



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 Eagle M3
Serial: UC-EpII-1-62411397-f80

Panchromatic Camera: ck = 79.800 mm
Multispectral Camera: ck = 79.800 mm

PPA Information: X: 0.000 mm
Y: -0.080 mm



Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track cross track	68.016mm 105.840mm	17004pixel 26460pixel
Image Extent		(-34.008, -52.920)mm	(34.008, 52.920)mm
Pixel Size		4.000µm*4.000µm	
Focal Length	ck	79.800mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	-0.080mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

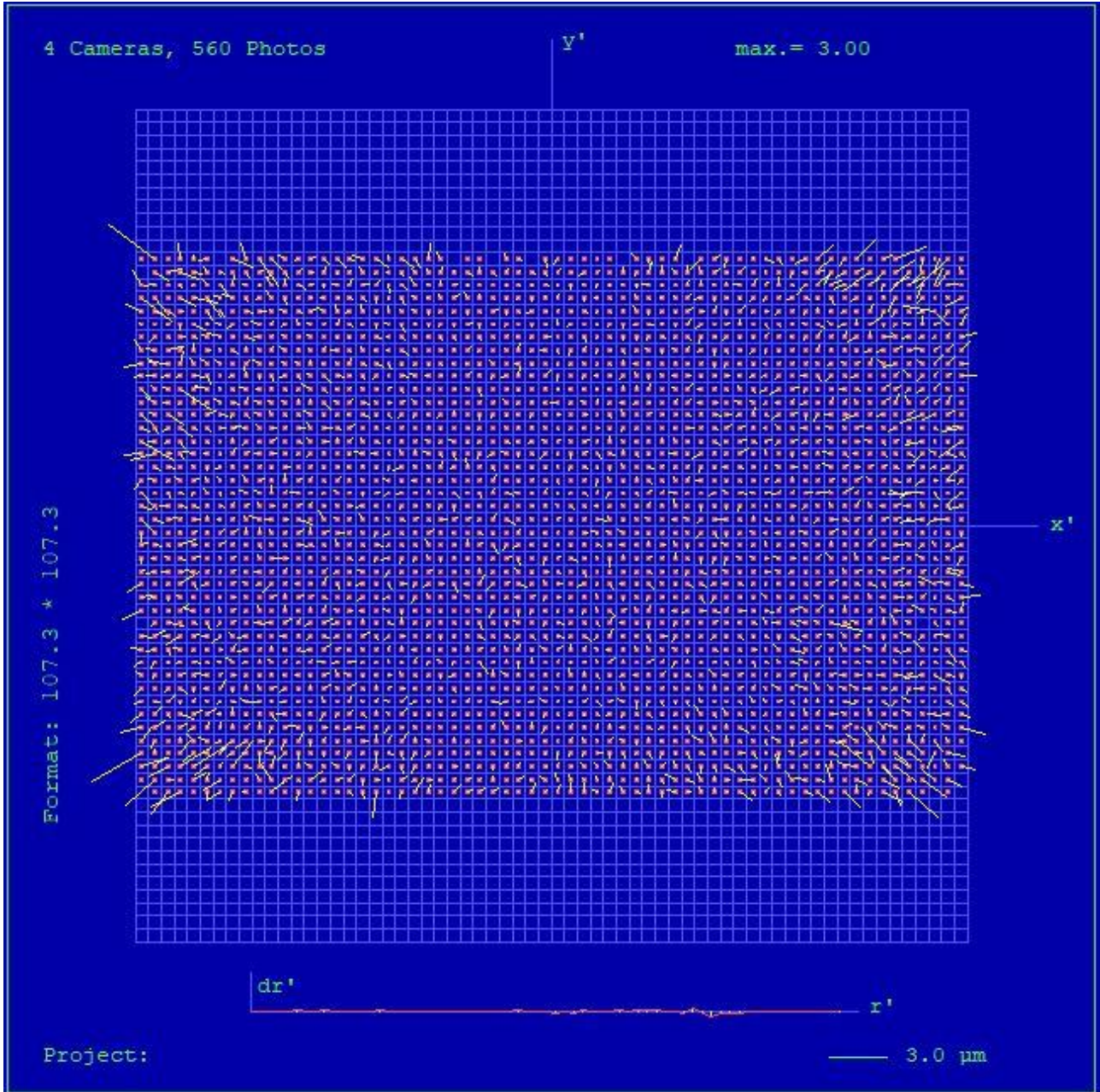
Multispectral Camera

Medium Format Multispectral Output Image (Upscaled to panchromatic image format)

