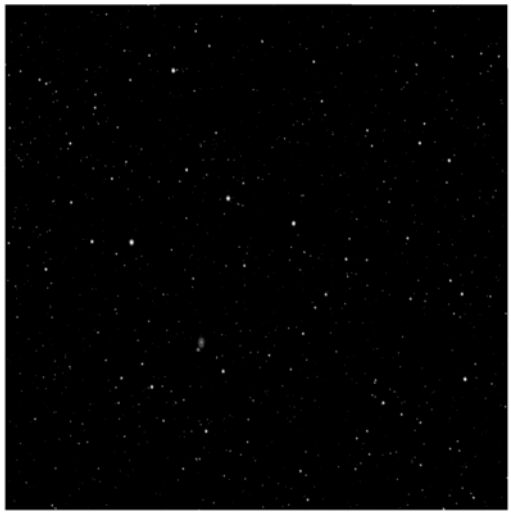
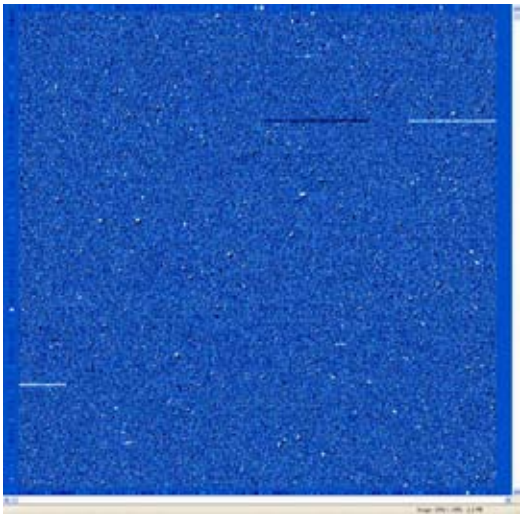
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 271.525DN; RMS= 1.256DN
FFT range (5, 1055)





9.2 FC1 CCD Minical test report

Dawn FC1 ICO CCD Calibration Test Block; DSC/UCLA

12 Dec 2007 (M Aye, S Schroeder, H Sierks, H U Keller, S Mottola at DSC; P Gutierrez, T Maue, M Richards at MPS)

- ccd temperature was found in steady state with rampage readings of -63.7C
  and camera head at -18.9C around 50% duty cycle; deck temperature is -2.8C with unit off
- all times herein are DSC local time/PST

10:30 voca check ok
10:32 checked space weather on noaa, found sun on decline of small solar event
10:40 FC1 thermal data is ok to proceed
10:48 all stations go for test

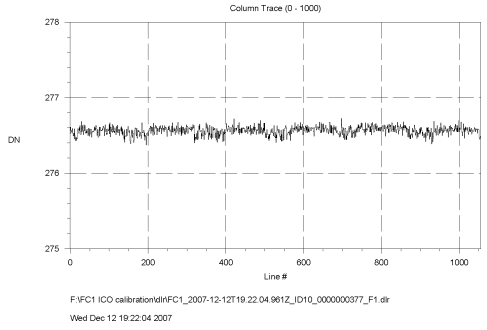
10:49 FC1 CCD cal sequence radiated
10:56 power on and boot ok
10:57 temp snap shot: CCD -62.53, radiator -77.75, ch -22.89, i/f -2.6, all degC
11:00 UDP upload successful, FEE is on and ok
11:06 20 minutes for thermal stabilization with test image acquisitions (4)
11:15 cal lamp is off
11:20 imaging test pattern, storage read outs, serial readout, darks
11:41 CCD checkout sequence started, done.
11:57 opening door, ok
12:14 door is closed at enc #35, filter wheel at F1, enc #36
12:19 FEE off, hk ok
12:27 first image received
12:30 test pattern received and ok
12:34 found noise pattern in serial images, have to get characterized
12:57 43 images received, will get open door images soon...
13:09 71 images downloaded, star field are sub framed due to coding residual:-(
14:05 last packet received, FC1 is powered off
14:08 ccd temp going up by ccd non-op htr, ch htr enabled, thermal handover done successfully
14:17 temperatures are back to cruise, non-op heaters are operating nicely
14:20 no gaps reported, end of test

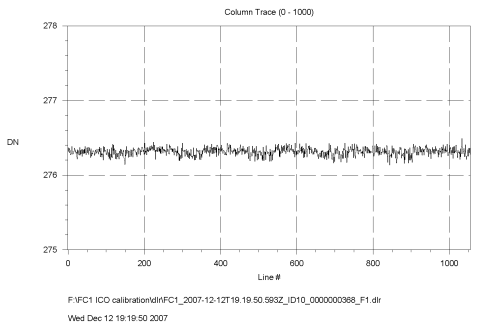
Summary:

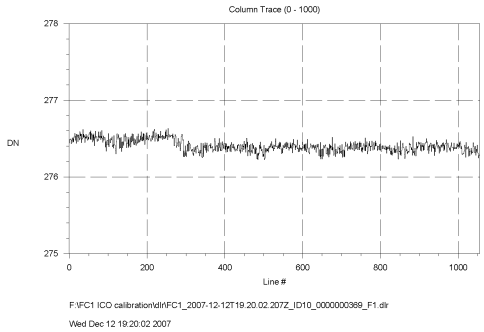
The Dawn Framing Camera FC1 was turned on for slightly more than 3 hours for CCD checkout by use of calibration lamp. It received 68 cmds, acquired 72 images, 5644 hk frames, and 5716 events. All radiated sequences ran nominally, the instrument worked fine, all subsystems were activated during test.
Both mechanisms were operated in order to gain confidence: the filter wheel was operated thru all filters imaging 'random' star field as of ICO pointing. The front door was opened and closed successfully.
Analysis of serial images reveals pattern at 5Hz and triplet at 45/50/55 Hz visible at a level of about 0.4 DN in the images. Check of s/c TVac data shows same triplet in fft, but non visible in image display; thus at fairly low intensity. Same for FC2 in performance checkout, triplet or single frequency 45, 50, or 55Hz visible, but effect not detectable in image display.
Star field came down as sub frames. This was unexpected as full frames were thought to be commanded. Check of coding revealed residual in commanding sequence that had sub framing switch set to on using default windowing setting. Images are ok for the purpose of this test just taking advantage of the open door.
Two out of 18 open door images show faint streaks, they appear to come from +x moving towards -x in z-x plane. Streaks may be investigated in more detail by stereo imaging using both cameras concurrently.
Quicklook analysis of cal lamp images show residual charge at the CCD. The data set is usable for comparison with ground data and FC2 data as of FC2 calibration test on Dec 14, 2007.
Thanks to the Dawn team at JPL, DSC, and home at MPS. There is data to analyze though..
H Sierks for the FC Team, 12 Dec 2007

attachments:
- this report of activity
- line scans of the 10 serial images
- fft of the 10 serial images
- image display of 19:20:48 serial image
- two streak images taken in clear filter with 30sec exposure time:
  FC1_2007-12-12T20.01.28.785Z_ID10_0000000417_F1.dlr
  FC1_2007-12-12T20.02.08.823Z_ID10_0000000418_F1.dlr
- residual charge histogram for reference in ground and FC2 comparison

Attachments:







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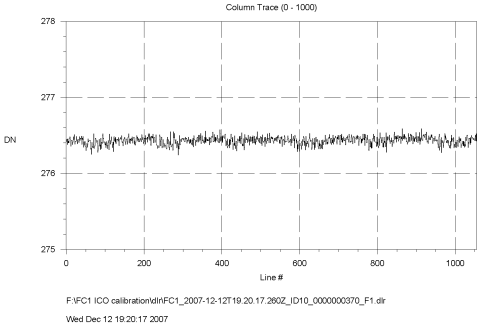

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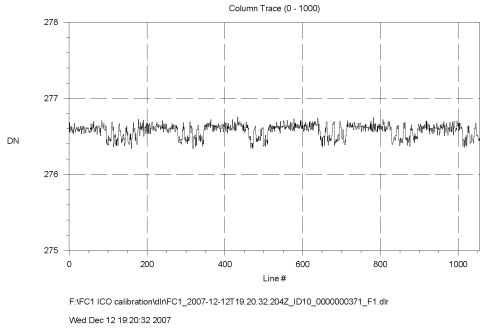

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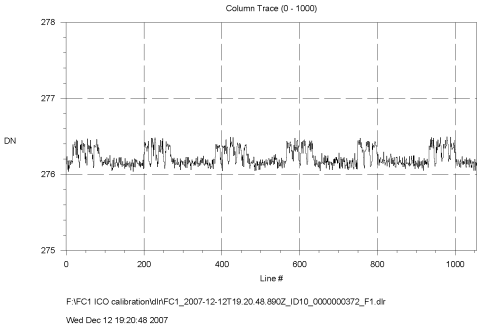

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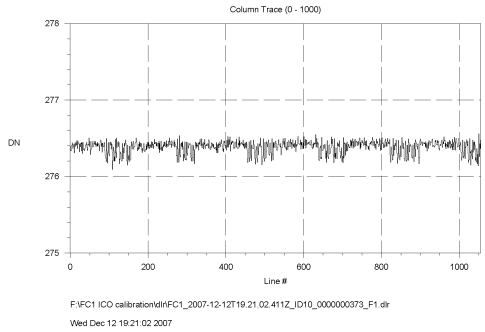

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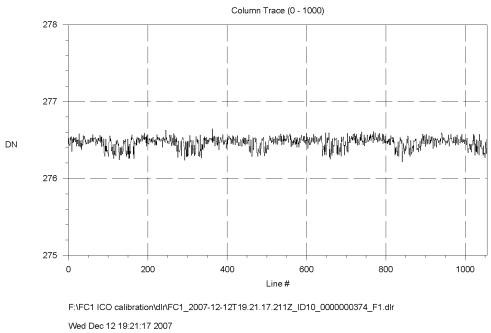

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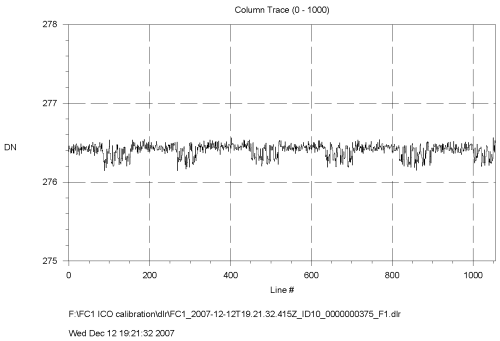

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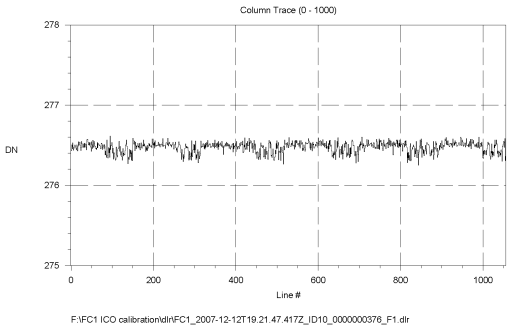

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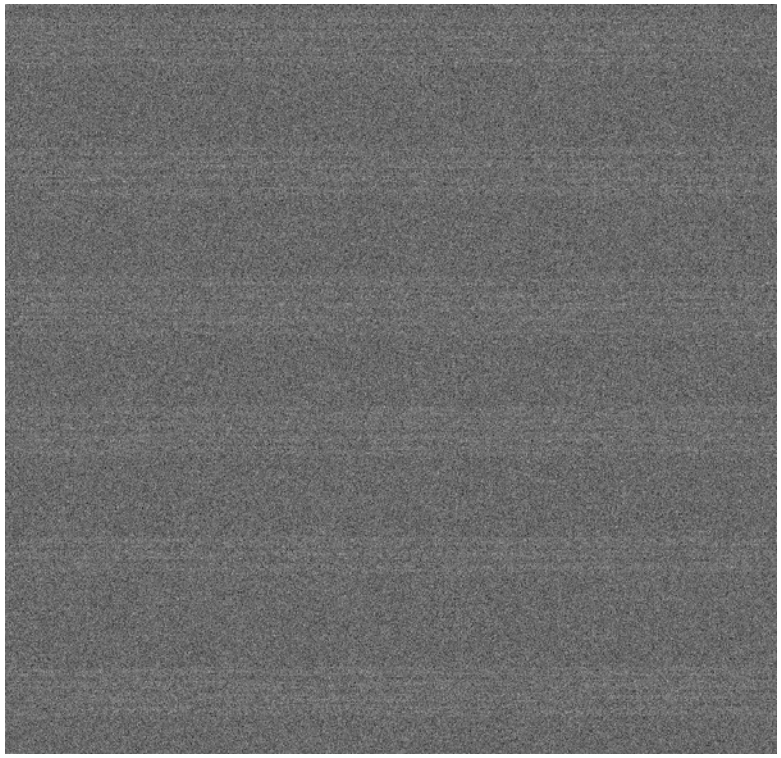
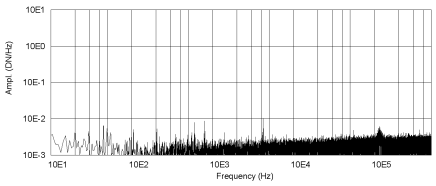
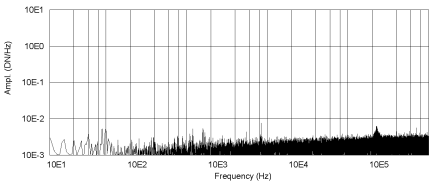
Wed Dec 12 19:21:47 2007

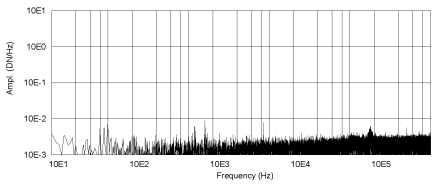




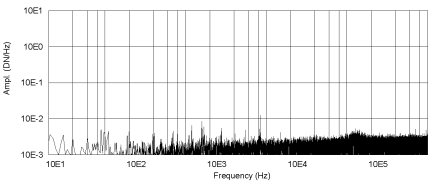
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.22.04.961Z_ID10_0000000377_F1.dlr
Wed Dec 12 19:22:04 2007
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 276.562DN; RMS= 1.221DN
FFT range (5, 1055)



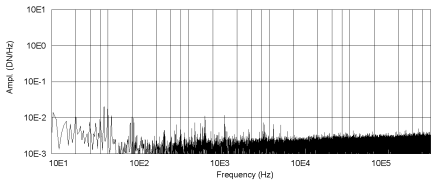
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.19.50.593Z_ID10_0000000368_F1.dlr
Wed Dec 12 19:19:50 2007
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 276.312DN; RMS= 1.239DN
FFT range (5, 1055)



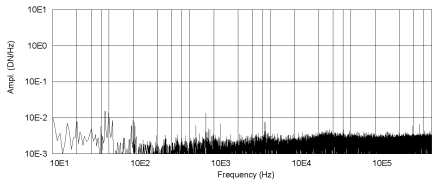
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.20.02.207Z_ID10_0000000369_F1.dlr
Wed Dec 12 19:20:02 2007
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 276.411DN; RMS= 1.233DN
FFT range (5, 1055)



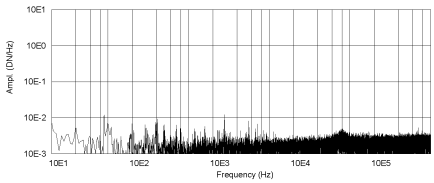
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.20.17.260Z_ID10_0000000370_F1.dlr
Wed Dec 12 19:20:17 2007
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 276.431DN; RMS= 1.230DN
FFT range (5, 1055)



