OSIRIS

Optical, Spectroscopic, and Infrared Remote Imaging System

Shutter parameters for exposure time calculation

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Prepared by:
J. Deller

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Prepared by: J. Deller (signature/date)

Approved by: H. Sierks (signature/date)

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1/a	22/2/2017	Kovacs	Sec. 3 and 4	added
1/b	18/10/2017	Deller	all	Added a description of ballistic mode, clarified calibration file calculations and changed introduction. Added Sec. 5

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1 General aspects

1.1 Scope

This document describes the OSIRIS shutter operation modes used during the course of the mission as well as the method and parameters used for calculating the effective exposure time as described in RD5. In Section 5 the exposure time correction for on-CCD stacked images acquired in ballistic mode is validated using an exemplary sequence.

1.2 Reference Documents

no.	document name	document number, Iss./Rev.
RD1	OSIRIS user manual	RO-RIS-MPAE-UM-004, D/s
RD2	Transfer function between the encoder measurement and the blades position of the FM WAC SHM	RO-RIS-UPD-TN-W333-219
RD3	Transfer function between the encoder measurement and the blades position of the FM NAC SHM	RO-RIS-UPD-TN-N333-213
RD4	Interface Plate	RO-RIS-UPD-DM-W331
RD5	OSIRIS calibration pipeline OsiCalliope	RO-RIS-MPAE-MA-007, 1/c
RD6	Operation of the OSIRIS Shutter	RO-RIS-MPAE-TN-082, D/-

1.3 Introduction

The OSIRIS WAC and NAC utilize a mechanical shutter for exposure control. The shutters have two parallel moving blades which move in front of the CCD, allowing illumination (exposure) times from a few milliseconds up to several minutes on the detector, limited in principle only by the amounting noise generated by cosmic rays impacting on the CCD. The shutter blades are moved by precisely controlled motors, and their actual position is detected by optical encoders coupled to the motor shafts [RD1]. The shutter drive electronics provide a flexible method to generate arbitrary speed – position profiles for the shutter motion.

The OSIRIS shutter has been operated in various modes that need different exposure time correction to calibrate the resulting images. The operation mode is stored in the keyword SHUTTER_OPERATION_MODE of the image header, and the following modes have been used during the Rosetta mission:

- NORMAL
- BALLISTIC
- BALLISTIC_STACKED
- BALLISTIC_DUAL

To calibrate the images the exact exposure time of each pixel is essential. The exposure time correction is described in RD5, and the corresponding keyword in the HISTORY section of the header, EXPOSURE_CORRECTION_TYPE, can have one of the following values:

- NORMAL_PULSES
- NORMAL_NOPULSES
- BALLISTIC_PULSES
- BALLISTIC_NOPULSES
- BALLISTIC_STACKED_NOPULSES.

In case of errors, when the images cannot be exposure time corrected, the keyword EXPOSURE_CORRECTION_TYPE will begin with UNCORRECTED, followed by the reason for failure:

- UNCORRECTED_UNKNOWN
- UNCORRECTED_SHUTTER_ERROR_A
- UNCORRECTED_SHUTTER_ERROR_C
- UNCORRECTED_SHUTTER_ERROR_D
- UNCORRECTED_ERROR_PULSES.

Each shutter blade is driven by a motor in one of its bearings. The other bearing is attached to a position encoding device that stores the value of a timer each time the encoder disk is moved to a new position. These shutter profiles allow a reconstruction of the shutter blade's leading edge position, and are stored together with most of the images.

The exact time each line of the CCD has been exposed to the light and the effective exposure time can be determined exactly in case the shutter profiles have been acquired and stored together with the image. In this document, the parameters needed for this calculation are described in Section 2.1 and 2.2. If no shutter profiles have been acquired or the shutter pulses cannot be used, either a constant correction value is used as given in Table 1 for exposure time correction, or reference profiles that are described in Section 4.

2 Shutter operation mechanism

While the basic operation of both the WAC and the NAC shutter is described in RD6, a short wrap-up of the shutter operation is given here.

The schematic in Figure 1 shows the principal parts of the shutter mechanics. When both blades are in the home position, the CCD is covered by the first blade. When the shutter is activated, the first blade is moved to the side by the motor. Acceleration and therefore the resulting velocity of the blade is controlled by a preloaded shutter driver profile that describes the acceleration curve using 512 byte resolution.

Nominally, the first blade is the locked by a latch in the open position. After exposing the CCD the desired time the second blade is fired and moved, covering the CCD again. When arriving at the end position, it opens the latch releasing the first blade. Both blades then travel together into the home position without additionally exposing the CCD, driven by pivot elements in the bearings of the four-bar mechanism. As the back travel is not further controlled, it is called a 'ballistic' travel into home position.