Image Format	long track cross track	68.016mm 105.840mm	5668pixel 8820pixel
Image Extent		(-34.008, -52.920)mm	(34.008, 52.920)mm
Pixel Size		12.000µm*12.000µm	
Focal Length	ck	79.800mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	-0.080mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		



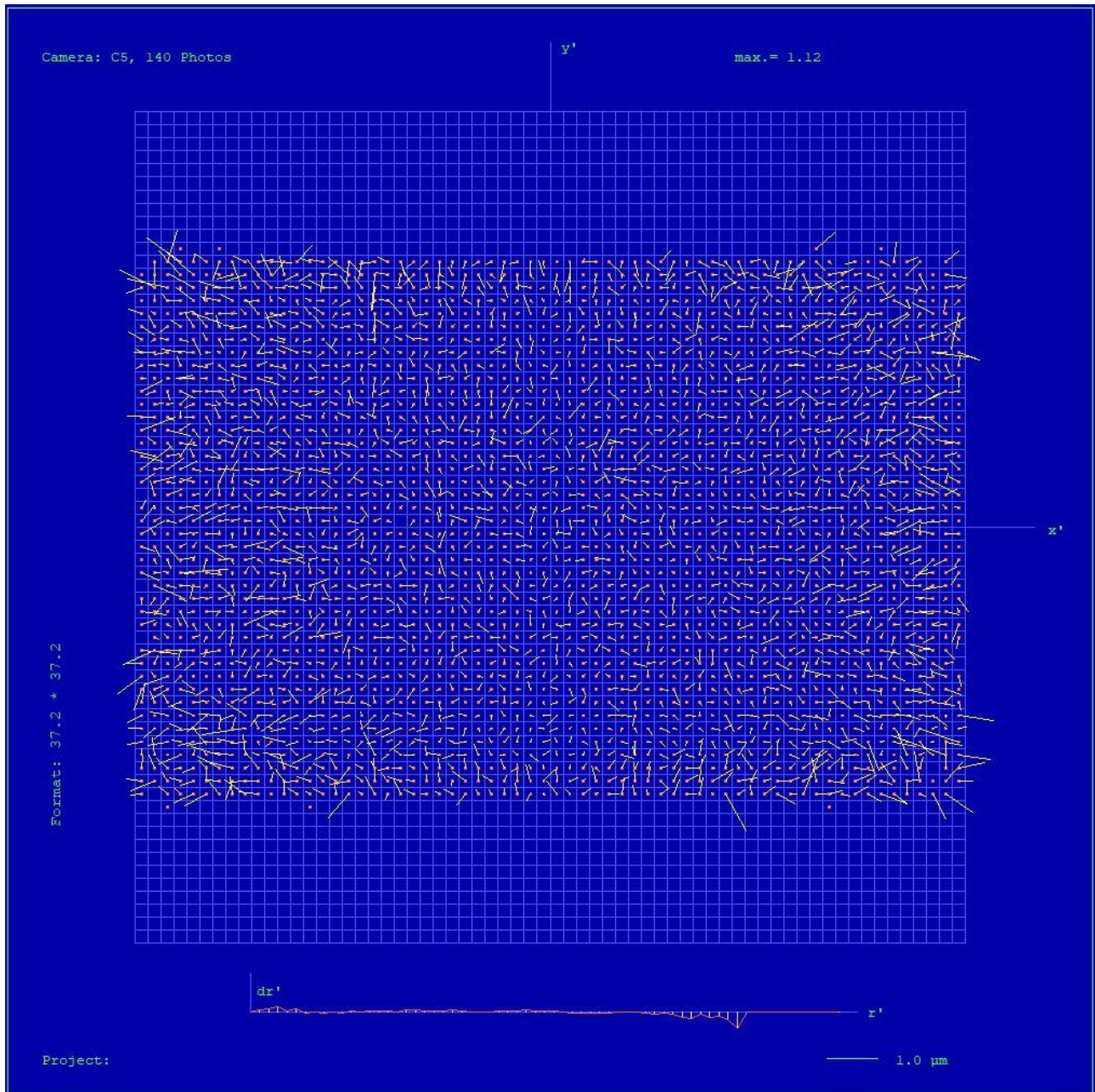
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.64 μm**



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.47 μm**



Explanations

Calibration Method:

The geometric calibration is based on a set of 140 images of a defined geometry target with 394 GCPs.