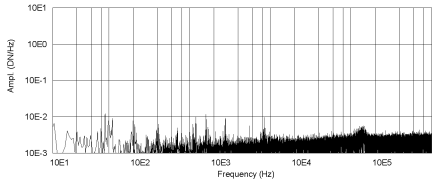
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.20.48.890Z_ID10_0000000372_F1.dlr
Wed Dec 12 19:20:48 2007
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 276.219DN; RMS= 1.212DN
FFT range (5, 1055)



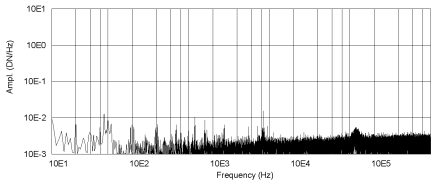
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.20.32.204Z_ID10_0000000371_F1.dlr
Wed Dec 12 19:20:32 2007
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 276.577DN; RMS= 1.215DN
FFT range (5, 1055)



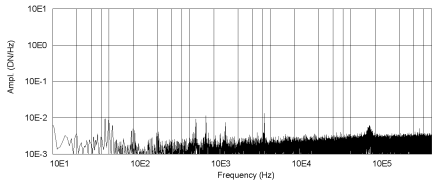
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.21.02.411Z_ID10_0000000373_F1.dlr
Wed Dec 12 19:21:02 2007
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 276.388DN; RMS= 1.223DN
FFT range (5, 1055)



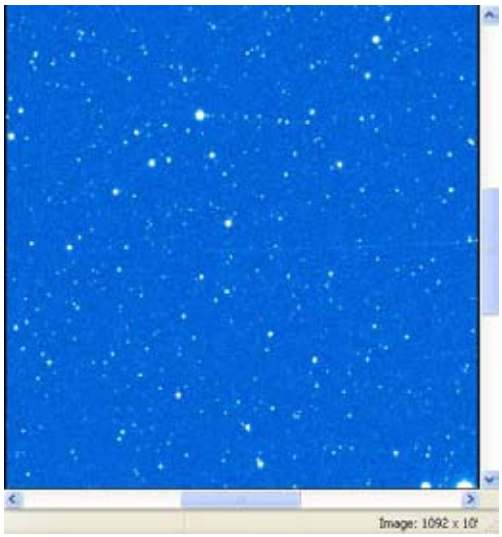
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.21.17.211Z_ID10_0000000374_F1.dlr
Wed Dec 12 19:21:17 2007
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 276.467DN; RMS= 1.224DN
FFT range (5, 1055)

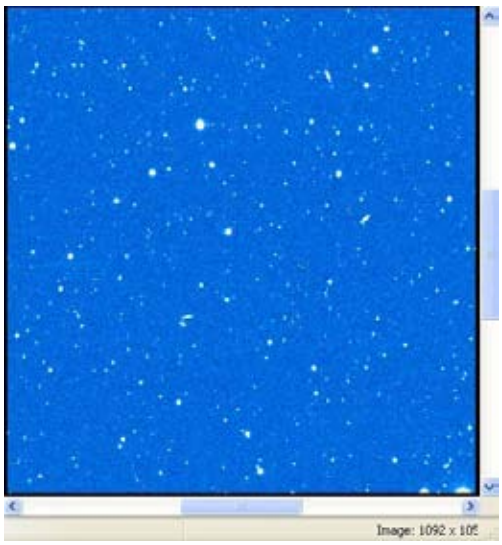


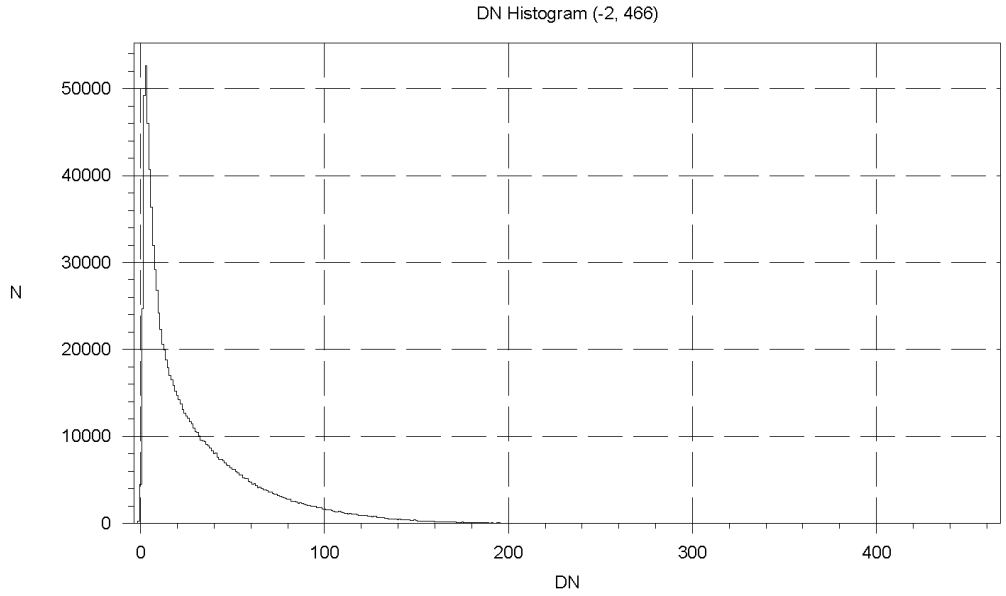
F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.21.32.415Z_ID10_0000000375_F1.dlr
Wed Dec 12 19:21:32 2007
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 276.404DN; RMS= 1.228DN
FFT range (5, 1055)



F:\FC1 ICO calibration\dlr\FC1_2007-12-12T19.21.47.417Z_ID10_0000000376_F1.dlr
Wed Dec 12 19:21:47 2007
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 276.475DN; RMS= 1.226DN
FFT range (5, 1055)







F:\FC1 ICO calibration\dlr\ren\DESM.TRI

Mon Dec 10 18:04:39 2007

9.3 FC1 Performance test report

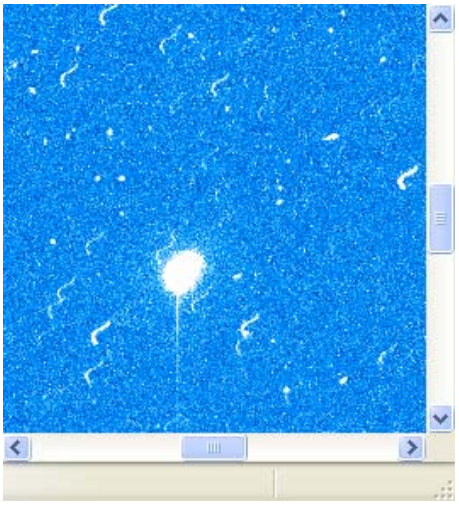
This is a brief summary of the activities conducted on Feb 21st 2008 (2008-52)
Pass started right on time at 1400Z. Connection was established with both DawnEgseSrv in Lindau and Dawn-QM-Egse at DSC

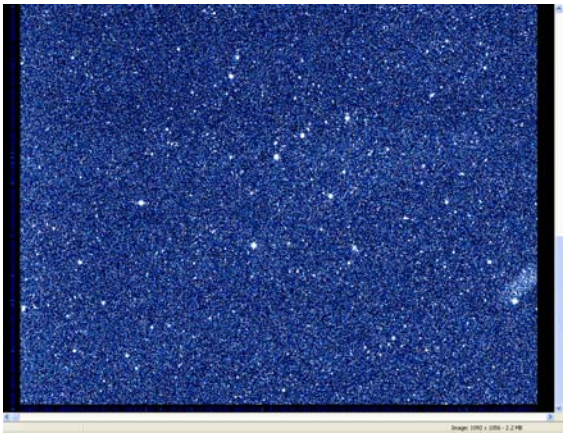
1420Z Power on . Boot sequence was nominal. VR8 packet counter before the operation of the camera is 667065 VCDUs
1427Z FEE swtich on, MCU status 10, Door encoder 35 (Closed), Filter encoder 36 (1)
Voltages and currents
30.60
0.60
16.24
31.94
12.10
64.28
5.20
269.50
-5.08
-74.80
5.29
1211.00
3.37
229.80
2.53
763.80
-5.21
-28.27
Temperatures
-59.66
9.72
5.74
7.49
7.75
-21.89
-22.89
-23.89
-21.90
-22.89
-76.75

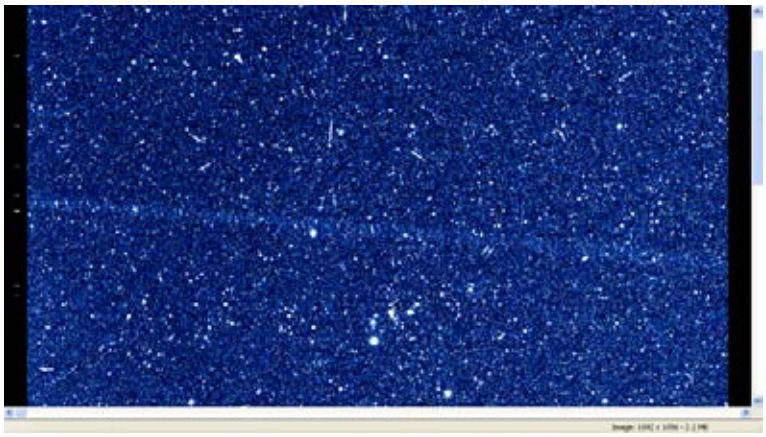
1438Z DSC reports that Epoxy spacecraft has gone into safe during the night and the Epoxy team asks if it is possible to avoid commanding in the next two hours.
The fact is that there is no commanding scheduled and if the need should come to send a contingency sequence, we are still free to do so. They will not take the tracking pass from us.
1448Z 25 min after power on, the i/f temperature has rised from 1 to 5 C.
CCD Temperature (PT2000) as rised from -62 to -57.
Thermal control is catching up from a minimum temperature of approx -24 C
1523Z 1 hour after power on, the i/f temperature is 8.2 C.
CCD Temperature (PT2000) is -54.1 C. We read -51.90 C
Thermal control is stabilizing around 42%
1530Z The stabilization period has completed with 21 images (as opposed to the 20 displayed in the control file).
The standard set of reference images are being acquired.
1555Z The set of dark images has completed with 42 commands and 40 images. Cal Lamp is enabled and ready for the cal lamp phase.
1615Z Cal lamp set completed with 34 images (as opposed to the 35 displayed in the control file). The counters show 98 commands and 74 images.
Playback started at 1616Z
1640Z All images transmitted to VR8. VCDU counter shows 774202
1646Z Back in RT124K. 48 image were transmitted. Starting Door opening sequence.
1650Z Door opened successfully (Encoder 14).
1905Z Engineering data playback has completed. The images in all filters and long exposures have completed nominally. The command and image counters show 130 and 97. CCD temperature is back to -52.5 C, i/f temperature down to 8.3 C.
With an open door, thermal control stabilizes around 15 % on the CH, 40% on the Baffle
1925Z Second playback round provided 25 more images for a total of 73. Image 481, that did not complete in the first playback session came corrupted. This is in line with past experience from FC2 Performance, where the images that were interrupted never recovered.
1930Z Turn to Vega started.
2225Z Telemetry re-established. Camera reports 343 commands and 214 images acquired in total. This is in line with the expected transmission of 213 commands and the acquisition of 117 images. CCD temperature (PT2000) is -52.5 C and i/f temperature 9.8 C. The camera reads -50.50 C
2237Z Door closed nominally for an encoder value of 35. The filter wheel is back in clear filter at encoder 36.
2258Z The final darks were acquired for a total of 220 images.
2303Z FEE was switched off nominally
2308Z Camera was switched off nominally and the CCD non-op heaters stayed off. CH heaters are initially off but are expected to kick in as soon as the CH cools below -22.
2313Z FC Team gave GO for upload of the Calibration sequence. 1st bit radiation time was 23:08:28
2315Z Playback of VR3 showed no errors and just a warning about the door being already closed during the FCPrepPowerDown.
2324Z Playback of VR7 completed and science data started to come
2338Z The temperature of the CH has stopped falling, probably because of the non-op heaters (the low datarate does not allow to confirm that the heaters are really cycled).
2358Z Playback completed. 219 images have been retrieved. Image 529, the last in VR10, is missing. Probably we should be able to recreate them from the DSC files.

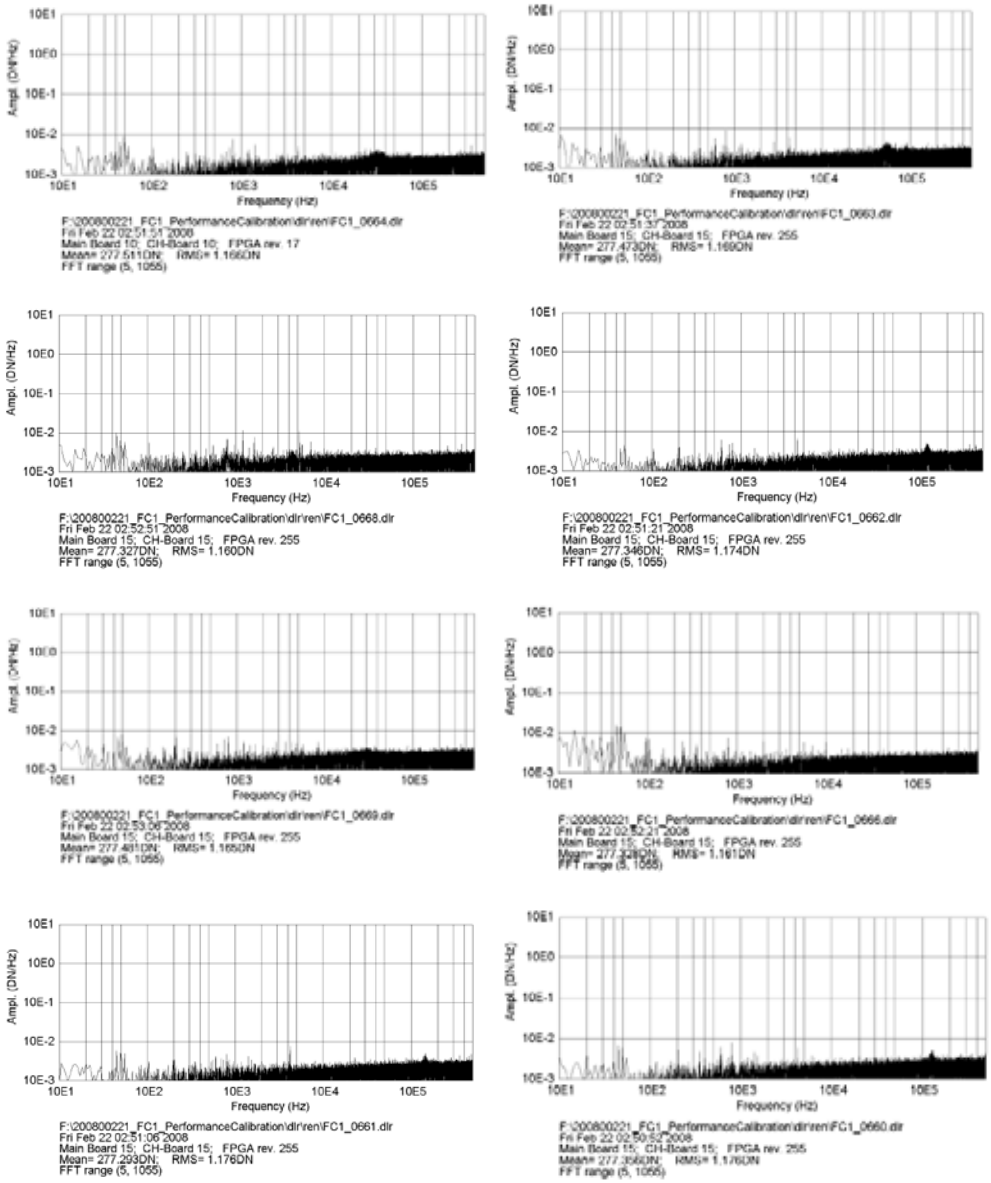
DOY 053
0010Z The activity of the CH non-op heaters is confirmed. Temperatures 1 hour after power down are -61.1 C on the CCD, 4.5 on the i/f.
0133Z DSC generated the TM files from TDS and both APID 74 and 76 showed no gaps, but TRAP still report corruption of image 481 (the one that was paused during continuous playback) and the missing of the end of 529 (from VR10)
Flight has requested and obtained approval to radiate the commands to replay dataset 1 on VRs 8 and 10 in an attempt to retrieve the missing data.
This replay was completed at 0142Z
0223Z FC1 is powered up for Calibration
0246Z Tracking pass is ended
0249Z VCDU counter on VR8 is 807026, on VR10 is 52552

After some workaround we were able to find the missing packets of image 529 and complete the image. Still image 481 found no missing packet, just a corruption at some point, but we have not been able to determine where it happened.