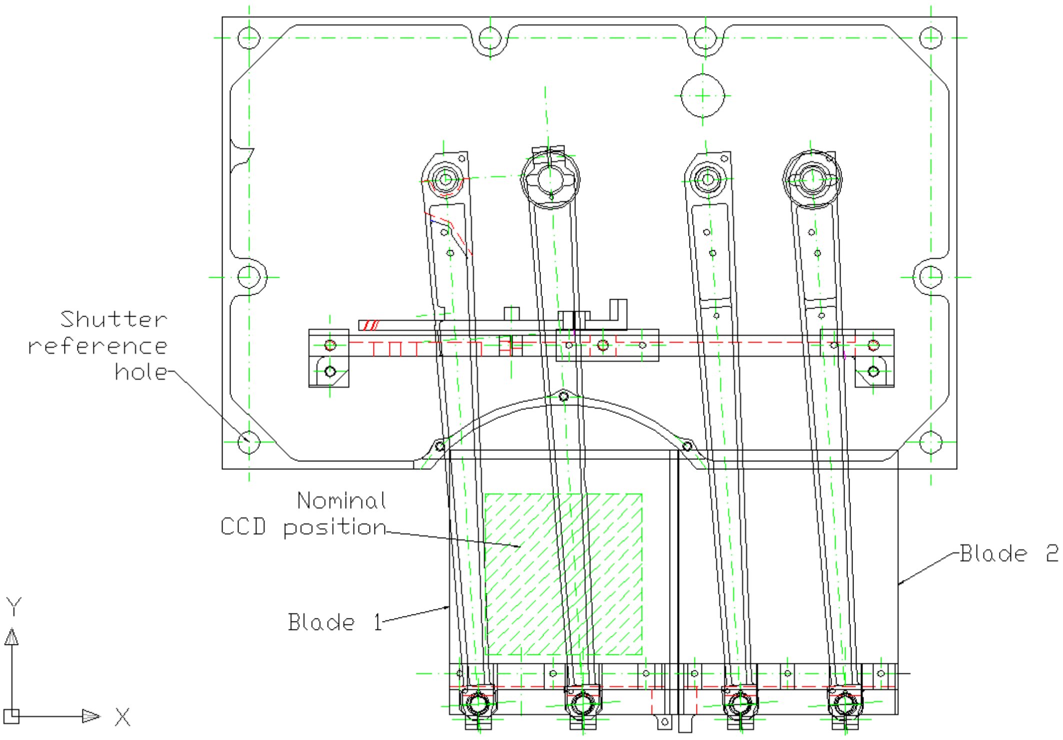

Figure 1 Shutter mechanism

2.1 *Shutter parameters*

The shutter parameters are used to calculate the blade cutting edge position, as a function of the encoder position. They are derived from the mechanical dimensions, measured during system integration [RD2, RD3] and operational tests.

The shutter transfer function is:

$$x = L \cdot [\sin(\Theta_0) + \sin(n \cdot 0.05° + \Theta_z - \Theta_0)] - x_0$$

Where:

	x :	cutting edge position of the blade, relative to the CCD edge
	L :	shutter arm length
	θ_0 :	rotation angle of the shutter arm in nominal (home) position
	n :	the number of encoder pulses
	θ_Z :	rotation angle of the shutter arm from nominal (home) position, to the zero encoder pulse position
	x_0 :	distance between the blade cutting edge and the CCD edge in the nominal (home) position

Table 1 Shutter parameters

Parameter	NAC FM		WAC FM		Source
	Blade1	Blade2	Blade1	Blade2	
L [mm]	100.00	100.00	100.00	100.00	RD2, RD3
θ_0 [°]	3.56	3.77	4.95	4.16	RD2, RD3
θ_Z[°]	1.025	1.95	1.9	1.2	Calculations*
x_0	8.796	6.956	9.136	7.146	RD2, RD3, RD4
Counter rollover	0	1	1	0	Calculations*
Default exposure time correction [s]	-0.0027		-0.0025		Calculations*

* Calculations are based on matching full shutter data of images acquired with ZEROPULSE_FLAG = FALSE and with ZEROPULSE_FLAG = TRUE:
- WAC_2008-03-19T21.48.40.651Z_ID10_0000000150_F12.IMG
- NAC_2008-02-13T23.05.57.436Z_ID10_0000000200_F21.IMG

2.2 Exposure time calculation method

The motion of the shutter blades is controlled by the driver electronics, based on a preprogrammed speed profile. Since the velocity is not constant across the CCD surface, and the acceleration profiles of the two blades are different, the actual illumination time can only be calculated from the shutter position function. In order to obtain the position-time function, the shutter system uses encoders on the motor shafts. For the precise time base, the electronics utilize a 2.1 MHz clock signal and two separate 14 bit counters, one for each blade. These counters are sampled each time the encoder sends a pulse.

The first counter resets at the exposure start signal when the first blade motor is activated. The second counter resets at the end of the commanded exposure time, when the second blade is activated. In this way the counters deliver a relative time value for each encoder position. Based on the shutter transfer functions [RD2, RD3], the actual positions of the shutter cutting edges are calculated. The time difference between the two shutter functions at the same location over the CCD is used when calculating the value for the line wise exposure time correction factor Δt as described in RD5.

2.3 Shutter activation in test mode

The configuration of the shutter electronics during activation is controlled by setting the shutter control byte mask as described in RD6. This allows the setting of a 'test' mode. This mode has two effects: The limitation of the shutter profile to 440 data points is revoked, and all pulses received are stored. Furthermore, the hall senor detecting the locking of blade 1 is disabled, preventing the triggering of TYPE_A errors.

Both effects are needed when operating the WAC shutter in the special ballistic operations modes, therefore the majority of images taken in a SHUTTER_OPERATION_MODE that is not NORMAL have been acquired in test mode, while for the majority of images in NORMAL mode the test mode was disabled. If the test mode is enabled, the TESTMODE_FLAG is set to TRUE, otherwise it is set to FALSE. The flag is stored in the SR_SHUTTER_CONFIG group in the image header.

2.4 Acquisition and analysis of the shutter pulses

The shutter pulses are generated and stored only when the position encoders are enabled and the image acquisition configuration includes the storage of the profiles.

In some cases, even if the shutter pulses are stored together with the images, analysis of the shutter pulse data shows that either the pulses cannot be used for calibration of the images, or that the shutter did not work as expected and the image cannot be calibrated altogether.