Number of point measurements for the panchromatic camera : >16000

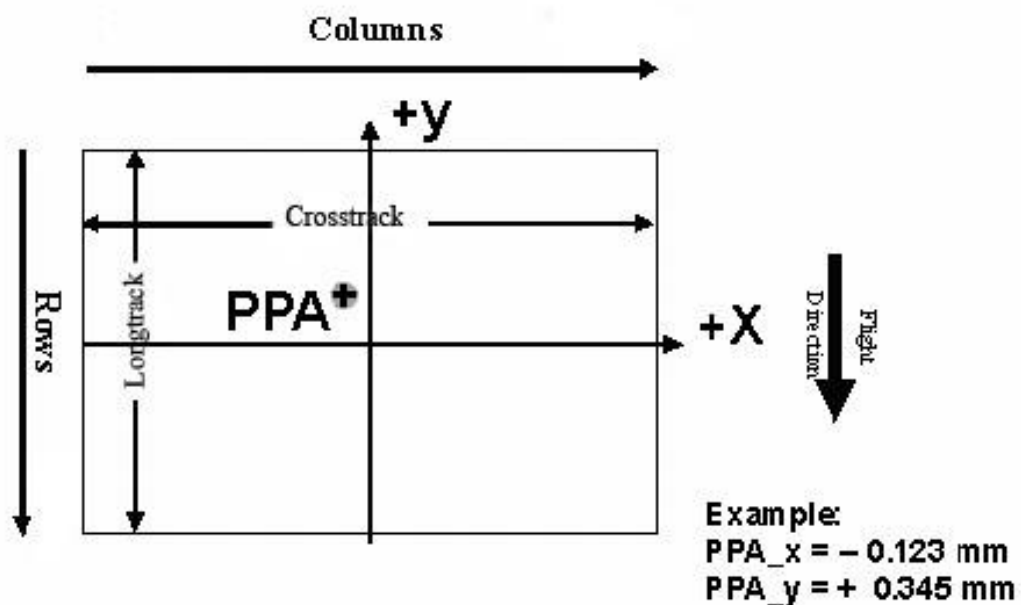
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

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

Level 2 Image Coordinate System:

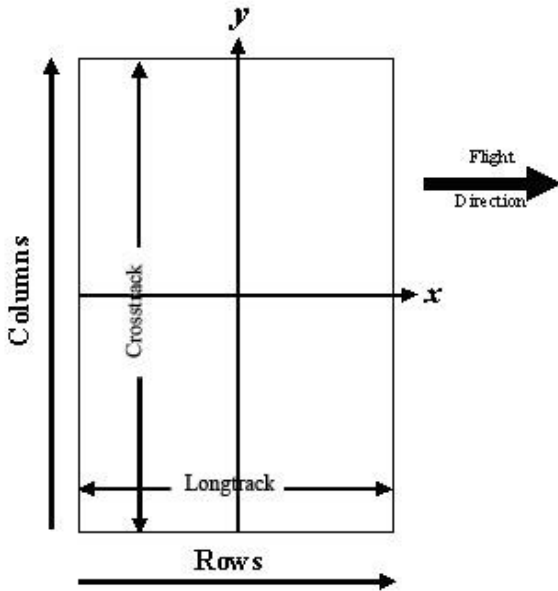
Lvl2, Camera prop. Orientation



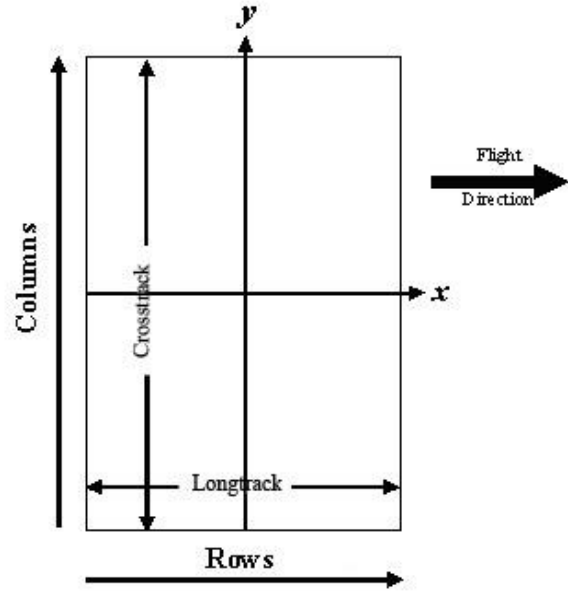
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



Level 3 Image Coordinate System:
(after rotation of 270° CW)



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

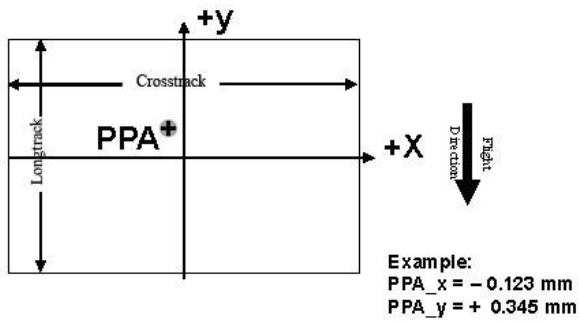
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified 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	-0.080
Level 3	0	0.000	0.000
Level 3	90	-0.080	0.000
Level 3	180	0.000	0.080
Level 3	270	0.080	0.000

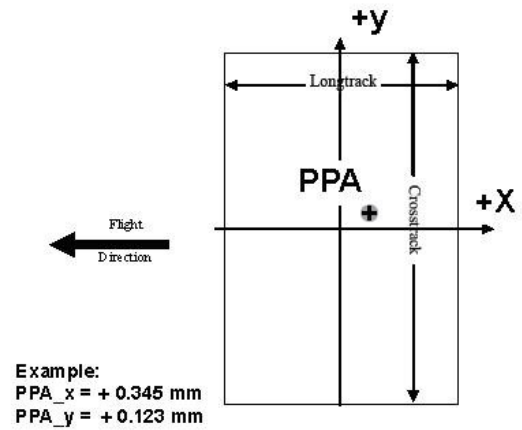


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

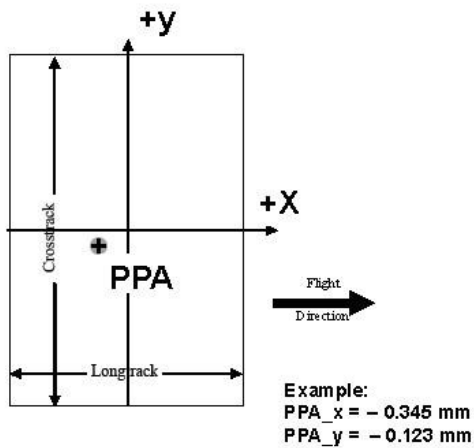
Lvl3, Rotation 0 deg clockwise



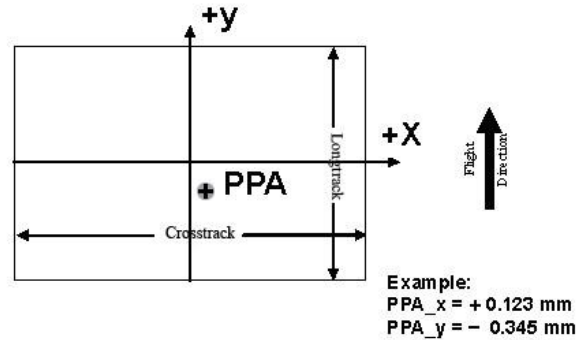
Lvl3, Rotation 90 deg clockwise



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 sagittal (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