9.4 FC1 Calibration test report

2008-053T18:12Z

Pass has started, connection to EGSEs at DSC and in Lindau is successfully reestablished.
FC1 and FC2 status is as expected: both cameras are off and ready for long-term cruise (CCD heaters warm and under S/C control, CH cold and under S/C control).
Duty cycle on the non-op heaters is approximately 50 % for the CCD and less than 10 % for the CH on both cameras.
Baseplate temperatures are 1.8 C for FC1 and 0.7 C for FC2.

Event playback showed no errors and just the usual warning about the door being already closed.
The camera reports having acquired 190 images with no errors.
It reports two (2) door operations (opening and closing) and 56 filter moves with no errors.

On a preliminary evaluation of the images, the effect of extra charge can be seen with bare eyes.

The playback completed with 190 images, 222 commands, 17165 HK packets and 2500 events

Side track: FC1 Performance investigation

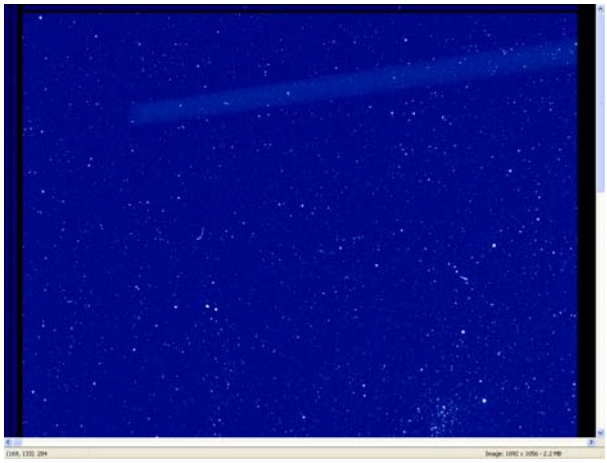
The second file delivered by DSC contained image 528, not 529. The fact that it is the beginning of an image triggered the saving of image 529 when this file was processed after the original file, but none of them contained the final two (2) packets of image 529

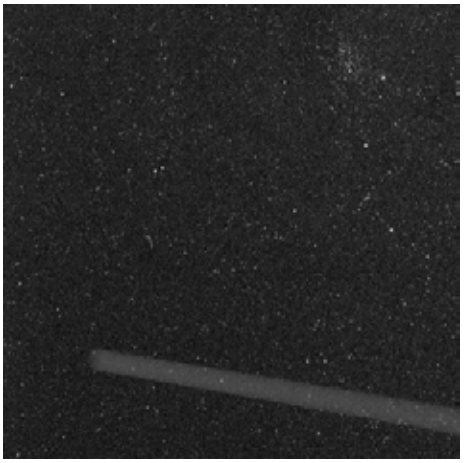
In the investigation of image 481:
The last packet received in the first phase of playback was 7976, with SCLK 256881709:082 (256881709 seconds and 1377296384 fractions). This packet included ULONGs [5270, 5521) of the image.
The first packet after resuming the playback was 7977, with SCLK 256881709:087 (256881709 seconds 1464152064 fractions). This packet included ULONGs [5521, 5772) of the image.
The attached file FC11A0000481_08052155318F5A.raw is the image as it was received on ground (prior to decompression). A row of zeros can be seen in the middle of compressed data starting at byte 22738 (ULONG 5684) until byte 23088 (ULONG 5772).
The conclusion is that the header of the packet and the beginning of the data of packet 7977 was transmitted correctly but not the end of the packet.

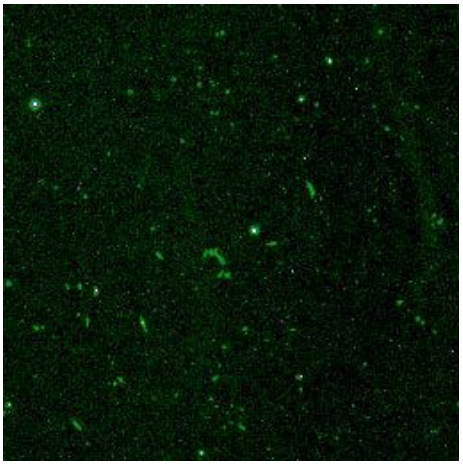
In the investigation of image 487:
The last packet received in the first phase of playback was 14710, with SCLK 256882245:031 (256882245 seconds and 515145728 fractions). This packet included ULONGs [181723, 181974) of the image.
The first packet after resuming the playback was 14711, with SCLK 256882245:036 (256882245 seconds 600985600 fractions). This packet included ULONGs [181974, 182225) of the image.
The attached file FC11A0000487_08052155627F5A.raw is the image as it was received on ground (prior to decompression). A row of zeros can be seen in the middle of compressed data starting at byte 728708 (ULONG 182177) until byte 728900 (ULONG 182225).
The conclusion is that the header of the packet and the beginning of the data of packet 14711 was transmitted correctly but not the end of the packet. Because of the late appearance of the error in the file, the relevance is small and escaped visual inspection, but a more detailed analysis shows a relevant difference with neighboring images.

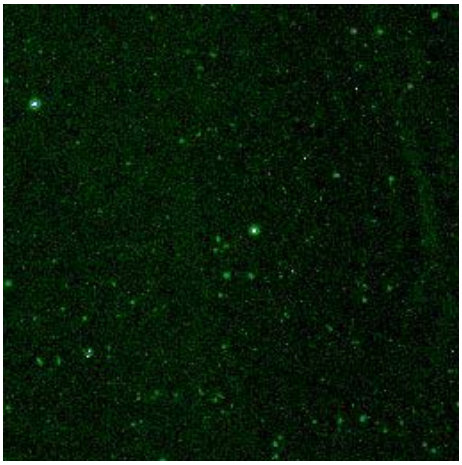
In the investigation of FC2 image 408:
The last packet received in the first phase of playback was 8034, with SCLK 250006541:036 (250006541 seconds and 599293952 fractions). This packet included ULONGs [18824, 19075) of the image.
The first packet after resuming the playback was 8035, with SCLK 250006541:041 (250006541 seconds 686100480 fractions). This packet included ULONGs [19075, 19326) of the image.
The attached file FC21A0000408_07338020630F1A.raw is the image as it was received on ground (prior to decompression). A row of zeros can be seen in the middle of compressed data starting at byte 76722 (ULONG 19180) until byte 77304 (ULONG 19326).
The conclusion is that the header of the packet and the beginning of the data of packet 8035 was transmitted correctly but not the end of the packet.

Image 408 shows a second segment of missing data:
The last packet received in the second phase of playback was 8070, with SCLK 250006542:246 (250006542 seconds and 4122198016 fractions). This packet included ULONGs [27860, 28111) of the image.
The first packet after resuming the playback was 8071, with SCLK 250006543:031 (250006543 seconds 513327104 fractions). This packet included ULONGs [28111, 28362) of the image.
The attached file FC21A0000408_07338020630F1A.raw is the image as it was received on ground (prior to decompression). A row of zeros can be seen in the middle of compressed data starting at byte 112458 (ULONG 28114) until byte 113448 (ULONG 28362).

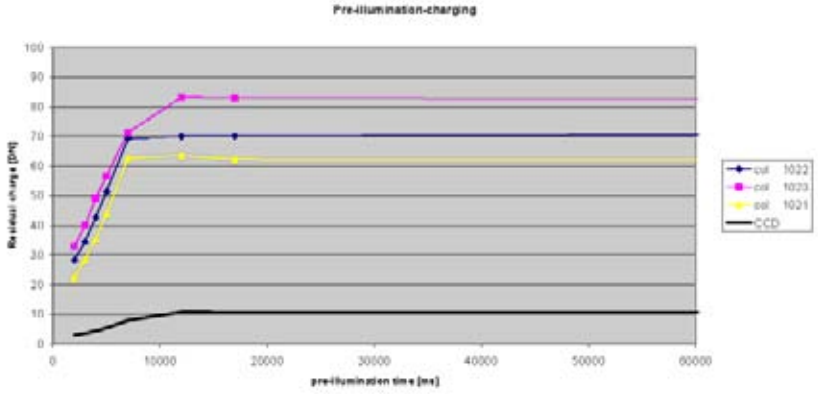




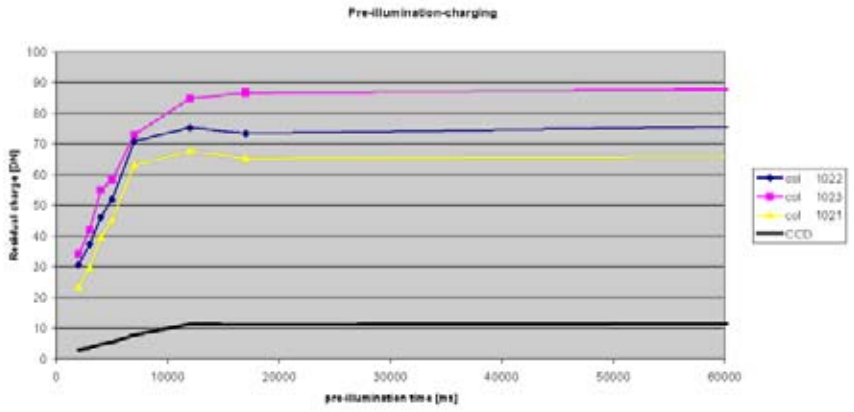


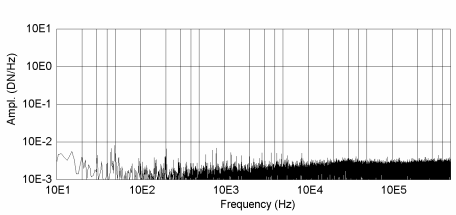


CallampOn t1 [ms]	CallampOff t2 [s]	CallampOn t3 [ms]	CallampOff t4 [ms]	col 1022 [DN]	col 1023 [DN]	col 1021 [DN]	CCD [DN]	pause time [ms]
0	0	0	> 193	28.3444	32.9032	22.4716	2.88537	2000
-1000	0	0	> 193	34.4624	39.9812	28.3645	3.53477	3000
-2000	0	0	> 193	42.7214	49.0824	35.4101	4.32477	4000
-3000	0	0	> 193	51.487	58.5047	43.9301	5.27627	5000
-5000	0	0	> 193	69.3171	75.301	62.6684	7.97986	7000
-10000	0	0	> 193	70.1108	83.3204	63.6255	10.715	12000
-15000	0	0	> 193	70.1859	83.0855	62.2344	10.6886	17000
-50000	0	0	> 193	70.7295	82.7995	62.0618	10.6278	52000

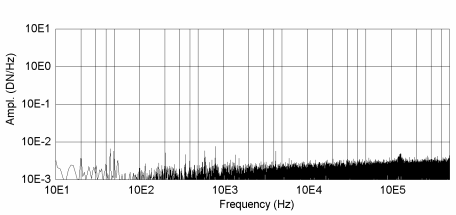


CalampOn t1 [ms]	CalampOff t2 [s]	CalampOn t3 [ms]	CalampOff t4 [ms]	col 1022 [DN]	col 1023 [DN]	col 1021 [DN]	CCD [DN]	pause time [ms]
0	0	0	> 100	30.7246	34.1111	23.601	3.02097	**2000**
-1000	0	0	> 100	37.4275	42.0918	29.7282	3.71174	**3000**
-2000	0	0	> 100	46.3051	55.1212	39.6519	4.84105	**4000**
-3000	0	0	> 100	62.0156	68.3106	45.3341	5.40396	**5000**
-5000	0	0	> 100	71.0295	73.0066	63.1701	7.91024	**7000**
-10000	0	0	> 100	75.4295	84.954	67.8795	11.4545	**12000**
-15000	0	0	> 100	73.5192	86.8167	65.4103	11.3684	**17000**
-60000	0	0	> 100	75.811	87.9663	66.1119	11.489	**62000**

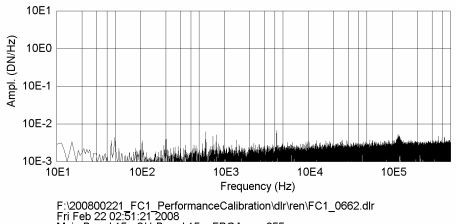




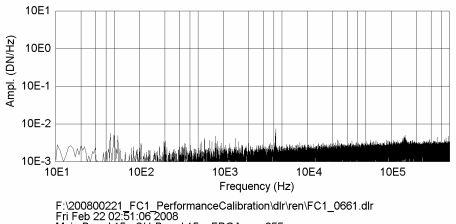
F:\200800221_FC1_PerformanceCalibration\dlr\ren\FC1_0669.dlr
Fri Feb 22 02:53:06 2008
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 277.481DN; RMS= 1.165DN
FFT range (5, 1055)



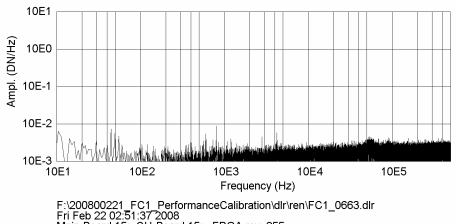
F:\200800221_FC1_PerformanceCalibration\dlr\ren\FC1_0660.dlr
Fri Feb 22 02:50:52 2008
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 277.356DN; RMS= 1.176DN
FFT range (5, 1055)



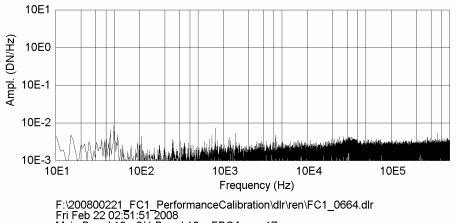
F:\200800221_FC1_PerformanceCalibration\dlr\ren\FC1_0662.dlr
Fri Feb 22 02:51:21 2008
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 277.346DN; RMS= 1.174DN
FFT range (5, 1055)



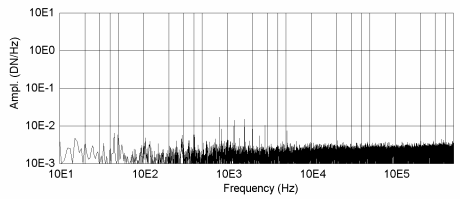
F:\200800221_FC1_PerformanceCalibration\dlr\ren\FC1_0661.dlr
Fri Feb 22 02:51:06 2008
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 277.293DN; RMS= 1.176DN
FFT range (5, 1055)