2.4.1 Shutter pulses not usable for exposure time correction

During the analysis of the shutter pulse data, the position and velocity of the shutter blade edge is calculated. If the shutter pulse data contains less than 400 points, the pulses are not further analyzed, and the image is calibrated using a _NOPULSES type EXPOSURE_CORRECTION_TYPE.

For successful shutter operation, the blade speed must be higher than 1m/s when reaching the CCD area (0.0 mm position). If this is not achieved, the exposure time correction mode is set to EXPOSURE_CORRECTION_TYPE = UNCORRECTED_ERROR_PULSES and the image will not be exposure time corrected.

The turning point is determined by the first position where the blade speed falls below 0.1 m/s. For ballistic modes the turning point must be before the locking position (30.0 mm position), otherwise the exposure time correction mode is set to EXPOSURE_CORRECTION_TYPE = UNCORRECTED_ERROR_PULSES and the image will not be exposure time corrected. For the EXPOSURE_CORRECTION_TYPE equal to BALLISTIC_PULSES, the turning point is critical to determine the exposure time per CCD line, as it is calculated as the time difference between the shooting and the returning of the first shutter blade.

The return (home) position is determined by finding the first position during the return phase where the velocity is less than half of the previous two positions velocity.

2.4.2 Counter rollover

Each counter holds the number of clock pulses since its reset. Considering that these units are 14 bit counters, the number will roll over after 16384 pulses. This rollover is partially handled by the on-board software. Partially means, that the spacecraft software examines the sampled values of the counter, and supposing a continuously increasing time, if the value is smaller than the previous one, the rollover number n is incremented and the pulse count is calculated by increasing its value by $n \cdot 16384$. This method should be corrected when the sampling time interval is larger than *16384/2.1MHz.*

2.4.3 The “ZEROPULSE_FLAG”

To ensure a stable reference point for the blades, the encoders provide an additional signal, a “zero pulse” to the electronics. This is a reference point of the encoder, thus not affected by the mechanical elasticity, or wear out. The position of this pulse is not coincident with the shutter nominal (home) position. During the image acquisition the “ZEROPULSE_FLAG” determines the first sampling position of the pulse count:

- ZEROPULSE_FLAG = FALSE: the first sample in the pulse array is the time count at the first encoder pulse (practically the start of the blade motion).
- ZEROPULSE_FLAG = TRUE: the first sample in the pulse array is the time count at the zero pulse position. This gives a more accurate positioning; however the counter rollover during the first time slot must be handled separately.

The keyword ZEROPULSE_FLAG is stored in the image header in the SR_SHUTTER_CONFIG group.

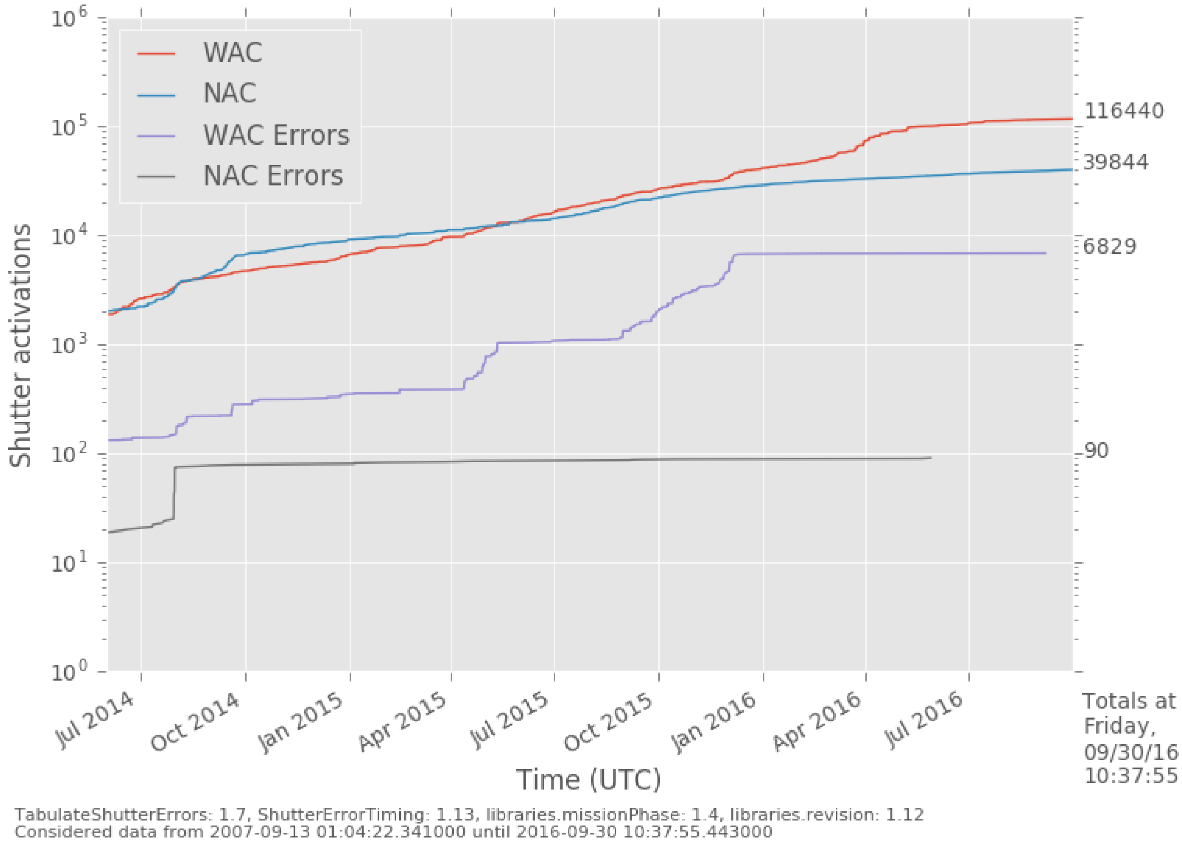

Figure 2 Cumulative number of shutter activations and shutter errors in the course of the mission