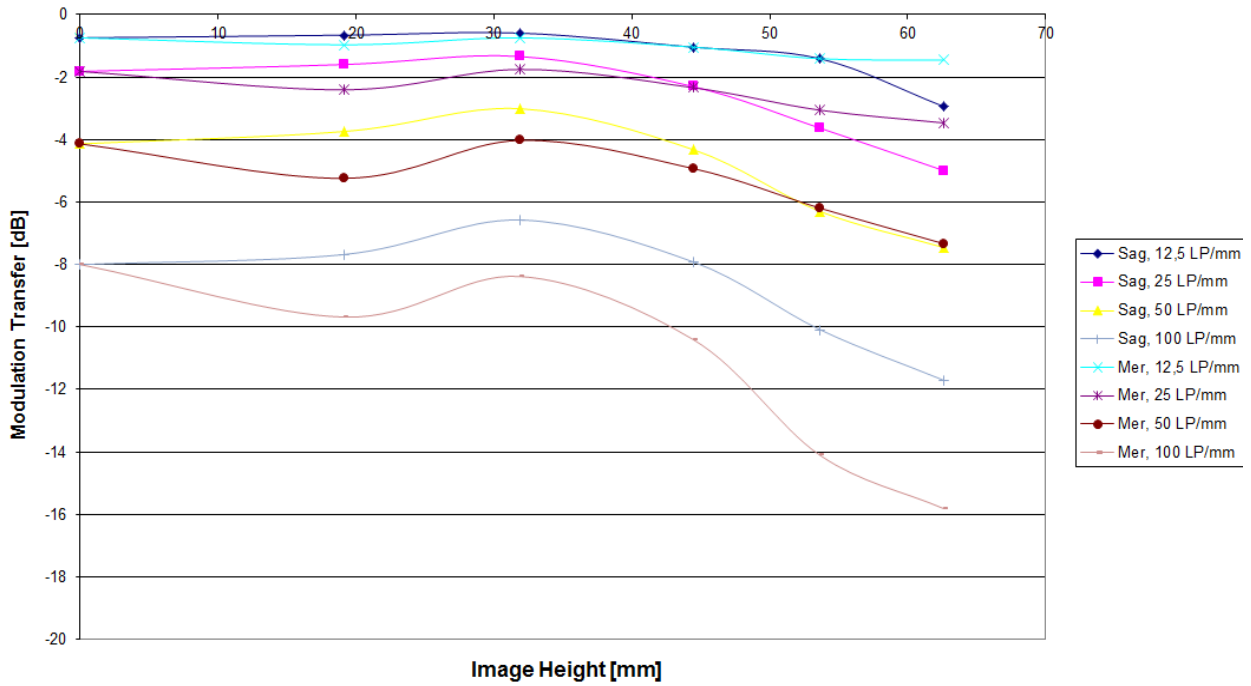
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

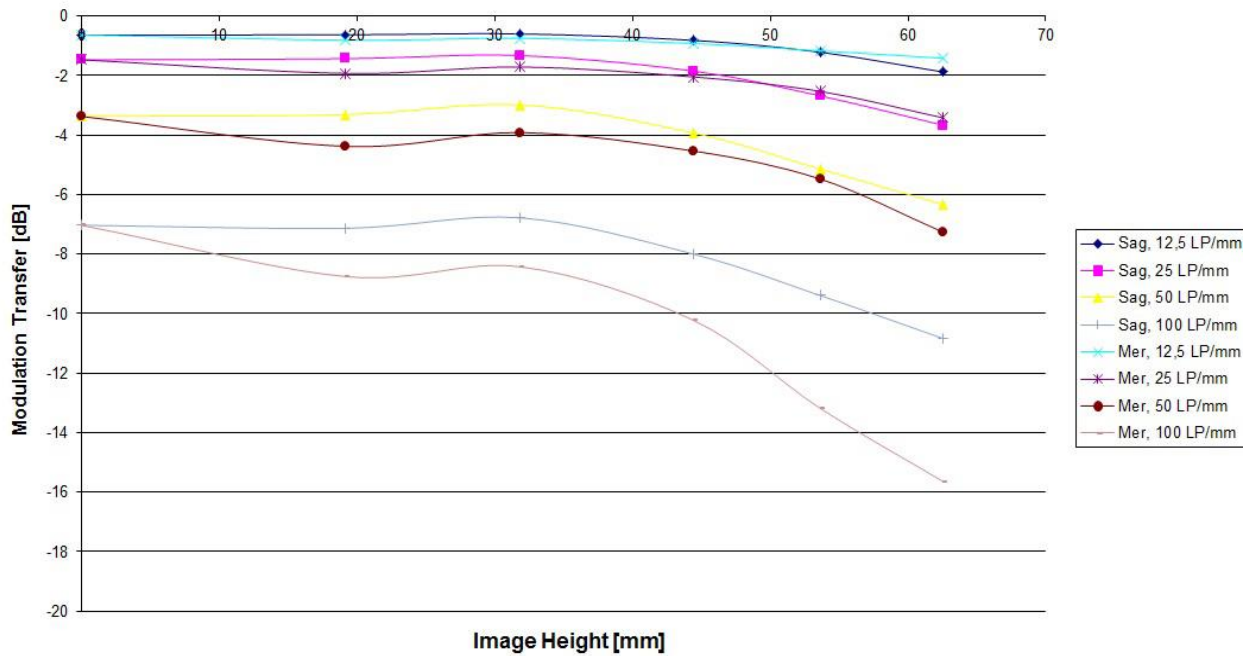
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic Vexcel HR Digaron 1:4/27mm, Qioptic GmbH, Germany
C5 (GREEN)	Qioptic Vexcel HR Digaron 1:4/27mm, Qioptic GmbH, Germany
C6 (BLUE)	Qioptic Vexcel HR Digaron 1:4/27mm, Qioptic GmbH, Germany
C7 (NIR)	Qioptic Vexcel HR Digaron 1:4/27mm, Qioptic GmbH, Germany