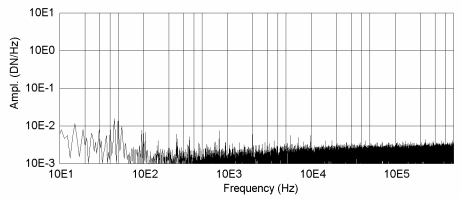


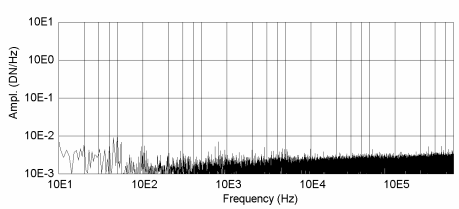
F:\200800221_FC1_PerformanceCalibration\dlr\ren\FC1_0663.dlr
Fri Feb 22 02:51:37 2008
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 277.473DN; RMS= 1.169DN
FFT range (5, 1055)

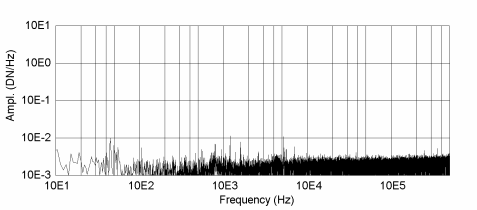


F:\200800221_FC1_PerformanceCalibration\dlr\ren\FC1_0664.dlr
Fri Feb 22 02:51:51 2008
Main Board 10; CH-Board 10; FPGA rev. 17
Mean= 277.511DN; RMS= 1.166DN
FFT range (5, 1055)









9.5 *FC2 Functional test report*

Dawn FC2 ICO block 1 (functional checkout); DSC/UCLA

18 Oct 2007 (HU Keller, H Sierks, P Gutierrez, M Richards, T Maue, S Mottola)

- ccd temp reached steady state at -66.8C/-66.5C with camera head at -21.7/-21.2C, pt2000 final calibration tunes not applied yet.
  (FC2-CCD-A: subtract 2.6 degC, FC2-CCD-B: subtract 2.6 degC, FC2-CH-A: subtract 2.8 degC, FC2-CH-B: subtract 2.2 degC)
  so real temperatures are closer to -69.4C with camera head at -24.5C compared to s/c tvac -61C at ch -19C, so ccd is ~3C colder in space wrt tvac
- PG implemented egse change to omit old packets which will enable us to see realtime events during playback; it cleans up s/c hk plots in playback
- updated fc egse and hk egse on these mods
- reported at the status mtg the ccd temp drop went fine, ~3deg colder than tvac, and calibration tune not in yet
- filter table will be jammed during playback as requested allowing all events coming down in playback (actions done last night by carol and team)

09:12 voca check (all times to follow are dsc local time/pdt)
09:20 checked space weather on noaa, sun is quiet, no solar event nor cme
09:22 red-line procedure walk thru done
09:29 all systems are go to proceed with fc2 functional test
09:34 4h life boat sent (ends 13:04 with 30min margin)
09:36 fc2 power on radiated
09:48 power on ok, memory check running, ch temperature drops as thermal control demon is not yet up and running
09:52 mass mem check ok, mcu turned on, hk & temps ok, power on htr test ok
09:56 all hk fine :-)
09:58 radiated extended heater test cmd
10:00 thermal control stopped, ch htr turned on for 5min
10:05 ch htr turned off, ok
10:06 table patch sent and verified: 125 steps to open door (flight config)
10:07 turned baffle htr on for 5min
10:12 ok, htr tests went fine
10:14 sent fee switch on, all hk fine, ok
10:22 sent cmd acquistion of 'ten basics'
10:30 egse detected 1 limit violation on fee +5v current, o/b hkmonitor did not detect this event, could be remnant of fee power up, checking..
-> verified by egse playback, ok as linked to fee power up
10:43 first test pattern streaming down, ok
10:49 all 10 images down and look fine, checking, see cosmics, images are ok; 1 of 2 serial images shows 3 minor peaks at frequencies 603, 800, 4198 Hz (reference for interference tests)
11:11 back to cmding after station handover
11:13 radiated cal lamp imaging sequence
11:21 images taken, processed and downloaded to the vr
11:24 radiated p/b cmd to download image data
11:31 images are fine so far, cal lamps are operative, ccd sensitive, optics transmissive, door still close :-)
11:36 last 2 cal lamp images appear slightly different in exposure while all settings were identical, checking. -> verified ok, was seen in ground test before
11:40 radiated heat pulse sequence
11:44 received alarm on 5V current as heater check does not turn off thermal control, ok as this test sequence is only used this very first time to checkout the flight hardware post launch.

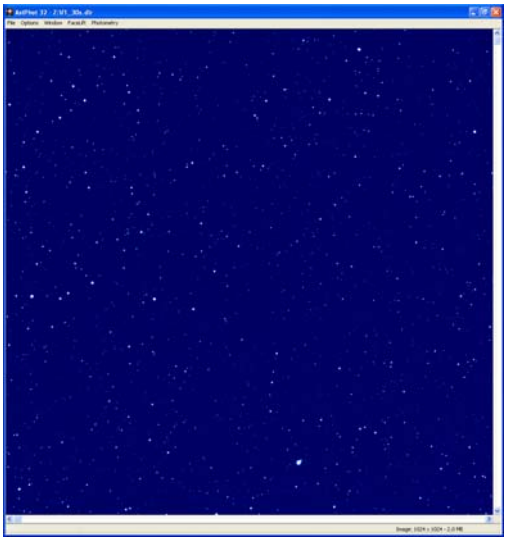
11:50 radiated filter hardware init cmd, executing, residual steps 0, so no change compared to pre launch configuration, F1 encoder is 62/1
11:55 filter wheel rotated to pos 2, ok, enc 55/2; cal lamp para changed, ok
11:58 2 full frames in F2, move to F3, ok, enc 46/3
12:00 2 full frames in F3, move to F4, ok, enc 39/4
12:03 2 full frames in F4, move to F5, ok, enc 30/5
12:05 2 full frames in F5, move to F6, ok, enc 23/6
12:08 2 full frames in F6, move to F7, ok, enc 14/7
12:11 2 full frames in F7, move to F8, ok, enc 7/8
12:14 2 full frames in F8, move back to F1, ok, enc 62/1
12:18 cancelled life boat sequence
12:20 4h life boat sent (ends 15:50 with 30min margin)
12:24 start playback of image data in vr8
12:40 all images are down, 0 gaps, analyzing images..
12:41 radiated back to realtime
12:43 radiated sequence to acquire dark images (2x 1sec,300sec,30sec)
12:57 6 darks acquired, streaming out, done
12:59 checked temperatures and hk prior to door opening, ok; door enc jitters between 9 and 10, decoded 'closed'
13:02 radiated door open sequence
13:04 door is open.
13:05 radiated 3 full frames in F1, goto F8, enc @ end of sequence: 7/8
13:10 checked ccd temperature: reached steady state at approx -52C compared to -48C in TVac, thus get ccd ~4C colder in space wrt tvac
13:16 radiated 3 full frames in F8, goto F7, enc @ end of sequence: 14/7
13:20 checked temperature effect of open door, see baffle temp drop and hot motor from door opening
13:30 radiated 3 full frames in F7, goto F6, enc @ end of sequence: 23/6
13:44 radiated 3 full frames in F6, goto F5, enc @ end of sequence: 30/5
13:53 temperature snap shot: radiator -69.8C, cold stack -54.6C (pt2000 corrected), CCD -53.0C; baseplate is at 6.8C comp to ~13C in TVac
13:58 radiated 3 full frames in F5, goto F4, enc @ end of sequence: 39/4
14:12 radiated 3 full frames in F4, goto F3, enc @ end of sequence: 46/3
14:26 radiated 3 full frames in F3, goto F2, enc @ end of sequence: 55/2
14:40 radiated cancel life boat sequence
14:42 4h life boat sent (ends 18:12 with 30min margin)
15:00 stefano checked ccd bias and found it consistent with ground tests
15:08 temperature snap shot: radiator -69.8C, cold stack -56.2C (pt2000 corrected), CCD -53.9C; baseplate is at 7.0C comp to ~13C in TVac
15:26 resumed cmd capability after station handover
15:28 radiated 3 full frames in F2, goto F1, enc @ end of sequence: 62/1
15:44 radiated 'random' filter access f1, f4, f7, f1, 2x, 1sec, 30sec, ok
15:52 radiated close door cmd, enc changed from 53/open to 9-10/closed
15:55 radiated acquisition of darks, running, done, ok
16:09 radiated door init, executed (mcu pwr busy), ok
16:12 radiated fee pwr off and check hk, done, taking hk snap shot
16:19 ready for preppowerdown, radiated, done and fine, checked parameter hardware and life time table dumps and ok
16:25 power down fc2, ok
16:29 ccd temp going up by ccd non-op htr, ch htr enabled, thermal handover done successfully
16:38 filter table patch sent and verified
16:42 cancelled life boat sequence
16:45 ready for playback, radiated, awaiting first light images
17:30 all images downloaded, analyzing..
18:30 all temperatures back to cruise, non-op heaters are operating

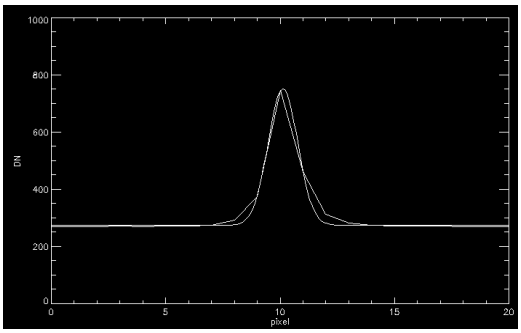
Conclusions:
The FC2 was turned on and run for more than 7 hours in commissioning block 1 (functional checkout). It acquired 102 images, 11967 hk frames, and 11654 events. All radiated sequences ran nominally. All FC subsystems were found alive and unaltered by the launch event. The electronics performed nominally, the CCD and optics performed nominally. Filter wheel mechanism checkout cw and ccw and multiple filter change test were ok, front door operation was nominal, a door init was run to leave the unit in nominal state.
Two housekeeping alarms were noted: one was identified as artefact of FEE switch on, when FEE ON was reported, but a subset of related hk not updated yet, thus misleadingly sending an out-of-limit. The 2nd out-of-limit was real, the motor pulse check to verify the filter and door motor windings are present, was run on top of thermal control, thus heaters and motors run simultaneously during this test when TC turned on the camera head heater. This occurred once triggering yellow alarm, which is well within the unit capability.
The image data was quicklook analysed, find samples attached. Optical performance shows high sensitivity and good star psf (sigma 0.64px for star Asellus Borealis), the unit is well in focus. Deeper analysis is to come. Congratulations to the Dawn JPL flight team and the DSC team making this test a success.
H Sierks for the FC Team, 18 Oct 2007

Attachments:
(1) pdf-file of expected star field
(2) bitmap of star field as seen by FC2 in clear filter, 30sec exposure (mirrored wrt catalog star field)
(3) black stars on white ground representation
(4) sample PSF of one star to demonstrate optical performance
(5) housekeeping logs in pdf format

star: Asselus Borealis
mag = 4.6
exp_time = 3 s
max DN = 745

Gaussfit:
sigma_x = 0.643697
sigma_y = 0.654397




1000
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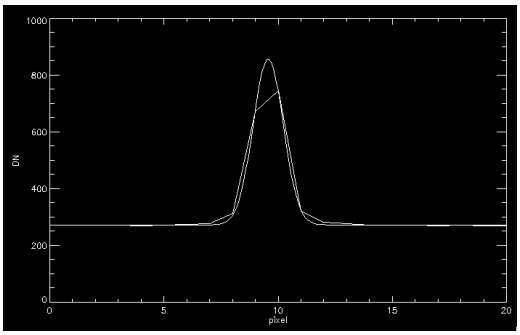
200
0
DN
0
5
10
15
20
pixel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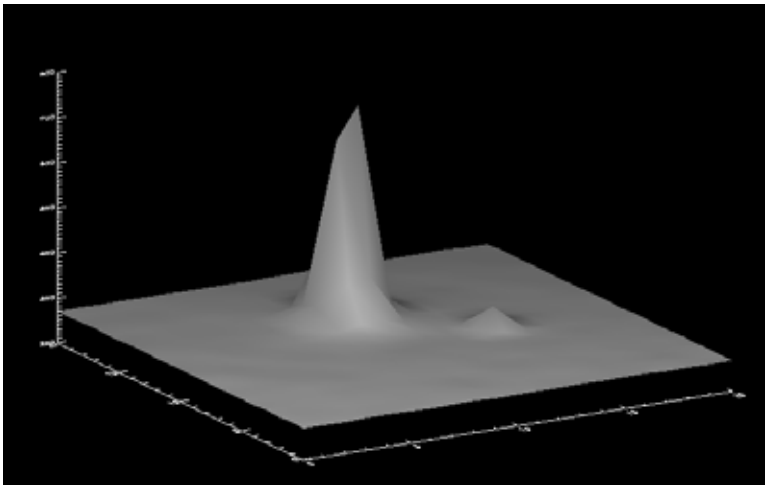
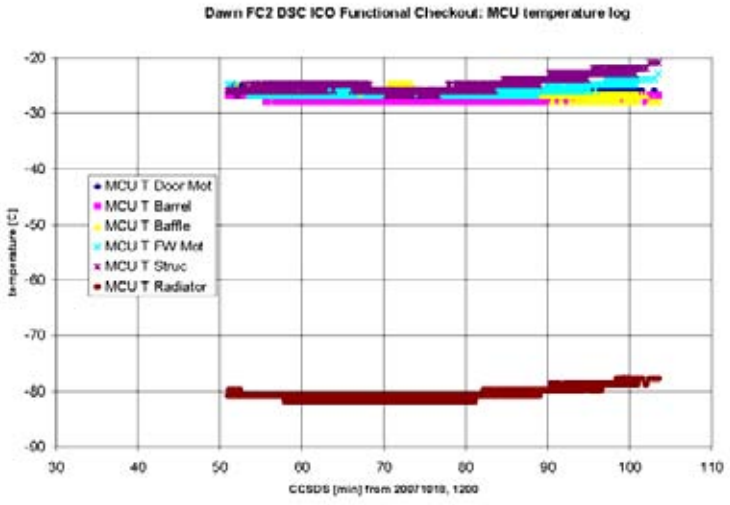


Dawn FC2 DSC ICO Functional Checkout
Housekeeping Summary

HK data from first hour of ICO FC2 Functional Checkout was ripped and plotted. Preliminary statistics – averages, range, standard deviation – of voltage, current and temperature parameters were produced for the entire interval or a part of the interval (see Count). The following table is a summary of these statistics.