3 Shutter operation modes

The shutter operations manual RD6 describes the nominal operations of the shutter. After the failure of the latching mechanism in the WAC, preceded by a steep increase in shutter errors that can be seen in Figure 2, the nominal operations mode could not be used any more to acquire images, and a series of 'ballistic' modes has been developed to cope with the non-locking of the first blade. These modes require special treatment during the exposure time correction of the calibration pipeline.

The shutter operation mode used to acquire an image is not directly stored in the level 0 image file header on board of the spacecraft, but added on ground into the level 1 image header using

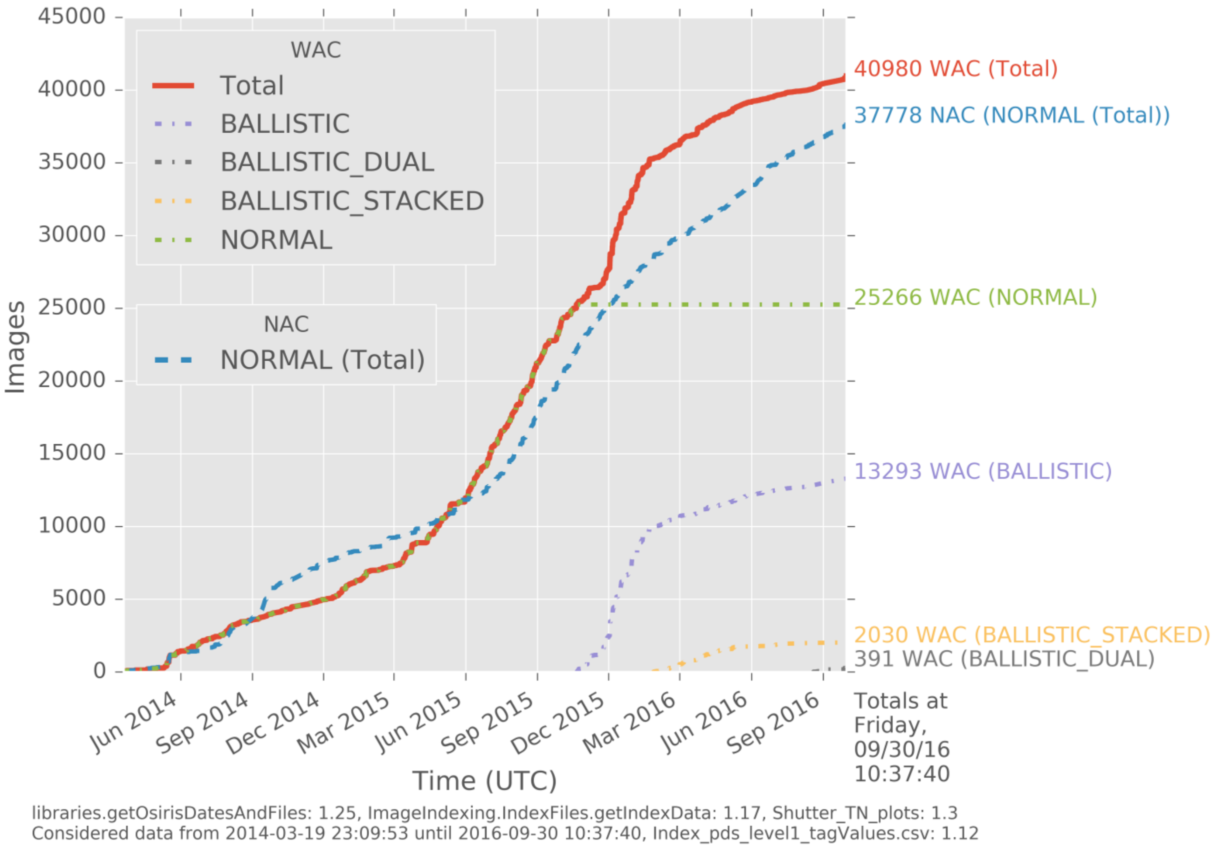

Figure 3 Cumulative number of images per SHUTTER_OPERATION_MODE during comet phase

the keyword SHUTTER_OPERATION_MODE that is stored in the SR_SHUTTER_CONFIG group. The number of images acquired in each mode can be seen in Figure 3.

In the following, the characteristics of the shutter operation modes are explained. The details of the exposure time correction methods are described in the next section.

3.1 NORMAL operation mode

In the NORMAL operation mode the image is acquired according to the description in the shutter manual RD6. The camera is normally configured with test mode disabled. If configured, the 440 data points of the shutter profiles for each blade are attached to the image file and can be used for the exposure time correction. All error conditions can occur. This is the only mode used for all NAC image acquisitions.

In the NORMAL mode of operations, the uniformity of the CCD illumination is better than 1/500. Using calibration data, the deviation of the achieved exposure time to the commanded exposure time was measured, and is given in Table 1.

3.2 The WAC shutter in BALLISTIC operation mode

During summer 2015, the WAC shutter showed an ever increasing number of locking errors (see Figure 2), and eventually failed to lock entirely. To recover science operations, a new operations mode has been implemented, called the "ballistic" mode. This is not described in the shutter operations document [RD6].

