

VEXCEL
IMAGING

ULTRACAM

Calibration Report



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Bahia, Brasil 2013

Photo on page 1 courtesy of Hiparc Geotecnologia, Brasil

www.hiparc.com

UltraCam Lp, GSD25 cm, RGB



ULTRACAM

Geometric Calibration

Camera:

UltraCam Falcon Prime

Serial:

UC-Fp-1-40616106-f100

Panchromatic Camera:

ck = 100.500 mm

Multispectral Camera:

ck = 100.500 mm

PPA Information:

X: 0.000

Y: 0.000



Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track cross track	67.860mm 103.860mm	11310pixel 17310pixel
Image Extent		(-33.930, -51.930)mm	(33.930, 51.930)mm
Pixel Size		6.000µm*6.000µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Multispectral Camera

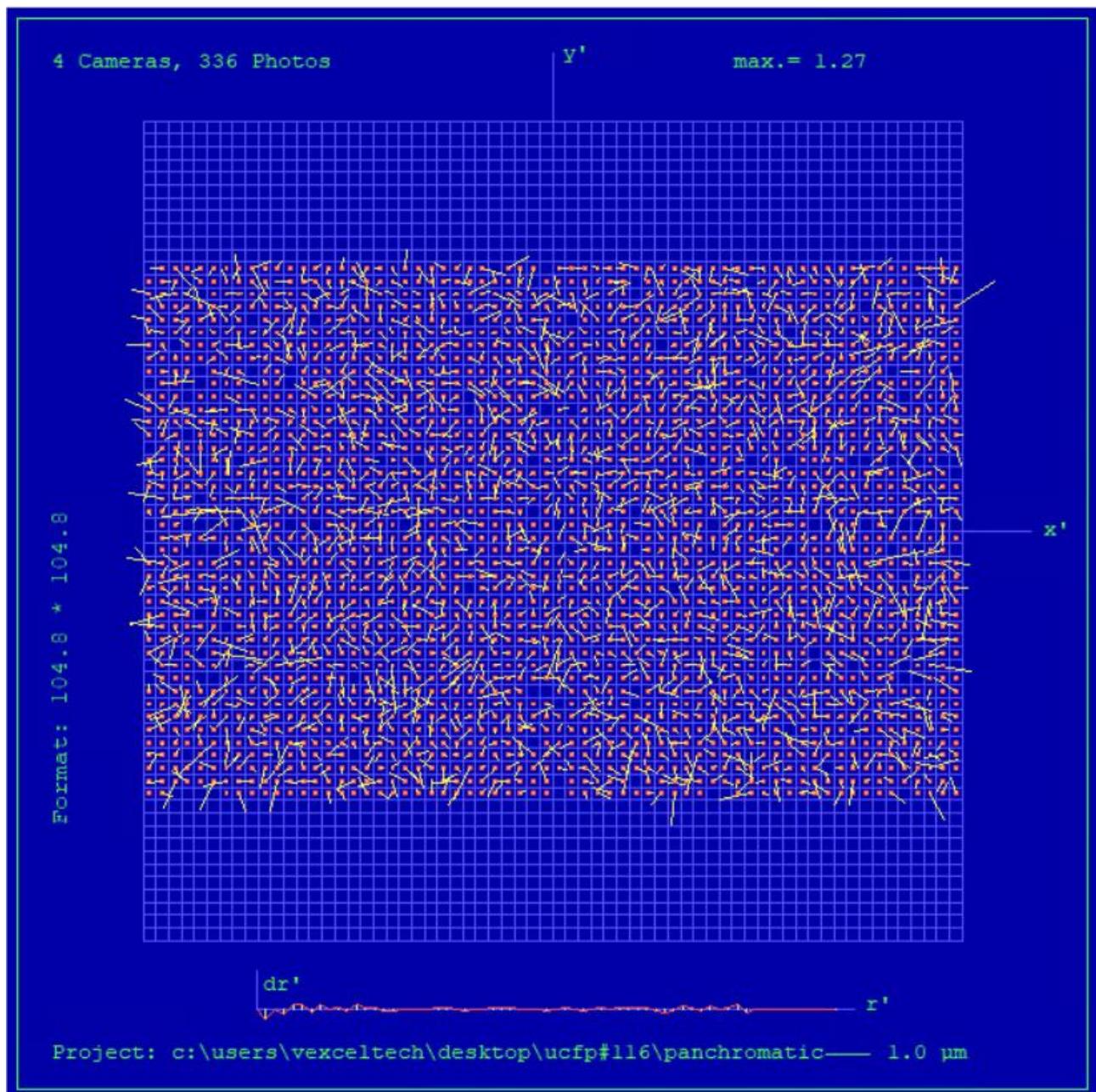
Medium Format Multispectral Output Image

(Upscaled to panchromatic image format)

Image Format	long track cross track	67.860mm 103.860mm	3770pixel 5770pixel
Image Extent		(-33.930, -51.930)mm	(33.930, 51.930)mm
Pixel Size		18.000µm*18.000µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		