Table 1 Statistics of HK currents, voltages and temperatures, Count the number of time samples

HK Parameter	Units	Maximum	Average	Minimum	Standard Deviation	Count
PCU +28V SC	V	31.00	30.56	30.20	0.225	1581
PCU +28I SC	A	0.84	0.63	0.32	0.161	1581
PCU +15V FEE	V	16.24	16.24	16.15	0.009	764
PCU +15I FEE	mA	60.34	36.52	33.57	2.393	764
PCU +12V FEE	V	12.15	12.14	12.09	0.004	764
PCU +12I FEE	mA	81.88	63.44	62.52	1.115	764
PCU +5V FEE	V	5.20	5.19	5.17	0.002	764
PCU +5I FEE	mA	303.70	271.41	269.95	3.355	763
PCU -5V FEE	V	-5.04	-5.08	-5.08	0.004	763
PCU -5I FEE	mA	-75.21	-75.56	-90.14	1.591	763
PCU +5V ANA	V	5.30	5.25	5.22	0.021	1581
PCU +5I ANA	mA	1355.40	1005.22	113.00	363.739	1581
PCU +3.3V DPU	V	3.33	3.32	3.30	0.004	1581
PCU +3.3I DPU	mA	398.70	241.00	226.95	28.604	1581
PCU +2.5V DPU	V	2.50	2.49	2.47	0.006	1581
PCU +2.5I DPU	mA	906.60	719.53	567.15	75.331	1581
PCU -5V ANA	V	-5.16	-5.17	-5.19	0.005	1581
PCU -5I ANA	mA	-18.44	-26.84	-28.05	1.416	1581
PCU Temp CCD	C	-59.09	-64.20	-66.62	2.391	1581
PCU Temp DPU	C	19.54	13.87	-3.59	3.830	1581
PCU Temp DCDC	C	10.07	4.97	-2.95	3.037	1581
PCU Temp Pos1	C	14.50	8.11	-2.77	4.267	1581
PCU Temp Pos2	C	14.84	8.99	-3.02	3.623	1581
MCU T Door Mot	C	-24.87	-26.22	-26.86	0.484	1506
MCU T Barrel	C	-25.86	-27.46	-27.86	0.520	1506
MCU T Baffle	C	-24.87	-26.44	-27.86	0.602	1506
MCU T FW Mot	C	-22.87	-25.96	-26.86	0.778	1506
MCU T Struc	C	-20.88	-24.80	-26.86	1.276	1506
MCU T Radiator	C	-77.74	-80.39	-81.73	0.930	1506



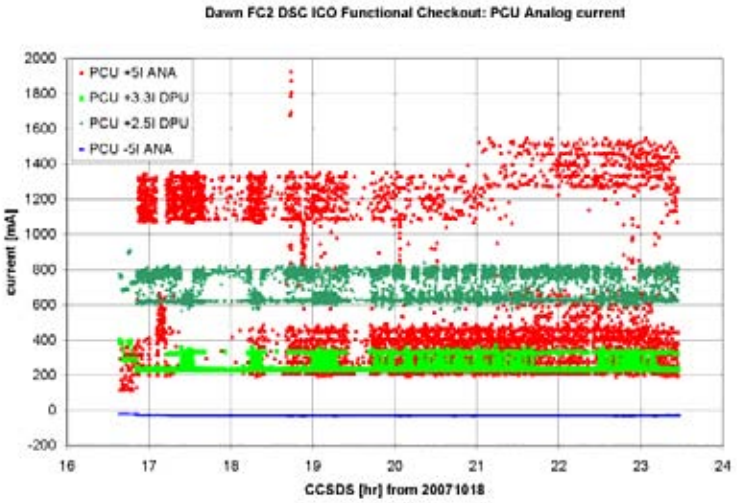
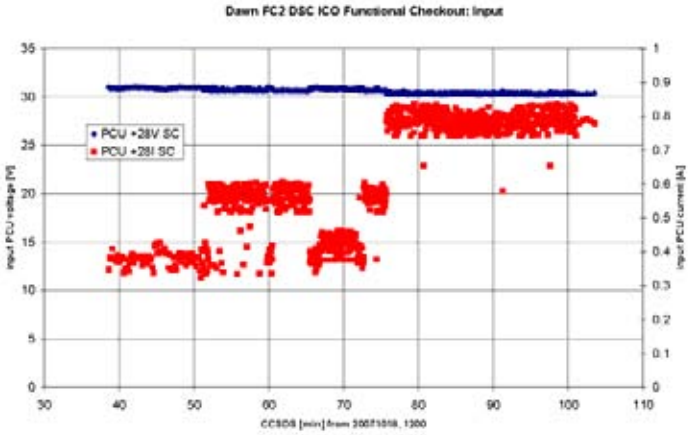


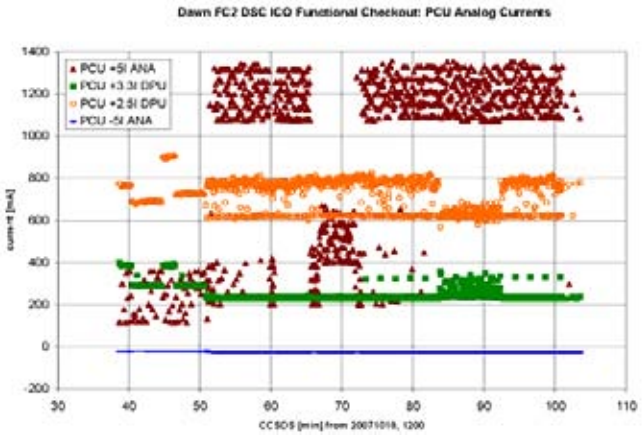
Table 2 Statistics of HK currents, voltages and temperatures during TVAC

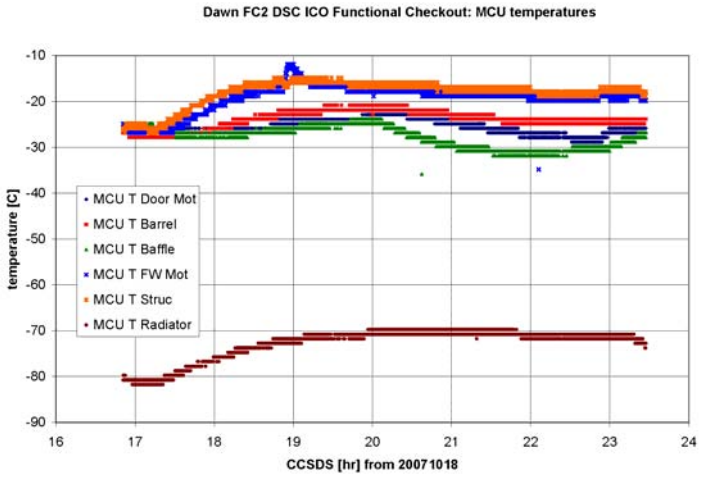
HK Parameter	Units	Maximum	Average	Minimum	Standard Deviation	Count
PCU +28V SC	V	31.44	30.96	30.52	0.194	7665
PCU +28I SC	A	0.84	0.60	0.32	0.127	7665
PCU +15V FEE	V	16.24	16.13	16.06	0.043	4955
PCU +15I FEE	mA	60.02	34.55	32.99	1.493	4955
PCU +12V FEE	V	12.14	12.12	12.06	0.008	4955
PCU +12I FEE	mA	81.92	63.97	62.70	0.648	4955
PCU +5V FEE	V	5.19	5.18	5.16	0.003	4955
PCU +5I FEE	mA	302.05	269.66	268.45	1.867	4955
PCU -5V FEE	V	-5.04	-5.08	-5.08	0.002	4955
PCU -5I FEE	mA	-74.78	-75.06	-89.55	0.650	4955
PCU +5V ANA	V	5.30	5.26	5.22	0.025	7665
PCU +5I ANA	mA	1354.20	678.13	132.40	426.816	7665
PCU +3.3V DPU	V	3.35	3.34	3.32	0.009	7665
PCU +3.3I DPU	mA	344.10	234.15	226.80	17.774	7665
PCU +2.5V DPU	V	2.52	2.50	2.48	0.008	7665
PCU +2.5I DPU	mA	860.70	761.08	569.85	73.174	7665
PCU -5V ANA	V	-5.14	-5.16	-5.19	0.007	7665
PCU -5I ANA	mA	-19.64	-27.15	-30.03	0.578	7665
PCU Temp CCD	C	-47.64	-54.47	-61.55	4.786	7665
PCU Temp DPU	C	35.99	23.88	5.03	7.156	7665
PCU Temp DCDC	C	24.58	16.82	5.03	5.241	7665
PCU Temp Pos1	C	28.42	20.29	5.77	6.087	7665
PCU Temp Pos2	C	28.72	20.97	5.41	5.696	7665
MCU T Door Mot	C	-23.87	-25.31	-26.86	0.753	7655
MCU T Barrel	C	-20.88	-24.82	-26.86	1.870	7655
MCU T Baffle	C	-23.87	-26.77	-27.86	0.876	7655
MCU T FW Mot	C	-16.89	-21.00	-24.87	2.738	7655
MCU T Struc	C	-15.89	-19.64	-23.87	2.862	7655
MCU T Radiator	C	-65.77	-71.26	-75.74	3.026	7655

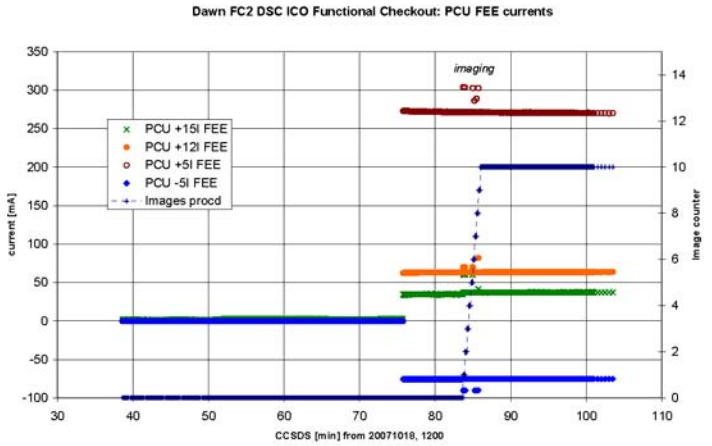
Table 2 provides a comparison to the ICO values of Table 1. These are the comparable statistics for data obtained during Dawn S/C TVAC, 2007-02-05. Differences are significant for currents and temperatures.
Temperatures during TVAC were higher than the ICO temperatures, the Radiator and CCD 10C warmer, the PCU 20C to 23C, the DPU 27C hotter, the CH 6-7C hotter, the Barrel 3C and the Baffle +-1C.
Average 5Vanalog current is significantly larger during ICO. The minimum value is smaller, but this is due to the memory test during the beginning 13 minutes of ICO, a test not run in TVAC.

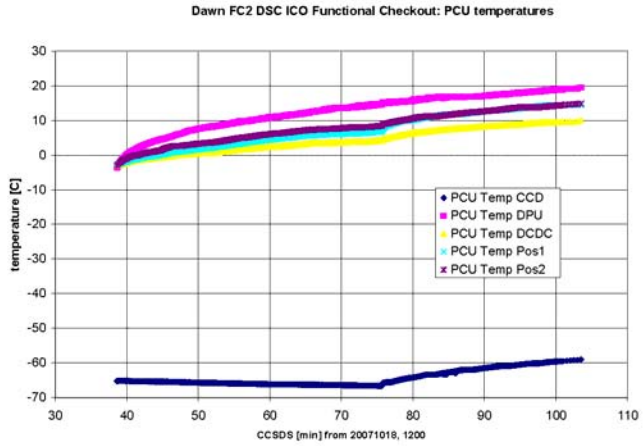
Following are the plots of temperature and currents. Voltages can be seen to vary insignificantly (Fig. 1), so they were not plotted.

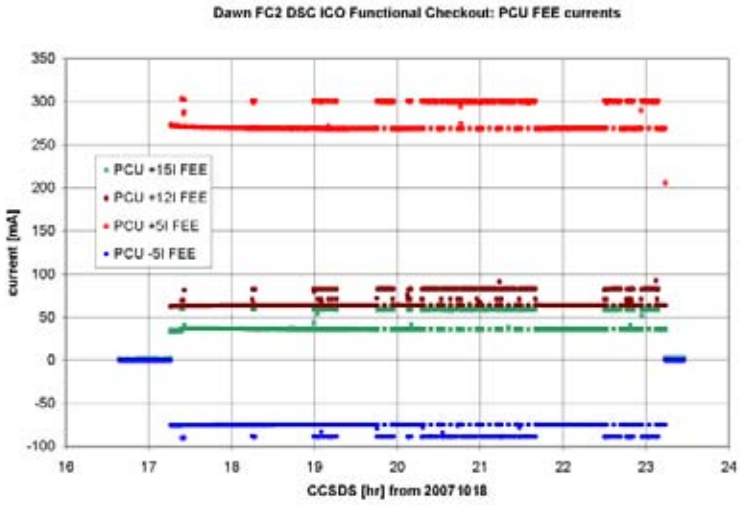

Dawn FC2 DSC ICO Functional Checkout: Input
PCU +28V SC
PCU +28I SC
CCSDS [min] from 20071018, 1200

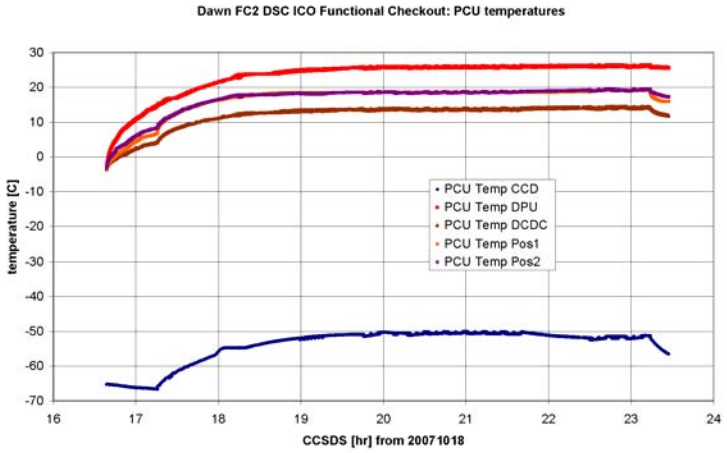

Dawn FC2 DSC ICO Functional Checkout: PCU Analog Currents
PCU +5I ANA
PCU +3.3I DPU
PCU +2.5I DPU
PCU -5I ANA
current [mA]
CCSDS [min] from 20071018, 1200


Dawn FC2 DSC ICO Functional Checkout: MCU temperatures
MCU T Door Mot
MCU T Barrel
MCU T Baffle
MCU T FW Mot
MCU T Struc
MCU T Radiator
temperature [C]
CCSDS [hr] from 20071018


Dawn FC2 DSC ICO Functional Checkout: PCU FEE currents
imaging
PCU +15I FEE
PCU +12I FEE
PCU +5I FEE
PCU -5I FEE
Images procd
current [mA]
image counter
CCSDS [min] from 20071018, 1200


Dawn FC2 DSC ICO Functional Checkout: PCU temperatures
PCU Temp CCD
PCU Temp DPU
PCU Temp DCDC
PCU Temp Pos1
PCU Temp Pos2
temperature [C]
CCSDS [min] from 20071018, 1200


Dawn FC2 DSC ICO Functional Checkout: PCU FEE currents
PCU +15I FEE
PCU +12I FEE
PCU +5I FEE
PCU -5I FEE
current [mA]
CCSDS [hr] from 2007 1018



9.6 FC2 Performance test report

Dawn FC2 ICO Performance Block; DSC/UCLA

03 Dec 2007 (H Sierks, M Aye, S Schroeder, S Mottola at DSC; P Gutierrez, T Maue, M Richards at MPS)

- ccd temperature was found in steady state with rampage readings of -64.8C and camera head at -18.9C at 48% duty cycle; pt2000 final calibration tunes not applied yet. (FC2-CCD-A: subtract 2.6degC, FC2-CCD-B: subtract 2.6degC, FC2-CH-A: subtract 2.8degC, FC2-CH-B: subtract 2.2degC) so real temperatures are closer to -67.4C with camera head at -21.7C; deck temperature is -2.6C with unit off
- all times herein are DSC local time/PDT