In this mode, only the first blade is used. For an exposure, the first blade is fired and moves over the CCD to expose the CCD. The blade is decelerated to reach zero velocity slightly before contacting the latch. The blade then falls back into home position in quasi-ballistic motion driven by spring forces only. This operation mode allows only a fixed exposure time that is different for each line of the CCD, ranging from about 20 ms in the last CCD line to 160 ms in the first CCD line.

For the ballistic mode, the WAC is configured with test mode enabled. This is done to enable the storage of more than 440 data points in the shutter profiles, needed to determine the exposure time per line, and to prevent the camera from generating a LOCKING_ERROR_A that would be thrown by the hall sensor not detecting the locking of the first blade. This is done to avoid wrongly flagging all images in ballistic mode as error and flooding the space craft control center and the operation teams with error messages.

3.2.1 Tweaking of shutter parameters for the WAC ballistic operation mode.

During the introduction of this mode, the shutter profile parameters where slightly tweaked to enhance performance and repeatability. After extensive testing during October and November 2015, an initial configuration for the ballistic mode was found. The only parameter to improve was the CCD travel distance that describes the distance after which the blade is supposed to decelerate to stop and turn to 'fall' back to home position. If this parameter is set to large, the blade might make contact to the latch and bounce back, leading to unpredictable behavior and therefore a large spread in flight profiles at the last CCD lines. On the other hand, if the parameter is chosen too short, a part of the CCD is not well illuminated and lost for scientific imaging. Figure 4 shows the value of this parameter from the first test images in ballistic mode.

The average profiles of 100 test shots for each of these parameter sets can be seen in Figure 5. These profiles are used to during calibration for the exposure time correction if there no profiles attached to the image files. The validity epochs of these data files are listed in Table 2. Table 3 lists the value of the CCD travel distance used and the sequences containing the test data.

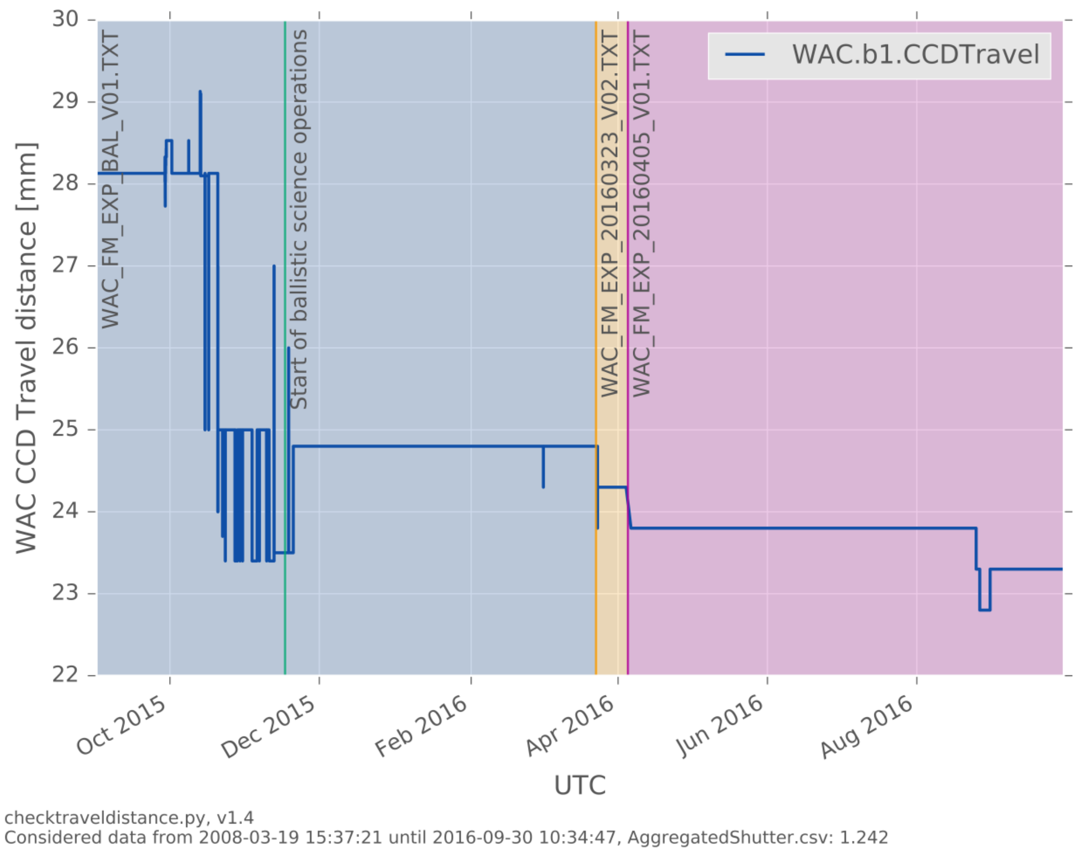

Figure 4 Value of the WAC CCD travel distance. Indicated is also the validity periods of the average shutter profile files used for exposure time correction in the ballistic operation mode.