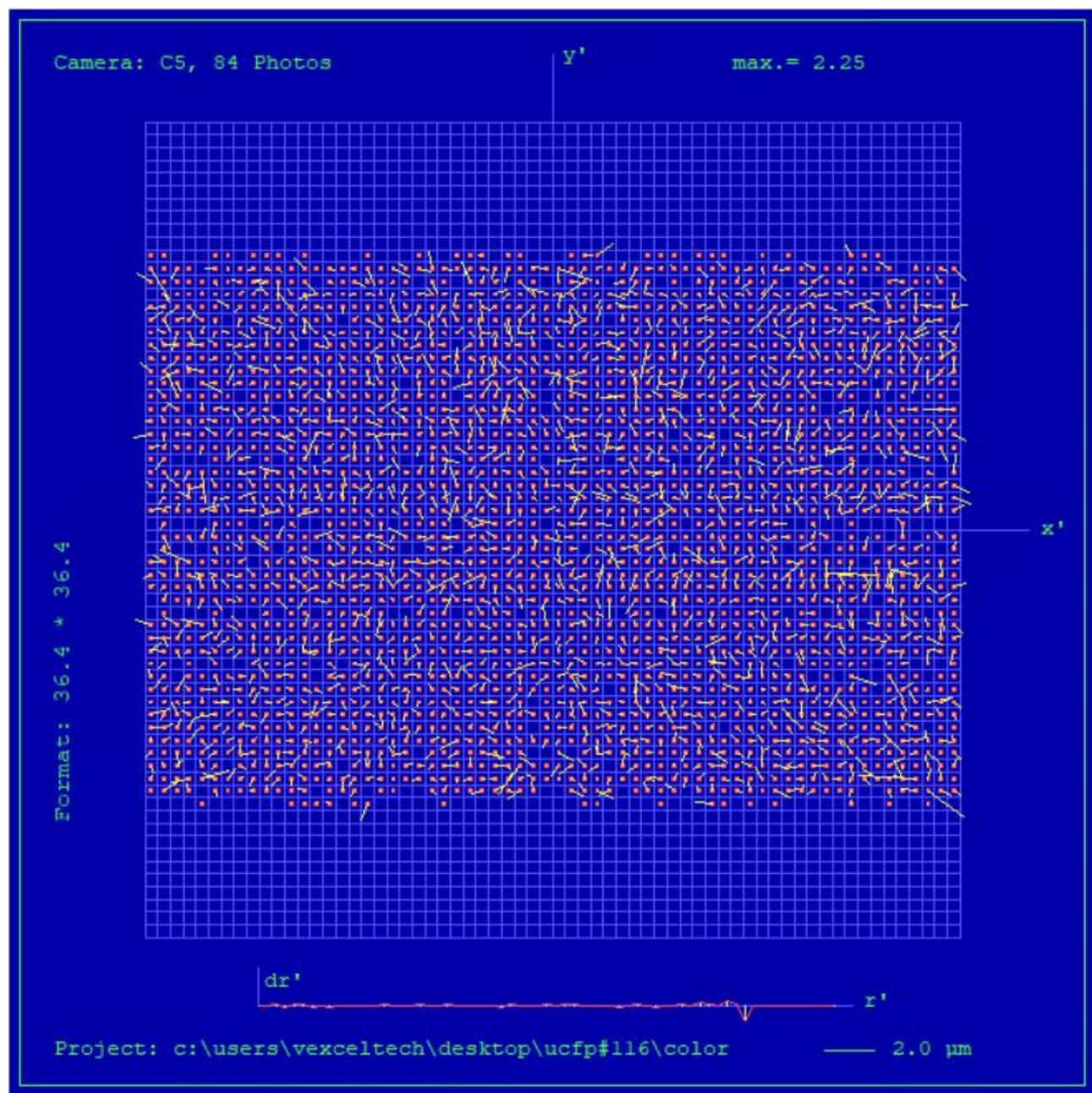
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): 0.56 μm



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): 0.63 μ m



Explanations

Calibration Method:

The geometric calibration is based on a set of 84 images of a defined geometry target with 394 GCPs.

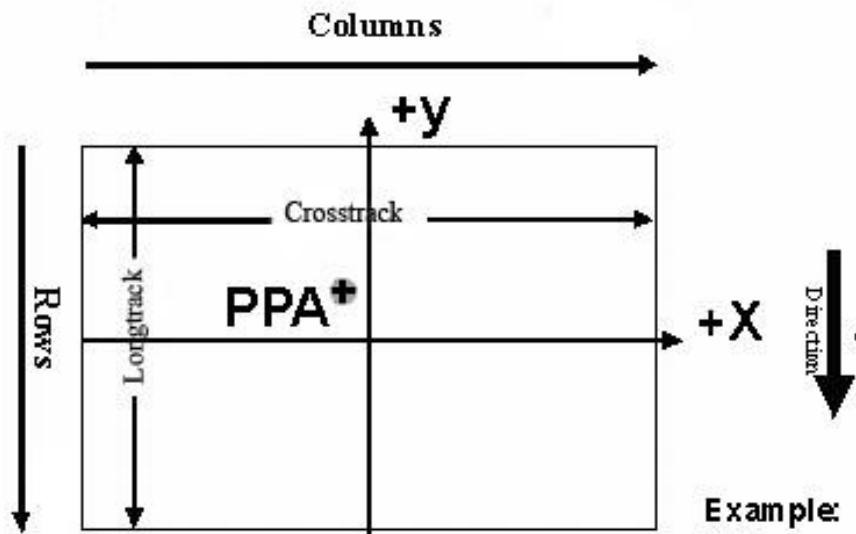
Number of point measurements for the panchromatic camera : >16000
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

Software used for the adjustment: BINGO (GIP Eng. Aalen, Germany)

Level 2 Image Coordinate System:

Lvl2, Camera prop. Orientation

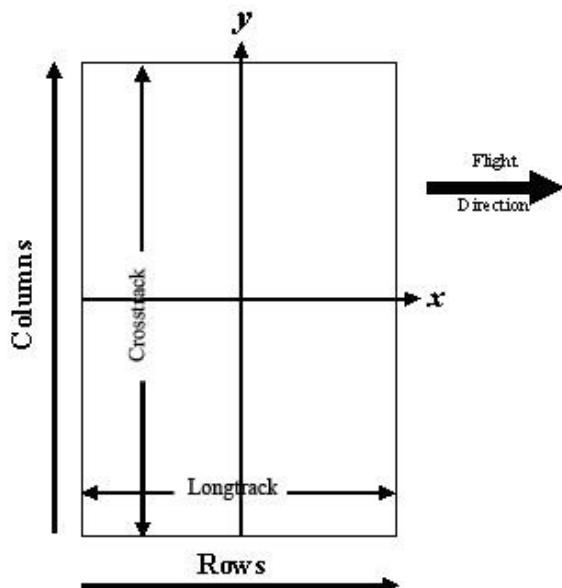




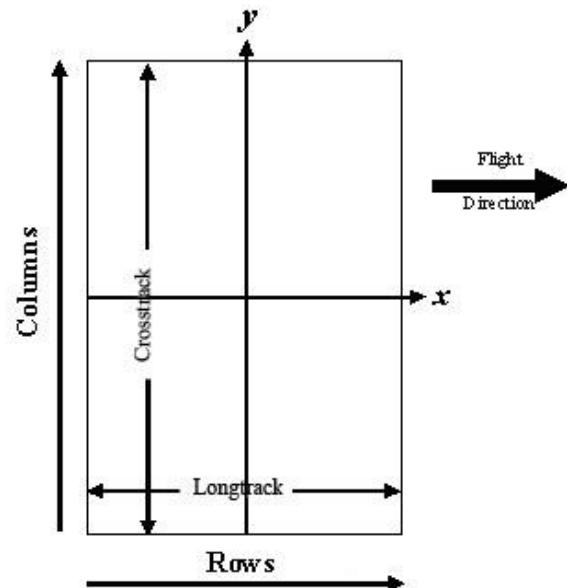
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).

**Level 3 Image Coordinate System:**

(after rotation of 270° CW)



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

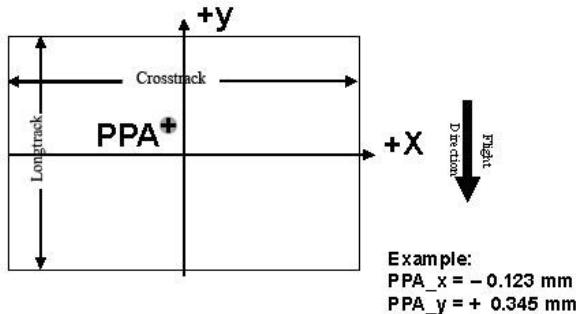
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified for clockwise (CW) rotation in steps of 90 degrees, according to the principal point coordinate given on page 4 for high- and low resolution images.

Image Format	Clockwise Rotation (Degree)	PPA	
		X	Y
Level 2	-	0.000	0.000
Level 3	0	0.000	0.000
Level 3	90	0.000	-0.000
Level 3	180	-0.000	-0.000
Level 3	270	-0.000	0.000

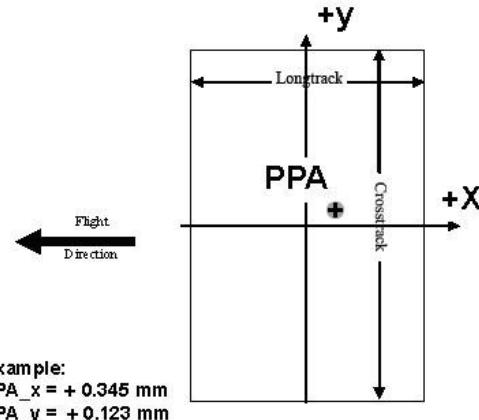


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

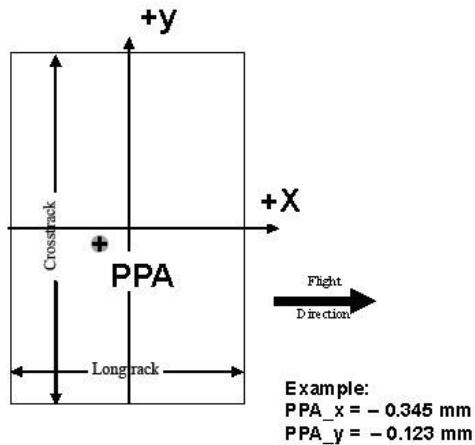
Lvl3, Rotation 0 deg clockwise



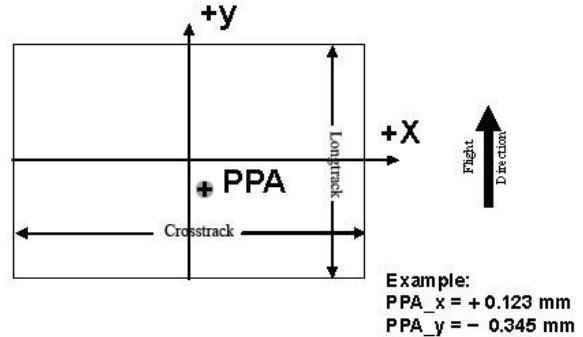
Lvl3, Rotation 90 deg clockwise



Lvl3, Rotation 270 deg clockwise



Lvl3, Rotation 180 deg clockwise





Lens Resolving Power

The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones.