15:30 voca check ok
15:44 checked space weather on noaa, sun is quiet, no solar event ongoing
16:02 all systems are go to proceed with FC2 performance test
16:19 light time to s/c is 1min 4sec (= distance of 19.2 Mio km)
16:20 4h life boat sent (ends 19:50 with 30min margin)
16:24 FC2 power on radiated
16:30 camera is on, boot was nominal, CCD at -65.61C, radiator -77.75C, camera head at -22.4C, thermal control catching up at 36% duty cycle and raising
16:36 FEE is on and HK is ok
16:38 table patch for checksum check received and confirmed
16:39 first image acquisition running on thermal stabilization sequence (21 times 30sec darks every 3min for total of 1h)
16:41 CCD is at -62.5C, started at -65.6C, will see where it stabilizes camera head is at -23.39/-24.39C toggling
16:48 thermal control reaches 63% duty cycle at camera head
16:58 note encoder values are #62 for filter wheel (F1), #9/10 for door (closed)
17:05 CCD is at -57.45C, camera head -22.4C, deck i/f 2.3C
17:19 CCD is at -57.33C stabilized, camera head still coming up at -21.4C, duty cycle 59%, 14 images acquired; rampage reads -57.4C CCD temp, thus missing the gradient between CCD carrier/die and cold finger stack
17:41 last image acquired, CCD -56.07, CH -20.4C, radiator -71.7C, I/F 4.2C
17:44 test pattern, storage and serials acquired, running darks..
17:48 camera head is stabilized at -19.4 reading, duty cycle is 43%, CCD -56.0C
18:02 darks are done, running cal lamp sequence, on and ok
18:23 images acquired, starting playback, darks look fine, test pattern ok
18:54 playback stopped, 49 of the 74 acquired images received, analysing..
19:04 desat ongoing and visible on pointing screen
action item: request accuracy of ra dec reading from s/c allowing 0.1 px resolution analysis to compare image data with
19:09 thermal control reached 21% duty cycle at -20C with FEE up and running, thus there is room to dive to lower CCD temperatures but throttling down thermal control, and by lowering deck temp (currently at +6.2C) with unit on, current CCD reading is -53.8C
19:18 desat completed, awaiting sequence to complete
19:35 storage area images analysed and ok, serial images checked and ok showing slight increases at 4 frequencies as seen in functional and ground test (600Hz, 800Hz, 1.4kHz, 4.2kHz)
19:42 life boat cancelled (radiated)
19:45 go to renew the 4h life boat, radiated (ends 23:15 with 30min margin)
19:50 radiated performance part 2, 41k on LGA reduces HK rate to 1 out of 20
20:23 s/c is still slewing to 20Cephei
20:35 turn completed, awaiting settling..
action item: how to get s/c roll angle for data analysis
20:50 acquiring darks prior to door opening
20:52 about to open door.. moving.. open, encoder reading is #53
20:55 temp snap shot: CCD -54.28, radiator -70.77, camera head -20.40, baffle -26.38, rampage CCD -53.6, CH -16.0, I/F 6.6 (all degC)
20:57 first image of 20Cephei acquired

21:10 20Cephei pointing is visible in deck temperature decrease of ~0.2degC which caused the FC E-box temperature decrease at power converter and DPU
21:25 still imaging thru filter wheel, currently at filter 8
21:28 back in filter 1 for deep exposures (600sec, 2x)
21:31 rampage monitor R-3047 is still monitored and in alarm, to be removed as requested as no physical hardware behind -> action item to project
21:38 pointing based on quaternions indicate jitter of 1 to 1.5 px in ra and dec over 10min, should be visible in long exposures if reading is right and representing physical movements of the s/c
21:40 2nd deep exposure started
21:51 deep exposures finished, total of 97 images acquired at this point in time, ready for playback
21:57 not receiving VR10 data as expected, potential residual of s/c safe mode
22:20 decided to continue with part3 and downlink VR10 at end of session
22:35 cancelled life boat
22:40 go to renew the 4h life boat, radiated (ends 02:10 with 30min margin)
22:56 radiating contingency product to deal with VR10 downlink routing
23:01 go to proceed with part 3 of performance sequence, and radiated
23:09 slewing to Vega
23:12 sub frame patches executed successfully
23:22 corrupted 1st image from VR10 received, downloading the 2nd
23:33 2 F8s and 600sec F1 received, analysing.., VR10 downlink halted
23:41 Vega imaging sequence started
23:47 pointing jitter is about 0.1 to 0.2px on the typical imaging time scale of few seconds
23:52 cmd counter at 174, total of 129 images taken so far
23:53 starting slew to corner of field of view

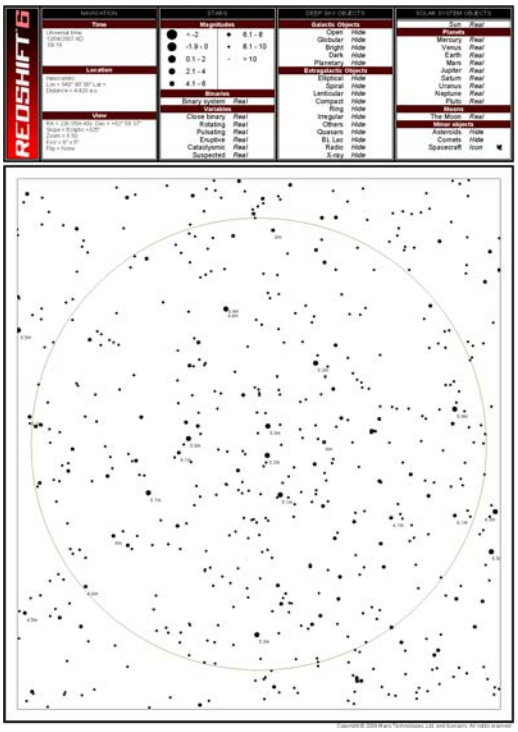
04 Dec 2007
00:05 patching CCD corner sub frames
00:06 imaging corner sub frames while slewing (nicely)
00:14 all images acquired and processed, cmd couner 208, image cnt 145
00:18 patches sent for intermediate sub frames and imaging
00:25 imaging done and processed, cmd counter 242, image cnt 161
00:31 patch done for center sub frame and imaging the 8 (by 2)
00:39 imaging done and processed, cmd counter 270, image cnt 177
00:41 patches sent for intermediate sub frames and imaging
00:51 imaging done and processed, cmd counter 304, image cnt 193
01:05 imaging done on outer frames and processed, cmd counter 338, images 209
01:14 cancelled life boat
01:18 temp snap shot: CCD -53.90, radiator -69.77, camera head -19.40, baffle -28.38, rampage CCD -53.6, CH -15.4, I/F 9.4 (all degC)
01:21 sequence block 5 radiated to close door, take dark, and shut down FC2
01:26 FC2 door is closed, encoder reads 10, closed. FW is at F1, encoder 62.
01:42 6 darks running
01:48 done, total of 215 images acquired. dark processed and shipped to VR
01:50 slewing back to ICO pointing
02:19 FEE off sent and down
02:24 FCPrepPowerDown, saving lifetime to NVRAM, done.
02:26 camera is off.
02:29 CCD non-op heater is on and running temp up as expected.
02:47 playback continues
03:00 VR10 playback completed, 20 images received on VR10 (as expected)
03:30 VR08 playbakc of initial cal lamp images completed
03:42 VR08 playback of Vega sub frames 256x256 done, saw Vega nicely crossing field of view pointing/slew to be checked as not following diagonal track (track rotated) and thus Vesta signature apparently lost in some images
03:45 VR08 final darks down, end of downlink, 215 images saved

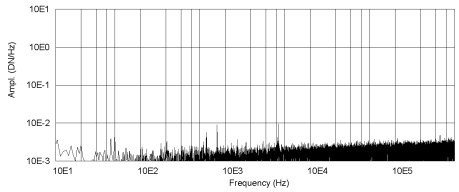
Summary:
The Dawn Framing Camera FC2 was turned on for more than 9 hours for performance checkout. It acquired 215 images, 17845 hk frames, and 18595 events. All radiated sequences ran nominally, the instrument worked fine.
Onboard image transfer checksum check was turned on for this test (FEE to DPU). All images were confirmed Ok in o/b transmission. All images were acquired as full frames; 112 of these were cropped onboard by the DPU to 256x256 size and transmitted as windows (sub frames).
The housekeeping monitor reported no alarms, all HK stayed well in limits. There was an issue with VR10 playback which could be a residual of s/c safe mode recovery (tbc).
The CCD reached steady state at -53C with camera head at -20C and deck at +9.7C, deck still slighly increasing temp. There is good potential to get CCD further down by decrease of camera head and deck temperatures. Thermal analysis by OSC should get initiated.
All FC subsystems were behaving fine as of functional checkout. Thermal and optical performance is excellent. Image data analysis is ongoing, hope we'll be able provide first quicklook results in time to Tuesday's 14:00 debrief.
A few actions/requests for clarifications were identified. The project should tune the CCD and Camera Head non-op readings as they are off by a few degrees.
Congratulations to the Dawn team at JPL, DSC, and home at MPS. This was a smooth test:-) ..and this is exciting.
H Sierks for the FC Team, 4 Dec 2007

attachments:
- this report of activity
- fft analysis of serial images
- first clear filter 20Cephei image b/w and inverted
- star catalogue FC FoV pointing 20Cephei

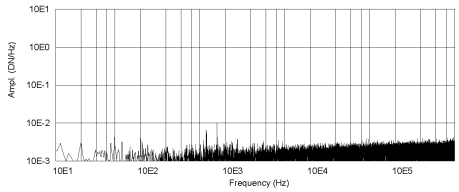
to come in time to debrief (tbc):
- image index file
- housekeeping data plots

- 20Cephei analysis
- Vega plot 256x256 and perhaps first spectrum
- slew assembly of Vega mosaics





F:\fc commissioning 2\dlr\serial\0383.dlr
Sat Dec 03 13:41:30 1977
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 268.481DN; RMS= 1.142DN
FFT range (5, 1055)



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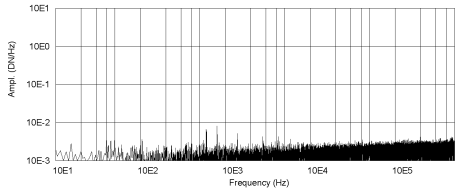
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 268.571DN; RMS= 1.141DN
FFT range (5, 1055)



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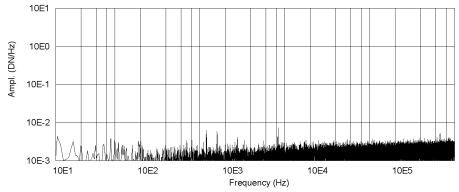
FFT range (5, 1055)



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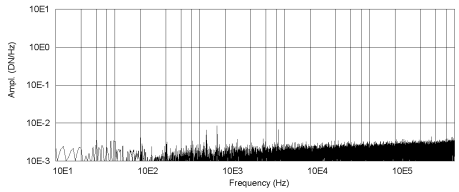
FFT range (5, 1055)



F:\fc commissioning 2\dlr\serial\0387.dlr
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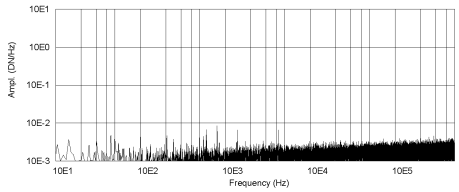
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 268.541DN; RMS= 1.141DN
FFT range (5, 1055)



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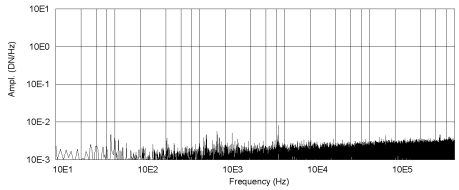
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 268.555DN; RMS= 1.141DN
FFT range (5, 1055)



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Main Board 15; CH-Board 15; FPGA rev. 255
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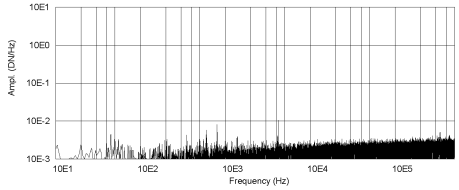
FFT range (5, 1055)



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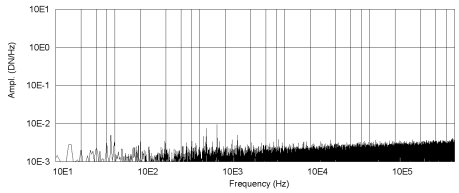
Main Board 9 ; CH-Board 9 ; FPGA rev .17
Mean= 268.497DN; RMS= 1.142DN
FFT range (5, 1055)



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Main Board 15; CH-Board 15; FPGA rev. 255
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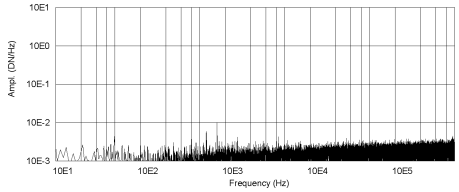
FFT range (5, 1055)



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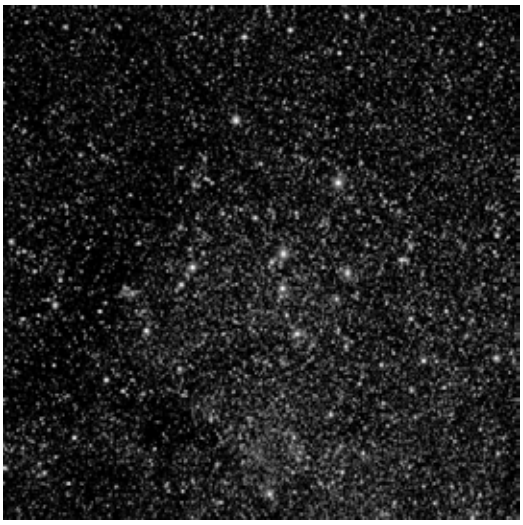
Main Board 15; CH-Board 15; FPGA rev. 255
Mean= 268.572DN; RMS= 1.141DN
FFT range (5, 1055)



Analysis of the Vega-slew images 2007/12/05

An analysis of the 32 (4 in each filter) 256x256 pixel images during the slew over Vega lead to the following results:

Figure 1 shows how well a Gauss-fit matches a simple adding of the DNs of the affected pixels.
Figure 2 compares the value of the brightest pixel with the height of the fitted Gaussian.

Conclusions: The differences between the two approaches are not very big (in the cases where the Gauss-fit converges to the correct solution).

In Figure 3 the PSF for the images during the slew is plotted.
The average is 1.36 pixel full width at half maximum in x-direction and
1.41 pixel in y-direction. The slew didn't seem to have an effect in widening the PSF.