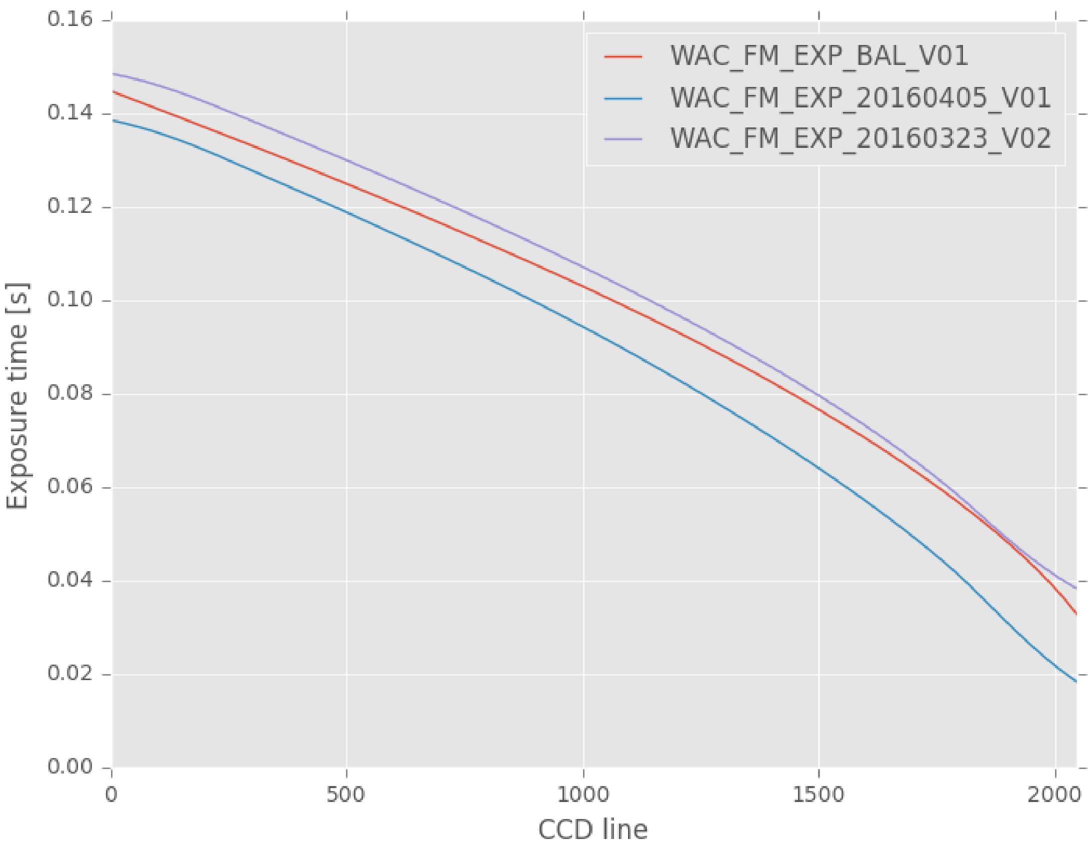

Figure 5 Average exposure time per CCD line as derived from 100 shots in the ballistic mode in 3 different configurations. See Table 3 for a definition of the sequences.

3.3 The WAC shutter in BALLISTIC_STACKED operation mode

Because of the fixed exposure time in the ballistic mode, the amount of light collected during one exposure was not sufficient to allow the usage of all but the brightest filter combinations. Therefore, the BALLISTIC mode was used only for images of the comet nucleus, in the broad band filters. To enable the detection of the faint structure in the dust and gas coma the BALLISTIC_STACKED mode was implemented.

In this mode, the CCD is exposed during multiple activations of the shutter in ballistic mode, while not being read out in between, therefore accumulating the charge in the CCD. Due to recharging the motor drive capacitor, a delay of 1.5 s in between each shutter activation was used.

This mode had to be commanded using a series of TCAcquireImage and TCMonitorObervation commands, increasing the number of telecommands used by OSIRIS significantly.

For this mode, the camera was configured to be in test mode. The configuration did not allow storing shutter profiles for stacked images. Therefore these images have to be calibrated using the average profiles described in Table 3 and Figure 5. Because the shutter profiles are varying, the expected flux error caused by varying exposure times is in the order of 10% to 20%.[1]

Images with stacking of up to 100 shutter activations have been commanded.

3.4 The WAC shutter in BALLISTIC_DUAL operation mode

In the planning of the final descent sequence during the end of mission it was recognized that the surface brightness of the comet at the distance and phase angle planned would saturate the CCD when operating in BALLISTIC mode. Therefore the definition of a new mode of operation was necessary.

In the BALLISTIC_DUAL operation mode, both blades of the WAC shutter where used again.

The first blade is fired, and using a power profile similar to the one used in BALLISTIC mode slowed down before reaching the position of the latch. The second blade is fired 15 ms after the first blade, with a similar power profile. The second blade is slowed down as well, and both blades travel together back into the home position driven by the bearing spring with a small current in the motor of the first blade to try to prevent reopening of the slit between both blades.

In this mode, the lower part of the CCD is exposed evenly with 15 ms exposure time. Only the last lines of the CCD are affected by a slightly more uneven exposure. Therefore the exposure time correction is equivalent to images taken in NORMAL shutter operation mode. Because during the final descent in an effort to minimize data volume no shutter profiles where acquired, all BALLISTIC_DUAL images are corrected with EXPOSURE_CORRECTION_TYPE = NORMAL_NOPULSES.

During the final descent of the spacecraft, 114 images including the very last one have been taken in BALLISTIC_DUAL operation mode.

4 Calibration files used by OsiCalliope

For “EXPOSURE_CORRECTION_TYPE equal to “NORMAL_NOPULSES”, the exposure time correction is constant for all lines of the CCD and given in Table 1 of this document.

When no shutter profile information is available for images taken by the WAC in the shutter operation mode of either BALLISTIC or BALLISTIC_STACKED, OsiCalliope uses average shutter profile data for calibrating the exposure time using EXPOSURE_CORRECTION_TYPE equal to “BALLISTIC_NOPULSES” or “BALLISTIC_STACKED_NOPULSES”.