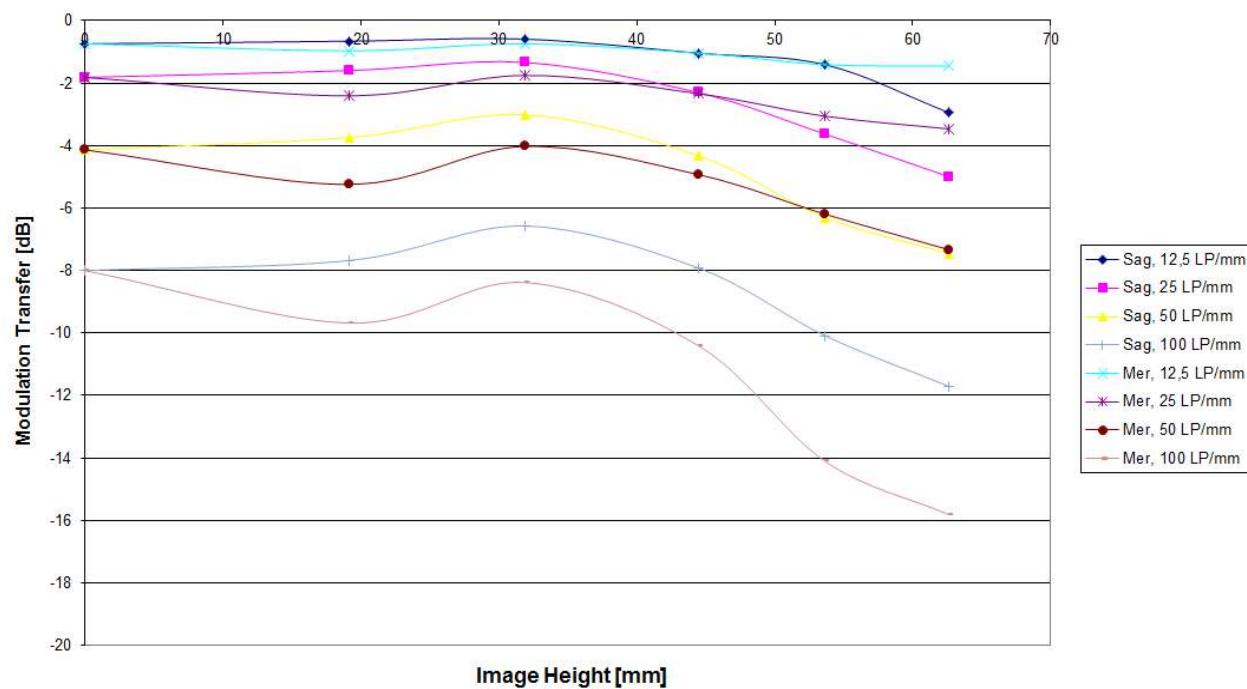
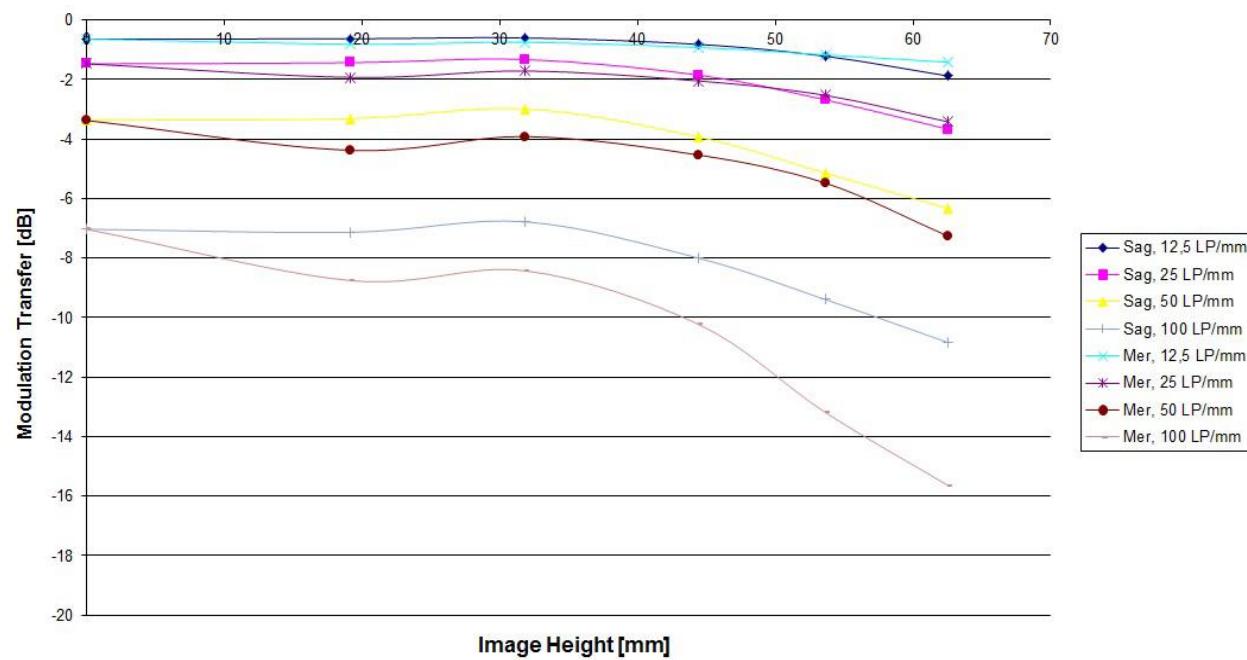
Please note that these values have been calculated and can vary up to 10% with optics from production (especially at high LP's).