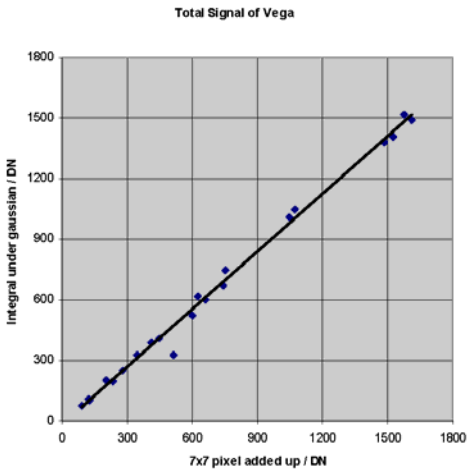


Figure 1

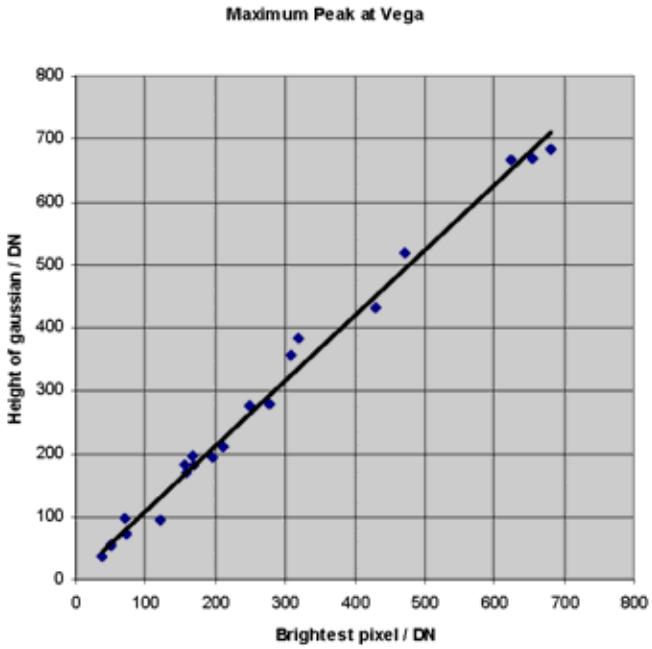


Figure 2

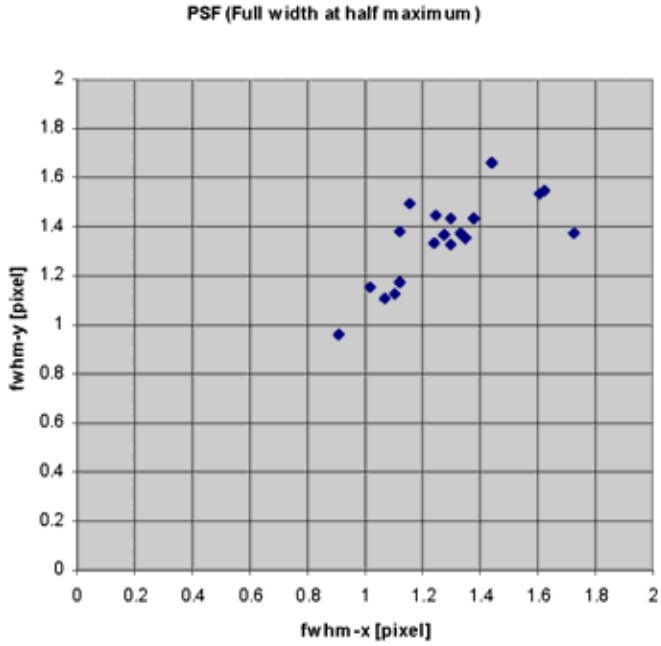


Figure 3

This is a preliminary summary of housekeeping data from the Dawn FC2 Performance Test on 04 Dec 2007, part of the Dawn instruments checkout. The data used in this summary were logged at the MPS server VestaXP during real time transmissions from the Dawn S/C. The data were monitored during the entire test also at FC EGSE at MPS as well as at the DSC.

The h/k data covered are FC instrument temperatures ands FC instrument voltage and current variations. MPS technical notes DA-FC-MPAE-TN-033, -035 are references for the h/k parameters.

The power from S/C to FC2 is shown in Figure 1. Test phases and h/k sample interval are indicated on the graphs of voltage and current. There is a clear tendency of under sampled data to underestimate variability of current variations. The lower current at beginning and end are due to FEE being off.

FEE voltages and currents are shown in Figure 2 and Figure 3, respectively. They are nominal. Here the variability is due to different modes of FEE operation, but a closer study would be required to correlate the mode as indicated by the currents with the imaging mode.

Other internal power lines from the PCU to DPU and MCU are termed analog. These are graphed in Figure 4 and Figure 5. Again the voltages are stable and the currents nominal. The same tendency to underestimate variability of the 5V supply current is apparent here as in Figure 1.

Temperatures are monitored through electronics in the PCU and MCU. These are shown separately in Figure 6 and Figure 7. Comparisons with non-op temperatures are possible for PCU Temp CCD and MCU T STRUCT h/k parameters. Spot checks with FC Mixed Display from dawnrampage indicate the non-op temperature at the CCD is approximately 2C colder than the PCU Temp CCD, and the non-op temperature at the camera head 1-2C warmer than the MCU T STRUCT.

The last parameters to be summarised here are the angle encoder values for the door and filter wheel in Figure 8. The regularity of filter wheel operations during parts 2 and 3 can be seen. Note that the encoder value for the door goes through zero in transitioning between closed (value 10) and open (value 53).

Figure 2 FEE voltages

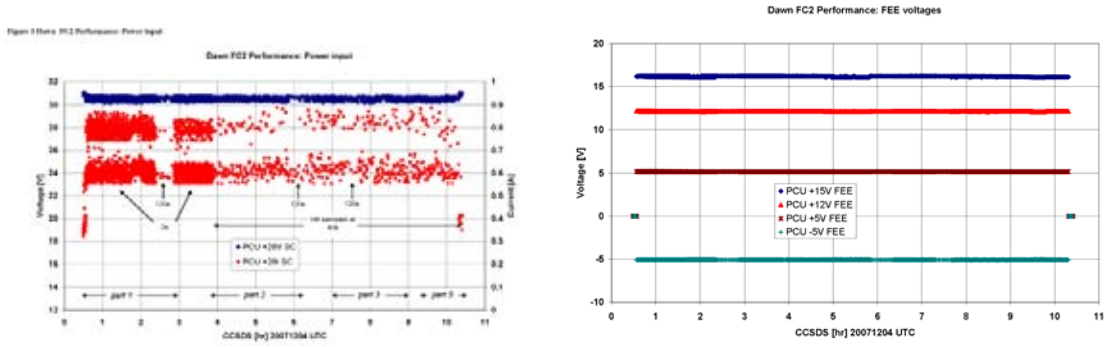


Figure 4 PCU Analog voltages

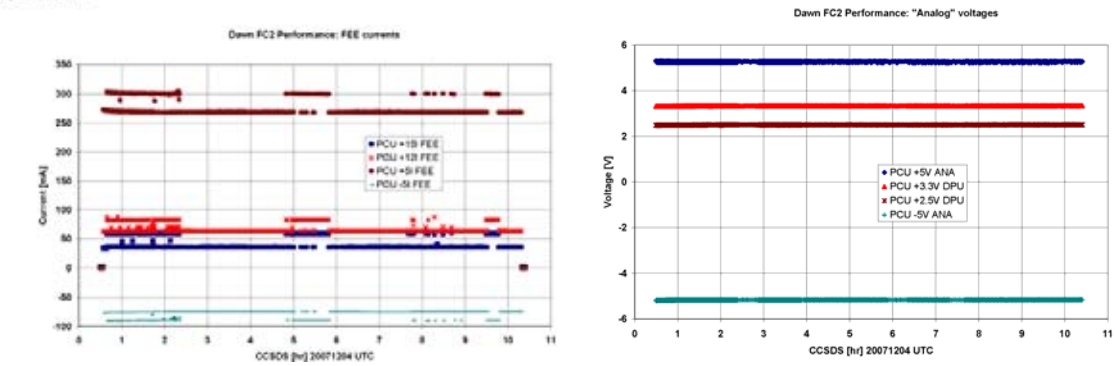


Figure 5 Analog currents

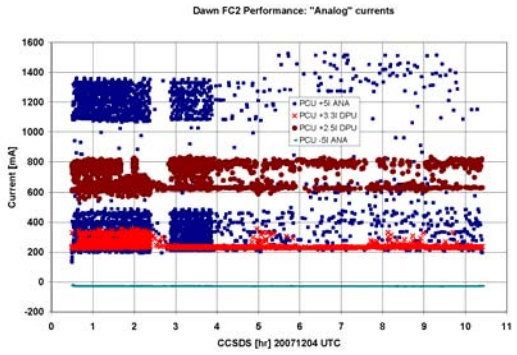


Figure 6 Temperatures monitored at the PCU

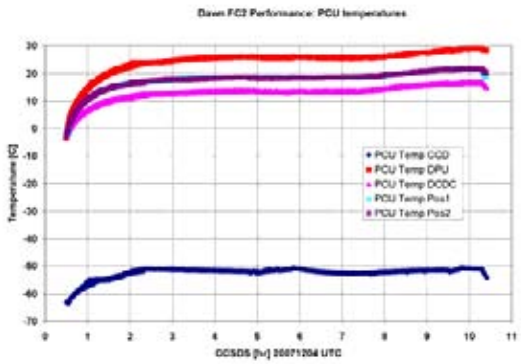


Figure 7 Temperatures monitored at the MCU

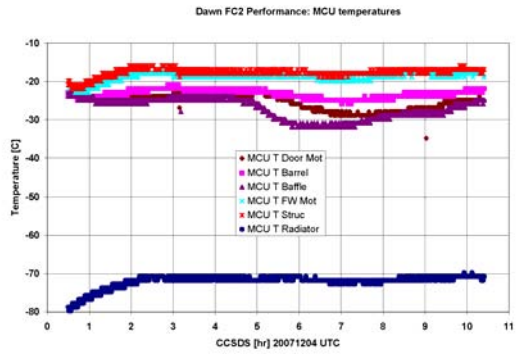
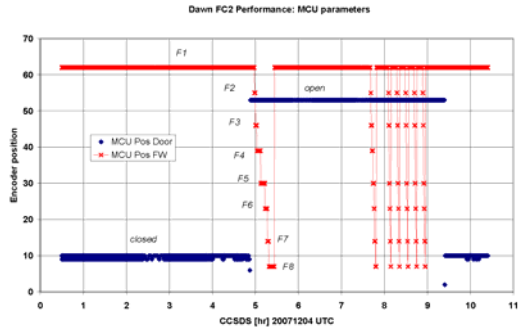


Figure 8 Encoder positions for door and filter wheel



9.7 FC2 Calibration test report

Dawn FC2 ICO Calibration Block Report; DSC/UCLA

13 Dec 2007 (M Aye, S Schroeder, H Sierks, S Mottola at DSC; M Richards, T Maue, P Gutierrez at MPS)

- ccd temperature was found in steady state with rampage readings of -64.8C and camera head at -18.9C at ~50% duty cycle; pt2000 final calibration tunes not applied yet; real temperatures are CCD -67.4C, camera head -21.7C; deck temperature is reading -3.9/-4.1C with unit off
- all times herein are DSC local time/PDT

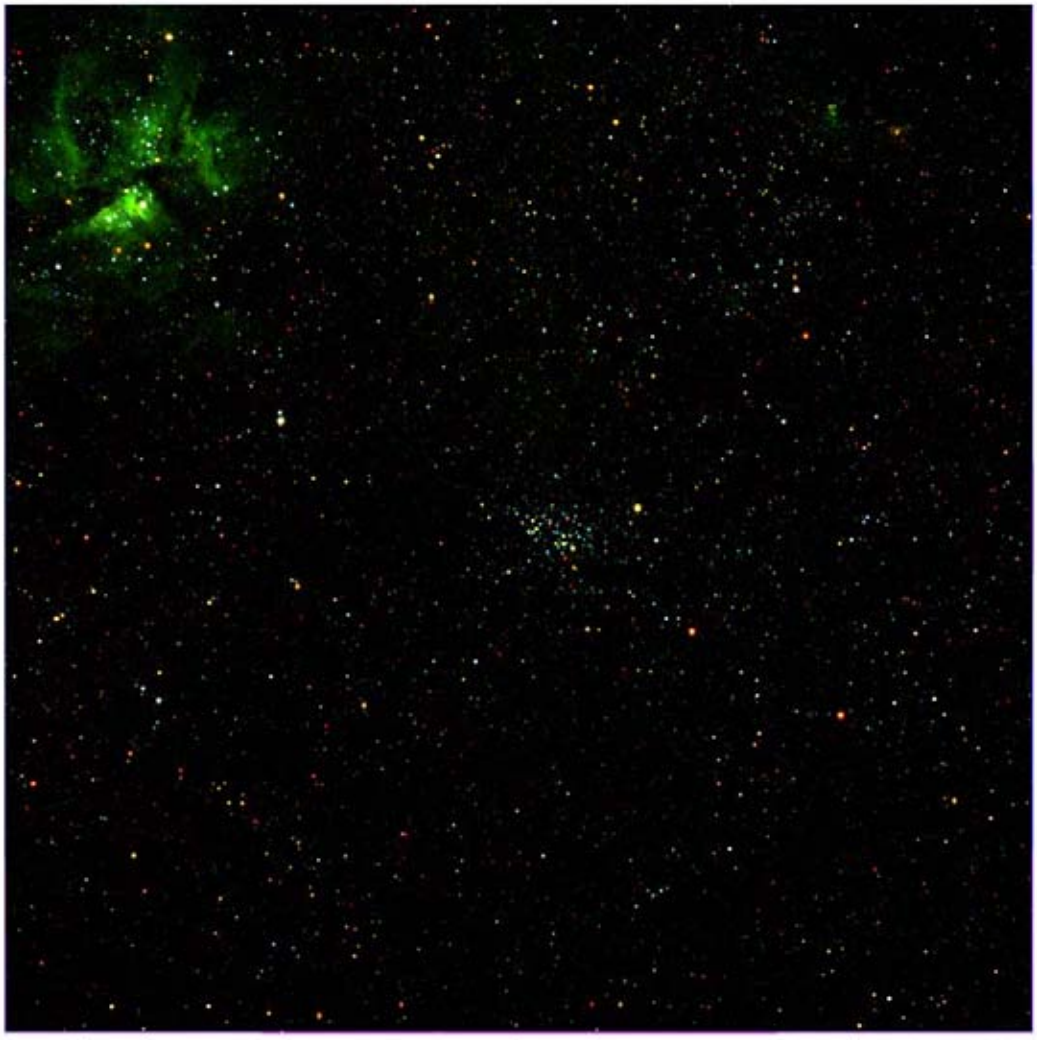
11:38 voca check ok
11:41 light time to s/c is 2min 45sec round trip (eq. 24.6 Mkm)
11:48 checked space weather on noaa, sun is quiet
12:02 data flowing, temp reading snap shot: FC2 CCD -65.8, CH -18.3, i/f -3.9/4.0, all C; duty cycle at CH is ~50%
12:05 all stations are go to proceed with FC2 calibration test
12:11 all stations are go to radiate FC2 calibration sequence
12:12 FC2 calibration sequence radiated
12:16 radiation complete
12:21 camera is on, booting was nominal, unit hk temp CCD -66.06, radiator -78.75,
camera head -23.39, baffle -29.38, PCU CSC -4.0 (closest to s/c i/f), all C
12:25 UDP upload successful
12:26 FEE is on, HK checked and ok, we are on 8sec hk rate
12:31 first image acquired
12:43 egse reports packet losses, most likely related to antenna switch over
12:53 turn to 51Peg started
12:54 imaging of 19 basics ongoing, including 10 serials..
13:15 CCD checkout sequence started
13:29 taking pre op darks
13:32 opening door, door open at enc reading 53, ok
13:38 center frame patch successful
13:39 settling is complete, oscillations is +-0.5px after 20min settling, period is approx. 800sec peak to peak
13:40 filter F1 done, turned to filter F2, ok
13:43 turned to filter F3, ok