Table 2 Average shutter profiles and validity epochs for exposure time correction in the ‘BALLISTIC_...’ operation modes of the WAC.

Filename	Validity epoch
WAC_FM_EXP_20160405_V??.TXT	2004-03-02T01:00:00 to 2016-03-22T23:59:59
WAC_FM_EXP_20160323_V??.TXT	2016-03-23T12:00:00 to 2016-04-05T12:00:00
WAC_FM_EXP_BAL_V??.TXT	2016-04-05T12:00:00 to 2016-09-30T23:00:00

Due to changes in the shutter configuration, these profiles had to be updated. The sequences used to acquire the data and the validity epochs are listed in Table 3. Each sequence contains

[1] This estimate is currently under further research. A preliminary study of the calibration error of an exemplary sequence with stacked images can be found in Section 5.

100 - 200 shutter activations acquiring the shutter profiles for each image. For each image, the line wise exposure time is calculated using the algorithm described for correction type NORMAL_PULSES in RD5:

- The shutter pulse array contains the number of clock pulses (2.1MHz) at certain encoder (angular) positions of the shutter blade arm.
- The encoder positions are transformed into shutter blade positions by the shutter blade transfer functions [RD2, RD3].
- The blade position – time function is calculated
- The difference of the above functions for the two blades at a certain CCD position gives the actual exposure time, for a given pixel. The average of these values is the MEAN_EFFECTIVE_EXPOSURETIME
- The exposure time is calculated as the difference of the above functions for the two blades at a certain CCD position.

The profiles listed in Table 3 are calculated as the line-wise average of exposure times for all files in the sequence and shown in Figure 5.

Table 3 Acquisition sequences for shutter profiles used in ballistic mode. The file version is given as the lowest version where the ACTIVITY_NAME is valid.

Filename	CCD travel distance [mm]	ACTIVITY_NAME	Acquisition date
WAC_FM_EXP_20160405_V01.TXT	23.8	STP102_SHUTTER_TEST	2016-04-05
WAC_FM_EXP_20160323_V02.TXT	24.3	STP101_SHUTTER_TEST*	2016-03-23
WAC_FM_EXP_BAL_V01.TXT	24.8	STP095_SHUTTER_PULSE_001	2016-02-11

*last 100 images in activity

5 Verification of image calibration for on-CCD stacked images.

After noting an unexpected drop in the total dust coma flux analysis that seemed to coincide with the switch from long exposures to on-CCD stacked exposures using ballistic mode the need came up to re-verify the calibration of on-CCD stacked images. The drop in the total dust coma flux was in the order of 1 to 2 magnitudes; therefore the effect could not be explained by random errors in the calculated line-by-line exposure time caused by the variability of the shutter movement in ballistic mode. The data analyzed here has been calibrated using OsiCalliope v1.36. Please note that the issues found in this study have been resolved in updated versions of the pipeline.

5.1 Verification of calibration using the exemplary sequence STP104_DUST_MON_102

5.1.1 Description of sequence

In this sequence, developed to monitor the dust environment during a full rotation of the comet and to search for source points of dust jets, a set of four images in two filters is taken at a cadence of 30 minutes. The filters used are ‘Red’ (F12) and ‘Green’ (F21). The first image is taken as a single exposure with ‘test’ mode enabled, and therefore calibrated using the shutter profile saved during exposure, the second image is an on-CCD stack of 50 exposures, and calibrated using the average profile.

5.1.2 Ratio of stacked and non-stacked images

To analyze the calibration of stacked images, the ratio of the single exposure image
`WAC_2016-04-13T07.01.39.229Z_ID10_1397549800_F12.IMG`
and the on-CCD stacked image containing 50 exposures
`WAC_2016-04-13T07.03.17.913Z_ID10_1397549351_F12.IMG`
was calculated in both level 1 (DN) and level 2 (calibrated in flux units). Characteristics of these images from PDS keywords are given in Table 4.

For level 1 images, the bias has to be subtracted first.

$$R_{L1} = \frac{DN_{\text{Stacked on board}} - BIAS}{DN_{\text{single exposure}} - BIAS}$$

For level 2 images, the images are in units of flux, therefor no further treatment is necessary:

$$R_{L2} = \frac{F_{\text{Stacked on board}}}{F_{\text{single exposure}}}$$

As the stacked image contains 50 exposures, the ratio R_{L1} is expected to have a value of 50 throughout the image. The ratio R_{L2} is expected to have a value of 1.

The ratio is displayed in Figure 6. A circular region of interest was selected in a shadowed region of the comet, as the flux in all images in this region is significantly above BIAS and below saturation.