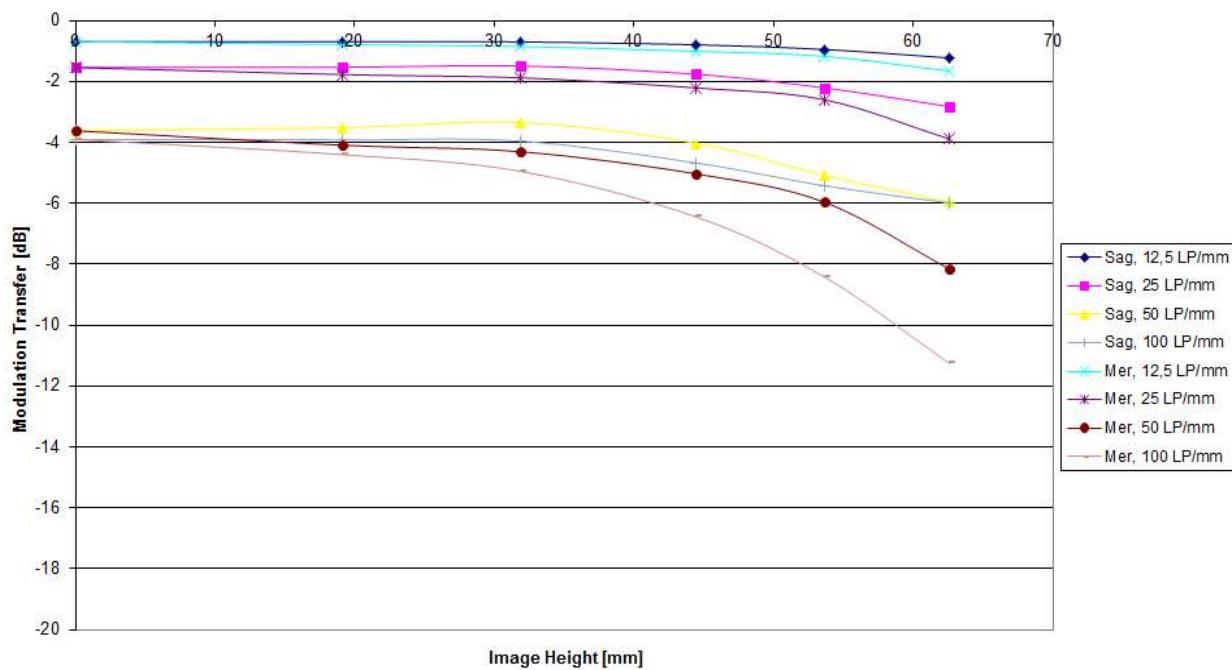
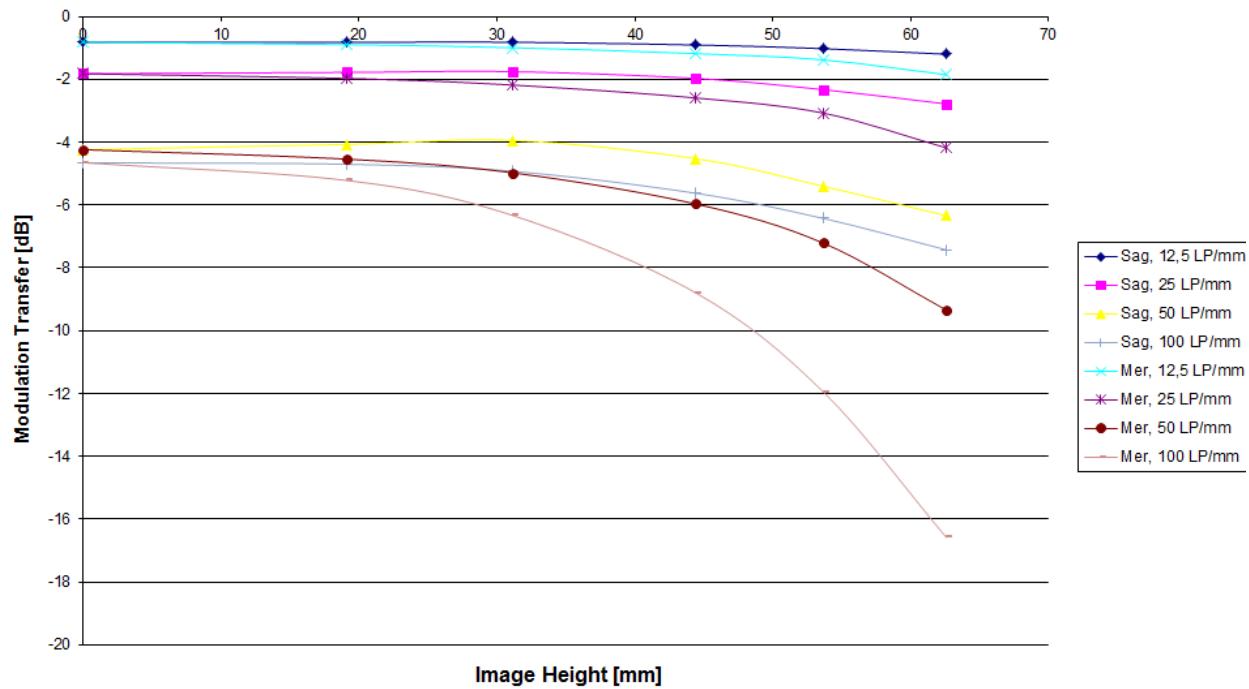
The curves are given for the meridional (tangential) and sagital (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

Cone	Lens
C0	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C1	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C2	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C3	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C4 (RED)	Linos Vexcel Apo-Sironar Digital HR 1:4/33mm, Linos GmbH, Germany
C5 (GREEN)	Linos Vexcel Apo-Sironar Digital HR 1:4/33mm, Linos GmbH, Germany
C6 (BLUE)	Linos Vexcel Apo-Sironar Digital HR 1:4/33mm, Linos GmbH, Germany
C7 (NIR)	Linos Vexcel Apo-Sironar Digital HR 1:4/33mm, Linos GmbH, Germany

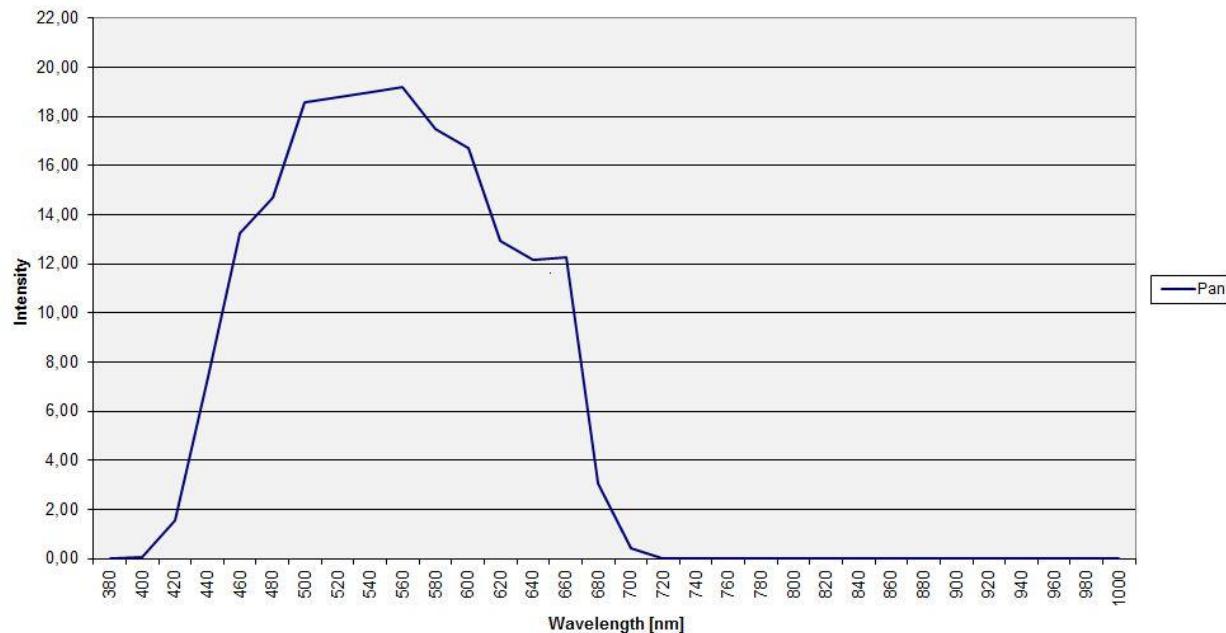
Modulation versus Image Height - Aperture f / 5.6