13:47 turned to filter F4, ok
13:54 turned to filter F5, ok
13:58 turned to filter F6, ok
14:02 turned to filter F7, ok
14:04 turned to filter F8, ok
14:05 temp snap shot: CCD -54.69, rad -71.77, ch -19.40, baffle -32.37 i/f 4.2, rampage ccd -54.1, rampage ch -14.8, all C
14:14 filter is back at F1/62
14:16 slew to 42Peg started
14:23 slew complete, start settling
14:25 p/b started, first images streaming down
14:34 playback stopped, total of 7 images received
14:35 imaging 42Peg
14:46 done, back in filter F1
14:49 slewing to Saturn
15:24 slew complete, start settling
15:30 playback started
15:32 looks like packet loss in image #8 (1st serial received)
15:33 next 4 serials look ok, no stripes nor noise pattern
15:42 all 10 serials are down, first dark received
15:48 playback finished for now, all 6 darks received, total of 23 images down
15:49 imaging Saturn:-)
16:20 slew to NGC3532 upper left starting
16:39 slew complete, start settling
16:43 start of playback
16:44 first image exhibits packet loss again
17:01 pb finished, got 15 images of ccd test sequence down, imaging upper left
17:09 first mini slew complete, turn to upper middle
17:11 pb started, first image is ok, no packet loss
17:20 pb finished, taking images in upper middle
17:22 slew to upper right started
17:23 slew complete
17:25 start pb
17:33 pb stopped, total of 51 images down
17:34 back to rt, imaging upper right
17:40 slew to mid right started
17:44 slew finished, pb started while settling
17:48 getting 52Pegs down, image is not centered, looks like 52Peg is approx. 34 by 11px offset
17:51 pb stopped, total 119 images down, imaging mid right
17:56 Saturn has x:34, y:11 px offset, looks like offset is due to overscan area not corrected for
17:57 imaging finished, slew to mid center
17:58 slew complete
18:00 pb cont'd, Saturn is nice:-), first NGC full frame coming, cool
18:07 pb stopped, imaging mid center in all filters, pointing is +-0.2px
19:17 slew to mid left started, center frame of mosaic done in all filters
19:18 slew complete, expecting data
19:20 pb starts, getting data
19:31 pb finished, total of 161 images are down, imaging mid left now
19:37 slew to lower left
19:39 start of pb
19:47 pb finished, got 7 images, imaging lower left mosaic, done
19:53 slew to lower center
19:57 start of pb
20:01 pb finished, imaging lower center, done
20:08 slew number 9 in progress
20:09 slew complete to lower right, start pb
20:17 pb finished, imaging lower right
20:23 back in clear, done, encoder reads 62, F1.
20:24 closing door, ok, encoder reads 9/10, closed.
20:25 temp snap: ccd -53.87, ch -20.40, radiator -69.77, baffle -30.37; rampage reading ccd -53.6, ch -16.0, i/f fc2 8.6, i/f fc1 4.3, all C
20:27 taking darks
20:49 slewing back to ICO pointing
21:25 slew back to Earth is complete
21:31 back on HGA
21:51 playing back data
22:29 last packet of last image is missing
22:35 FEE is off
22:40 PrepPowerDown finished, NVRAM written (life time table)
22:42 FC2 is off, end of test
22:45 last packet received, all images down.
22:48 CCD non-op heater is on and running CCD temp up as expected.
23:25 CCD is at 19.6C, camera head -18.3C, s/c i/f 1.5C

Summary:
The Dawn Framing Camera FC2 was turned on for more than 10 hours for in-flight calibration. It received 302 cmds, acquired 254! images, created 18605 hk frames, and 19272 events. All radiated sequences ran nominally, the instrument worked just fine.
Calibration images were taken of 51Peg, 42Peg, Saturn, and NGC3532 (as 3x3 mosaic) providing a reference data set for scientific analysis. A pointing offset was noted in all targetted observations indicating that e.g. CCD prescan area was not correctly taken into account. This issue should be followed up by the teams.

Analysis of cal lamp images revealed no residual charge at the CCD at cal lamp photon flux, see attachment. The cal lamp images were taken in engineering mode allowing analysis of averscan pixels.
Serial images were taken to characterize the noise floor at the CCD. The images did not exhibit patterns nor visible structures in the line scans, although all frequencies (5, 45, 50,55Hz) are visible in fft at somewhat lower intensities.
Quicklook check of open door images (total of 96 sub frames plus 98 full frame images) showed no indication of streaks in this run. However, the fields were crowded making faint streaks not easy to detect.
Congratulations again to the great Dawn team at JPL, DSC, and home at MPS. This was the 5th exciting run of a framing camera in flight, the 3rd for FC2. We got a rich data set for both cameras to keep us busy throughout the winter:-)
We got confidence in FC2 operation in flight that allows off pass or 2k (no FC hk) operation from now on. We'd like, however, run a 3rd campaign on FC1 with at least partial hk coverage before clearing FC1 for 2k or out of pass operation.
Thanks again to all who made the 70m antenna available, enabling this successful test.
H Sierks for the FC Team, 13 Dec 2007

attachments:
- fft analysis of serial images
- residual charge histogram of cal lamp images
- psf analysis of Saturn in all filters
- nice image of Saturn
- false color of NGC3532 with Eta Carinae



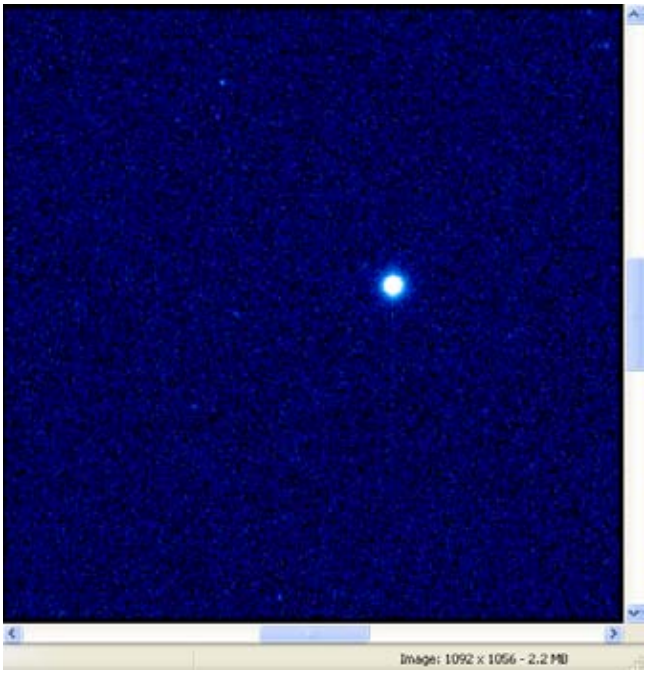
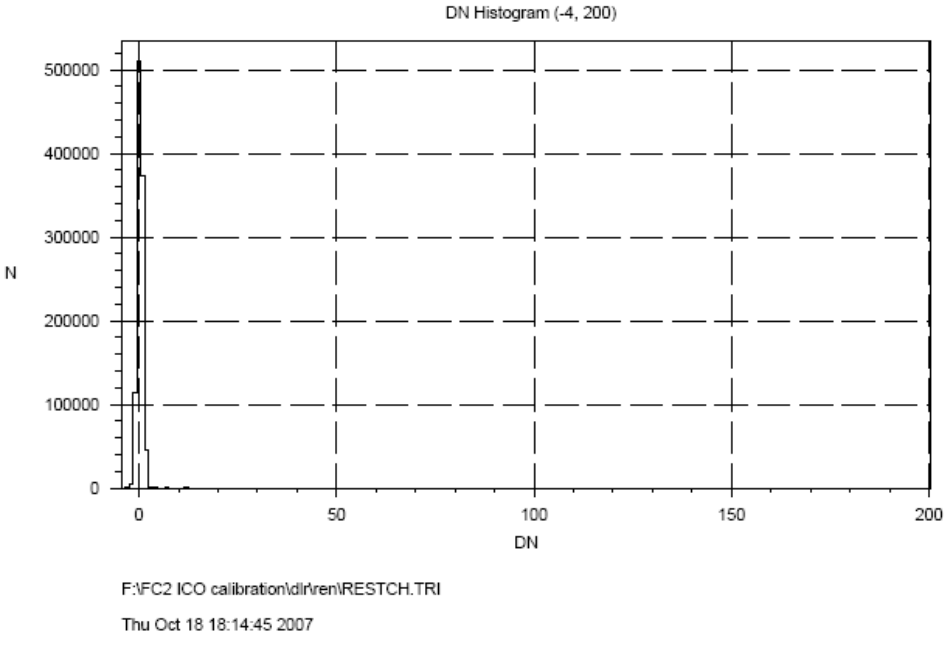


Image: 1092 x 1056 - 2.2 MB


DN Histogram (-4, 200)
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400000
300000
N
200000
100000
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50
100
150
200
DN
F:\FC2 ICO calibration\dlr\ren\RESTCH.TRI
Thu Oct 18 18:14:45 2007

PSF analysis on Saturn

2007/12/14

Observing Saturn with the Framing Camera provided a strong signal, suitable for PSF-analysis of FC2. Saturn was also the first solar system object to be observed and could tell if the apparent diameter of Saturn is large enough to be seen in an increased PSF.

Figure 1 shows the Saturn in a 256x256 pixel window taken with 680 ms exposure through the clear filter (F1).

Figure 1: Saturn through Filter 1 (false colour)

The PSF was determined with the shorter of the two exposure times in each filter, where the peak-signal was between 2000 and 4000 DN.

Table 1: Saturn's signal in all filters

Filter	Integrated Signal	Peak Signal
F1	8421	3998
F2	10453	4493
F3	8557	3023
F4	6480	2147
F5	5451	1968
F6	8903	3358
F7	10253	4086
F8	8295	3342

Table 2: PSF for Saturn in all filters

Filter	fwhm x	fwhm y
F1	1.35	1.34
F2	1.46	1.38
F3	1.52	1.62
F4	1.65	1.61
F5	1.62	1.50
F6	1.47	1.58
F7	1.44	1.51
F8	1.49	1.45

Table 3: PSF for Vega in all filters

Filter	fwhm x	fwhm y
F1	1.24	1.30
F2	1.03	1.16
F3	1.23	1.43
F4	1.32	1.63
F5	1.24	1.57
F6	1.40	1.46
F7	1.22	1.40
F8	1.26	1.39

The PSF shows about the same values in y-direction as for stars previously observed. In x-direction PSF is slightly increased, indicating that Saturn has an apparent diameter of around 1.35 pixel on the CCD.
In the following figures the 2D-PSF is displayed for all the eight filters.

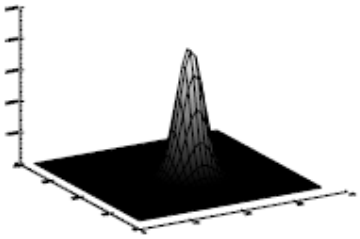


Figure 2: PSF for Filter 1

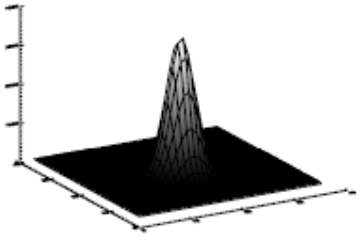


Figure 3: PSF for Filter 2

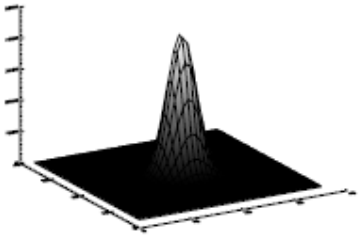


Figure 4: PSF for Filter 3

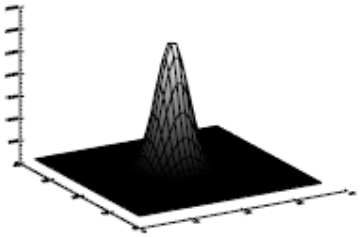


Figure 5: PSF for Filter 4

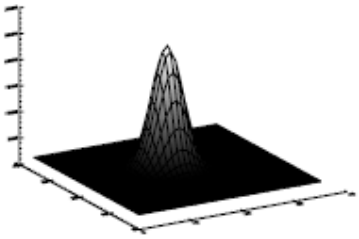


Figure 6: PSF for Filter 5

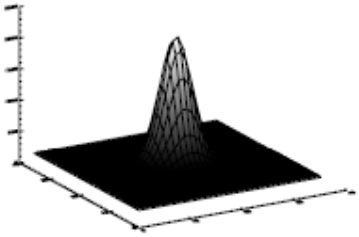


Figure 7: PSF for Filter 6

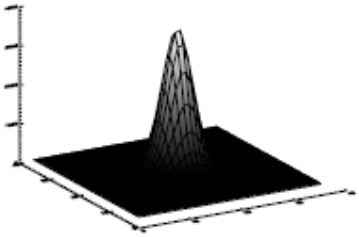


Figure 8: PSF for Filter 7

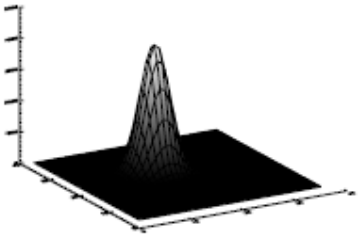
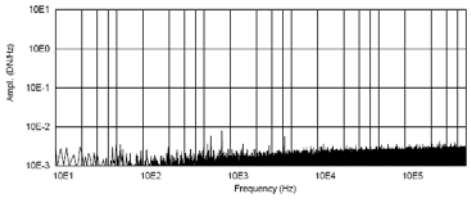


Figure 9: PSF for Filter 8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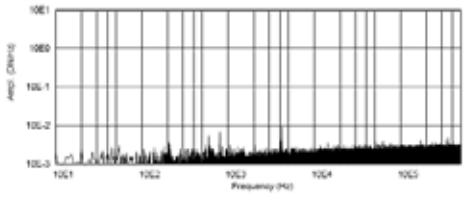
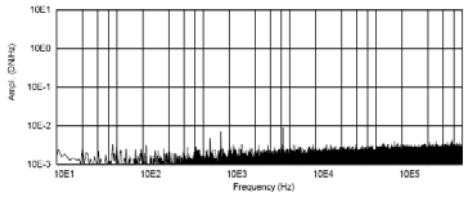
FFT range (5, 1055)


Ampl. (DN/Hz)
Frequency (Hz)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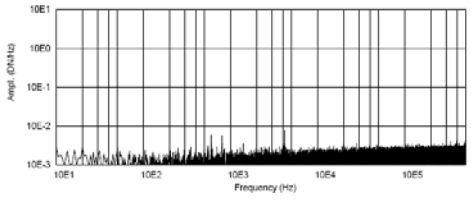
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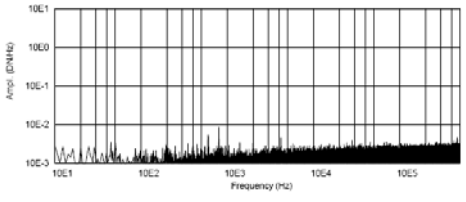
Ampl. (DN/Hz)
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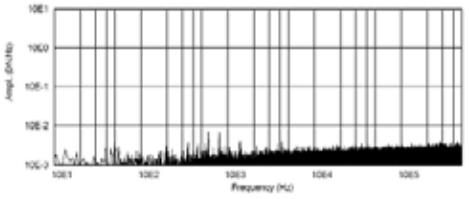
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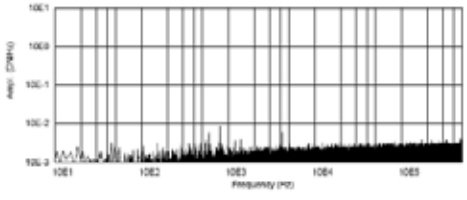
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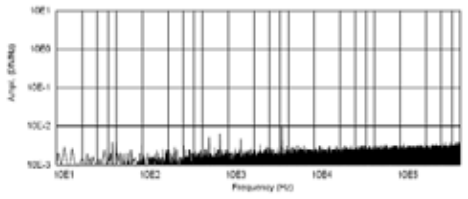
Frequency (Hz)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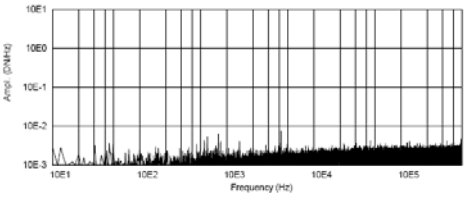
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