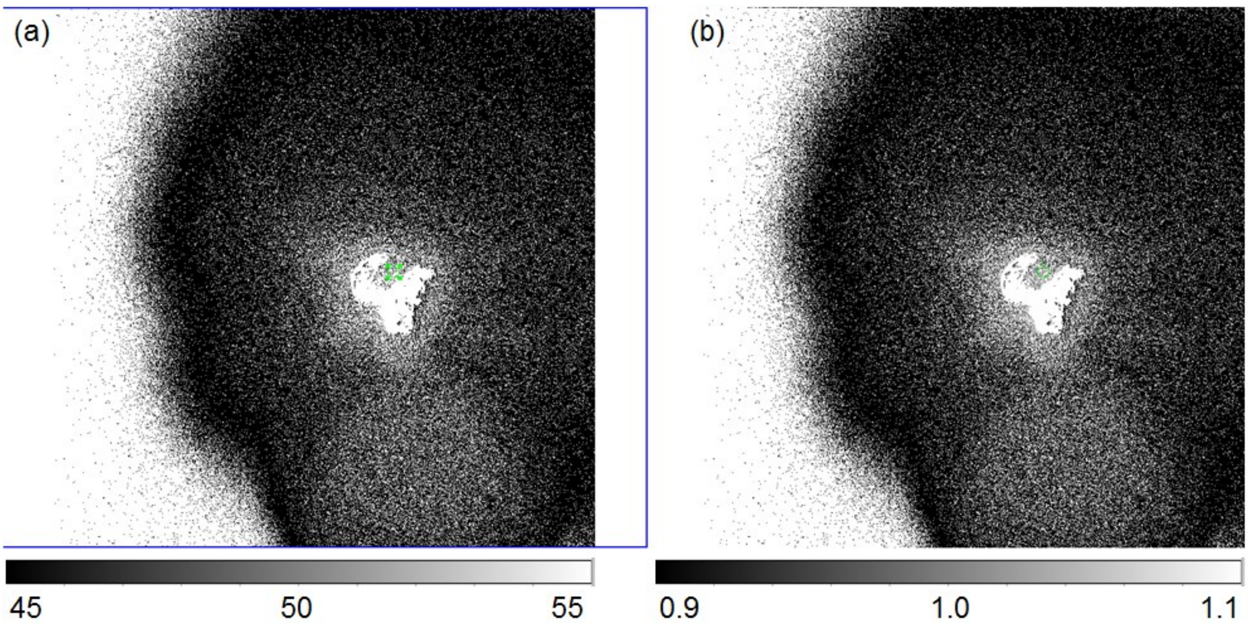

Figure 6 Ratio of single exposed and 50 exposure stacked images in level 1 (left, a) and level 2 (right, b). Values that are in the level 1 image of the single exposure below the BIAS value + 50

DN are masked, as well as values in the non-linear regime (DN > 45000). The region of interest is shown in green.

Table 4 Selected PDS Keywords of the images analyzed.

		WAC_\ 2016-04-13T07.01.39.229Z_\ ID20_1397549800_F12.IMG	WAC_\ 2016-04-13T07.03.17.913Z_\ ID20_1397549351_F12.IMG
	Stacking	1	50
Level 1	SOFTWARE_NAME	OsiTrap.exe	OsiTrap.exe
	SOFTWARE_VERSION_ID	v1.47.0	v1.47.0
Level 2	SOFTWARE_NAME	OsiCalliope.exe	OsiCalliope.exe
	SOFTWARE_VERSION_ID	1.0.0.36	1.0.0.36
	ROSETTA:SHUTTER_OPERATION_MODE	BALLISTIC	BALLISTIC_STACKED
	EXPOSURE_CORRECTION_TYPE	BALLISTIC_PULSES	BALLISTIC_STACKED
	MEAN_EFFECTIVE_EXPOSURETIME <s>	0.0921	4.4273
	BIAS_BASE_VALUES <DN>	234.010, 234.010	234.010, 234.010
	BIAS_TEMP_DELTA <DN>	4.251, 4.251	4.132, 4.132

Table 5 Statistics of the region of interest marked in Figure 6

	npix	surf_bri	surf_err	mean	median	min	max	var	stddev	rms
Level 1	1693	51.8323	0.174973	51.8323	51.3003	37.0981	81.4583	26.4147	5.13953	52.0864
Level 2	1693	1.06917	0.02513	1.06917	1.0582	0.764903	1.68036	0.011234	0.105989	1.07441

The statistic of this region is given in Table 5. This shows that while the mean ratio is not exactly as expected (51.8 and 1.06 for level 1 and level 2, respectively) with 4% and 7% the error lies within the expectation and cannot be the cause of a drop in flux of an order of magnitude. The exposure time averaged over all CCD lines for the two images are given in Table 4 with 0.0921 s for the single exposure and 4.4273 s for the stack of 50. The ratio of these numbers is

$$R_{\mathrm{EXP}} = \frac{4.4273\ s}{0.0921\ s} = 48.07$$

5.2 Wrong exposure time correction in sequence STP089_GAS_MON_003b

During this analysis it was discovered that the sequence STP089_GAS_MON_003b, the first GAS_MON sequence using stacked images in ballistic mode, was not properly calibrated.

The calibration pipeline is configured to determine the number of stacked images by using the last two digits in the Image ID in the filename (e.g. WAC_2016-04-13T07.03.17.913Z_ID20_13975493**51**_F12.IMG gives a stacking indicator of AB=51 which is decoded to $A \times 10^{B} = 5 \times 10^{1} = 50$). For the sequence STP089_GAS_MON_003b, the image ID is not properly set, and the image is calibrated as a single exposure. Changes to the filenames are not possible anymore. Therefore this sequence will be wrongly calibrated until the calibration pipeline is configured to infer the stacking type from the PDS keywords.

NOTE: This has been corrected, and in newer versions of the calibration pipeline the number of exposures used in the exposure time calibration is read from the keyword ROSETTA:NUMBER_OF_EXPOSURES.

5.3 Actions and recommendations from this report

The following actions are recommended to solve issues found during the preparation of this report:

1) The calibration pipeline should not infer the ballistic stacking type from the image name but instead from a PDS keyword. This would resolve the issue in Section 5.3. [Corrected]
2) The variability of the shutter profiles should be assessed in a long-term monitoring study using the profiles saved in single exposure images. This should lead to a full error analysis of the exposure time correction using averaged profiles.