Modulation versus Image Height - Aperture f / 6.7


Modulation versus Image Height - Aperture f / 8

Modulation versus Image Height - Aperture f / 9.5


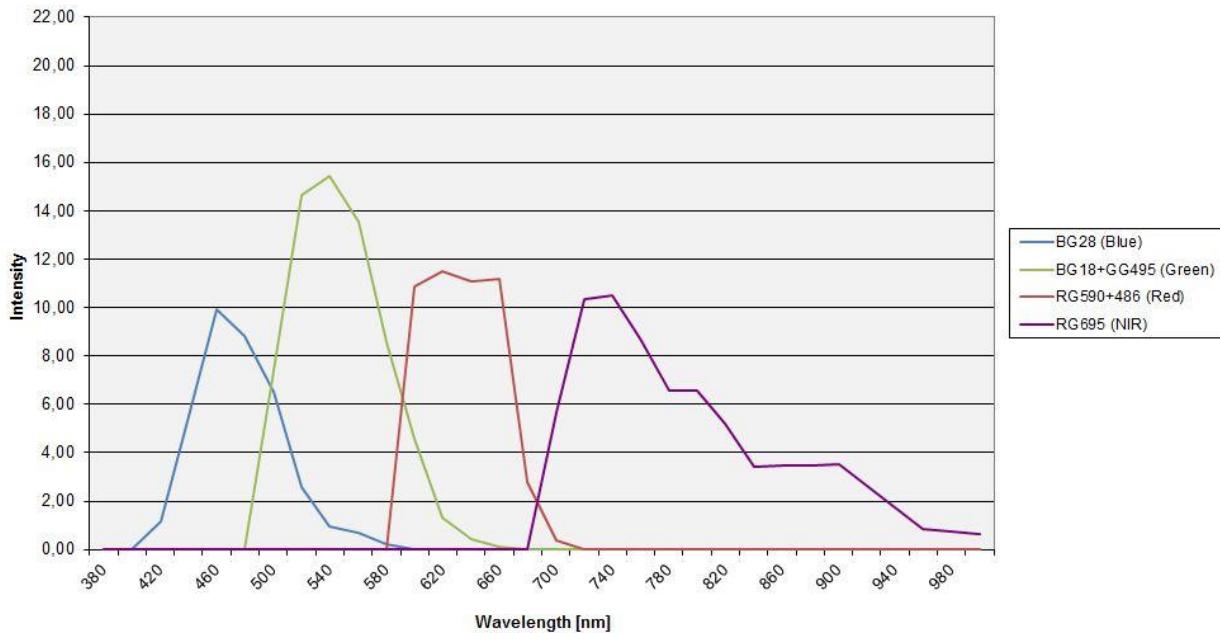


Spectral Sensitivity

Spectral Sensitivity Vexcel UCX - Panchromatic
with AR-106 Coating



Spektral Sensitivity Vexcel UCX - Multispectral
with AR-106 Coating





ULTRACAM

Radiometric Calibration

Camera:

UltraCam Falcon Prime

Serial:

UC-Fp-1-40616106-f100

Used Apertures	PAN	R, G, NIR	B
	F5.6	F4.8	F4.8
	F6.7	F5.6	F4.8
	F8	F6.7	F4.8
	F9.5	F8	F5.6
	F11	F9.5	F6.7
	F13	F11	F8
	F16	F13	F9.5
	F22	F19	F13

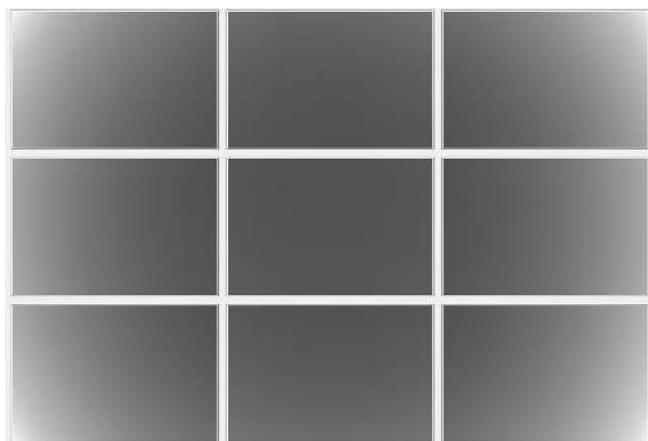
Dead Pixel Report: see Appendix I



Calibration of Vignetting for working Aperture F6.7

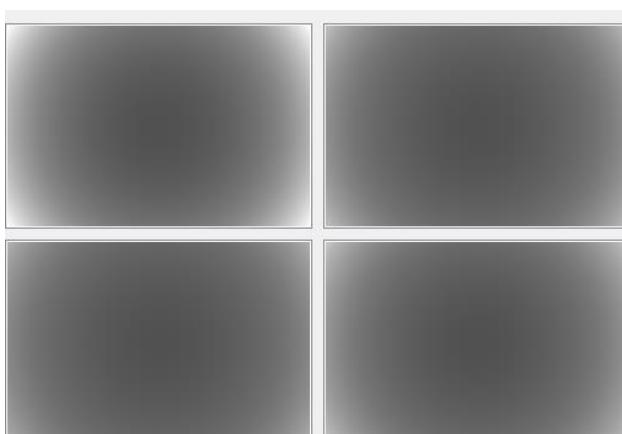
Aperture	PAN	R, G, NIR	B
	F6.7	F5.6	F4.8

Graphical Overview of Pan Sensors:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensors:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)



Explanations

Calibration Method:

The radiometric calibration is based on a series of 50 flat field images for each aperture size and sensor. The flat field is illuminated by eight normal light lamps with known spectral illumination curves.

These images are used to calculate the specific sensitivity of each pixel to compensate local as well as global variations in sensitivity. Sensitivity tables are calculated for each sensor and aperture setting, and applied during post processing from level 0 to level 1.

Outlier Pixels that do not have a linear behavior as described in the CCD specifications are marked as defective during the calibration procedure. These pixels are not used or only partially used during post processing and the information is restored by interpolation between the neighborhood pixels surrounding the defective pixels.

Certain pixels that are named Qmax pixels due to the fact that they can only store and transfer charge up to a certain maximum amount are detected in an additional calibration step. These pixels are treated differently during post processing, since their behavior can affect not only single pixel values but whole columns.



ULTRACAM

Shutter Calibration

Camera:

UltraCam Falcon Prime

Serial:

UC-Fp-1-40616106-f100

Panchromatic Camera:

4 * Prontor Magnetic 0 HS

Prontor-Werk Alfred Gauthier GmbH, Germany

Multispectral Camera:

4 * Prontor Magnetic 0 HS

Prontor-Werk Alfred Gauthier GmbH, Germany



Calibration of Shutter Release Times:

The shutter release times measured during the calibration describe the time from the moment when the electrical current through the shutter is turned off by the electronics, until the shutter is mechanically closed.

This time is relevant for the exposure control and needs to be known before image recording can take place.

Currently used SRT values (operation values):

Cone Number	Lens Serial Number	SRT F5.6 [ms]	SRT F6.7 [ms]	SRT F8 [ms]	SRT F9.5 [ms]	SRT F11 [ms]	SRT F13 [ms]	SRT F16 [ms]	SRT F22 [ms]	Measurement Tolerance [ms]
C0 (Pan)	12 23 55 19	6.85	6.98	7.08	1.30	7.52	7.69	7.82	7.96	+/- 0.2
C1 (Pan)	12 22 11 11	6.50	6.64	6.73	6.95	7.16	7.31	7.49	7.60	+/- 0.2
C2 (Pan)	12 22 11 03	7.05	7.13	7.11	7.25	7.48	7.60	7.78	7.94	+/- 0.2
C3 (Pan)	12 22 11 14	6.95	7.09	7.32	7.57	7.76	7.96	8.21	8.24	+/- 0.2
C4 (Red)	12 21 89 94	7.25	7.34	7.54	7.67	7.75	7.87	7.90	8.04	+/- 0.2
C5 (Green)	12 21 89 90	6.72	6.80	6.92	7.14	7.27	7.36	7.37	7.43	+/- 0.2
C6 (Blue)	12 21 89 92	6.61	6.62	6.62	6.75	6.96	7.11	7.28	7.39	+/- 0.2
C7 (NIR)	12 23 11 80	7.43	7.58	7.70	7.76	7.87	7.91	8.01	8.06	+/- 0.2



ULTRACAM

Electronics and Sensor Calibration

Camera:

UltraCam Falcon Prime

Serial:

UC-Fp-1-40616106-f100

Panchromatic Camera:

9 * FTF6040-M Area CCD Sensor by DALSA

Multispectral Camera:

4 * FTF6040-M Area CCD Sensor by DALSA



Calibration of Negative Substrate Voltage (VNS):

For optimum performance of the DALSA CCD sensors, the negative substrate voltage is adjusted to a value specified by DALSA.

This voltage value is measured to achieve the best anti-blooming performance possible for each particular sensor.

Currently used VNS and VOG values (operation values):

Cone_Sensor	Sensor Type	Sensor Serial Number	VNS Voltage [V]
00_00	FTF6040-M	157 701/025	22.50
00_01	FTF6040-M	157 701/017	22.50
00_02	FTF6040-M	157 701/007	22.50
00_03	FTF6040-M	157 701/011	22.50
01_00	FTF6040-M	157 701/014	22.50
01_01	FTF6040-M	157 701/018	22.50
02_00	FTF6040-M	157 701/027	22.50
02_01	FTF6040-M	157 701/030	22.50
03_00	FTF6040-M	157 701/028	22.50
04_00 (red)	FTF6040-M	157 701/035	22.50
05_00 (green)	FTF6040-M	155 293/073	21.80
06_00 (blue)	FTF6040-M	155 293/077	22.50
07_00 (NIR)	FTF6040-M	155 293/092	22.50



Calibration of Intensity Threshold for Exposure Control:

Each CCD sensor and electronics module varies slightly in global sensitivity and intensity scale.

Therefore the maximum possible intensity of each sensor needs to be measured to evaluate the sensitivity behavior of the CCD and electronics.

This value is used as a threshold for the exposure control dialogue shown in the in-flight user interface of the Eagle.

Currently used Threshold values (operation values):

Cone_Sensor	Sensor Type	Sensor Serial Number	Intensity Threshold [DN]
00_00	FTF6040-M	157 701/025	13370
00_01	FTF6040-M	157 701/017	13260
00_02	FTF6040-M	157 701/007	13690
00_03	FTF6040-M	157 701/011	13480
01_00	FTF6040-M	157 701/014	13560
01_01	FTF6040-M	157 701/018	13810
02_00	FTF6040-M	157 701/027	14460
02_01	FTF6040-M	157 701/030	13250
03_00	FTF6040-M	157 701/028	13440
04_00 (red)	FTF6040-M	157 701/035	13530
05_00 (green)	FTF6040-M	155 293/073	12340
06_00 (blue)	FTF6040-M	155 293/077	12580
07_00 (NIR)	FTF6040-M	155 293/092	12510



ULTRACAM

Summary

Camera:	UltraCam Falcon Prime
Serial:	UC-Fp-1-40616106-f100
Laboratory Calibration Date:	Apr-06-2020
Camera Revision:	Rev04.00
Date of Report:	Apr-15-2020
Version of Report:	V04

The following calibrations have been performed for the above mentioned digital aerial mapping camera:

- Geometric Calibration
- Radiometric Calibration
- Shutter Calibration
- Sensor and Electronics Calibration

This equipment is operating fully within specification as defined by Vexcel Imaging GmbH.



Dr. Michael Gruber
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Vexcel Imaging GmbH



Dipl. Ing. (FH) Helmut Jauk
Senior Project Engineer R&D
Vexcel Imaging GmbH



Appendix I

Dead Pixel Report:

Sensor number	Anomaly type	X-Coordinate	Y-Coordinate
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C00-00

PIXEL: 120/2993
PIXEL: 424/ 756
PIXEL: 431/ 833
PIXEL: 1097/ 525
PIXEL: 1417/1631
PIXEL: 1930/1194
PIXEL: 2161/3445
PIXEL: 2475/1531
PIXEL: 2762/3340
PIXEL: 3601/2422
PIXEL: 3895/3732
PIXEL: 4157/2964
PIXEL: 4532/3612
PIXEL: 4555/ 221
PIXEL: 4616/2548
PIXEL: 4763/1130
PIXEL: 5016/1215
PIXEL: 5372/ 653
PIXEL: 5987/1047

C00-01

PIXEL: 1825/2321
PIXEL: 2459/3334
PIXEL: 2517/2816
PIXEL: 2745/1964
PIXEL: 3060/3107
PIXEL: 3123/2605
PIXEL: 3253/2974
PIXEL: 4006/1647
PIXEL: 4216/3567
PIXEL: 4302/2061
PIXEL: 4412/1480
PIXEL: 4483/ 595
PIXEL: 5099/2116
PIXEL: 5154/2254



PIXEL: 5718/2493
PIXEL: 232/3264
PIXEL: 1163/1220

C00-02

PIXEL: 1701/2210
PIXEL: 3682/1143
PIXEL: 62/3665
PIXEL: 3198/3021

C00-03

PIXEL: 66/1406
PIXEL: 513/3162
PIXEL: 820/3060
PIXEL: 837/2057
PIXEL: 910/3807
PIXEL: 1365/1993
PIXEL: 1421/2632
PIXEL: 1648/2324
PIXEL: 2225/2327
PIXEL: 5085/2211
PIXEL: 5157/2301
PIXEL: 5224/1837
PIXEL: 5296/ 791
PIXEL: 5501/1679
PIXEL: 2763/2241

C01-00

PIXEL: 814/3270
PIXEL: 1435/3526
PIXEL: 1931/3837
PIXEL: 2578/ 955
PIXEL: 4349/ 386
PIXEL: 4578/ 663
PIXEL: 4599/2966
PIXEL: 5252/2647
PIXEL: 3870/3965
PIXEL: 5376/1680
PIXEL: 5376/1681
PIXEL: 5376/1682

C01-01

PIXEL: 3844/2700
PIXEL: 5018/1621
PIXEL: 5492/3073
PIXEL: 5648/ 369

C02-00

PIXEL: 3255/2001



PIXEL: 5226/ 740

C02-01

PIXEL: 44/2851
PIXEL: 52/2427
PIXEL: 249/ 397
PIXEL: 551/1756
PIXEL: 1362/3041
PIXEL: 2729/3224
PIXEL: 2906/1430
PIXEL: 3018/ 518
PIXEL: 3257/ 987
PIXEL: 3801/1626
PIXEL: 4113/3705
PIXEL: 4546/3773
PIXEL: 4781/1444
PIXEL: 4973/2429
PIXEL: 5609/ 211
PIXEL: 4513/1825
PIXEL: 97/3950

C03-00

PIXEL: 713/ 520
PIXEL: 722/1648
PIXEL: 987/ 864
PIXEL: 2667/1381
PIXEL: 3672/ 861
PIXEL: 4732/2124
PIXEL: 5057/3021
PIXEL: 3814/3489
COLUMN: 1006/1243

C04-00

PIXEL: 2844/1671
PIXEL: 4257/3612
PIXEL: 5507/1480
PIXEL: 2051/3391
PIXEL: 3085/2815
PIXEL: 4856/2297
PIXEL: 5511/2155
PIXEL: 5511/2156
PIXEL: 5512/2154
PIXEL: 5512/2155
PIXEL: 5512/2156

C05-00

PIXEL: 2096/1446
PIXEL: 3655/3618
PIXEL: 3943/2221



PIXEL: 5681/1348

PIXEL: 5876/2137

PIXEL: 5987/1577

PIXEL: 118/ 60

PIXEL: 695/1405

PIXEL: 695/1406

PIXEL: 5845/1343

PIXEL: 6016/ 49

PIXEL: 6016/ 50

C06-00

PIXEL: 1832/3609

PIXEL: 2772/1355

PIXEL: 3403/3355

PIXEL: 3981/ 377

PIXEL: 5117/1898

PIXEL: 54/3874

C07-00

PIXEL: 349/ 668

PIXEL: 968/ 800

PIXEL: 1493/3455

PIXEL: 1985/3491

PIXEL: 2272/1061

PIXEL: 4578/2297

PIXEL: 5043/ 760

PIXEL: 5737/ 976

PIXEL: 130/3795

PIXEL: 131/3794

PIXEL: 131/3795

PIXEL: 1100/3903

PIXEL: 2788/2755

Notes



COLUMN anomaly: all pixels below the Qmax detector at location (X,Y) may be affected.

PIXEL anomaly: single detector at location (X,Y) is not functioning within normal range

The Level0 coordinates exclude the two leftmost pixels containing the line index: the corresponding pixel can therefore be located at column (X+2,Y).

Appendix II

Calibration and Modification Dates

Type of Calibration	Laboratory Calibration Date	Modification Date	Modification Reason
Geometric Calibration	06.Apr.2020	N/A	
Radiometric Calibration	06.Apr.2020	N/A	
Shutter Calibration	06.Apr.2020	N/A	
Electronics and Sensor Calibration	06.Apr.2020	N/A	



Note: The above-mentioned Laboratory Calibration Dates represent the dates the camera was calibrated in one of our calibration labs for a full Laboratory Calibration. The Modification date represents a date on which the calibration has been modified due to a calibration enhancement or part exchange. It is an additional information and does not replace the Laboratory Calibration date in any way. With the Modification Reason, always the last modification to the calibration is highlighted.