Modulation versus Image Height - Aperture f/ 5.6

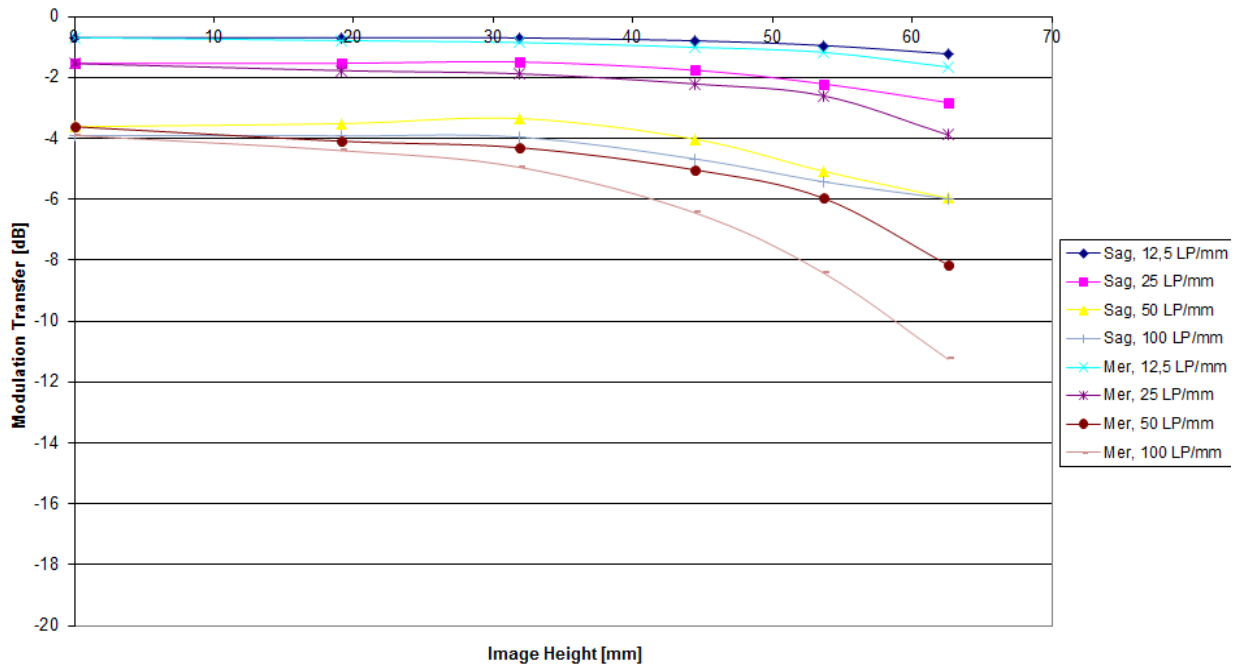


Modulation versus Image Height - Aperture f/ 6.7

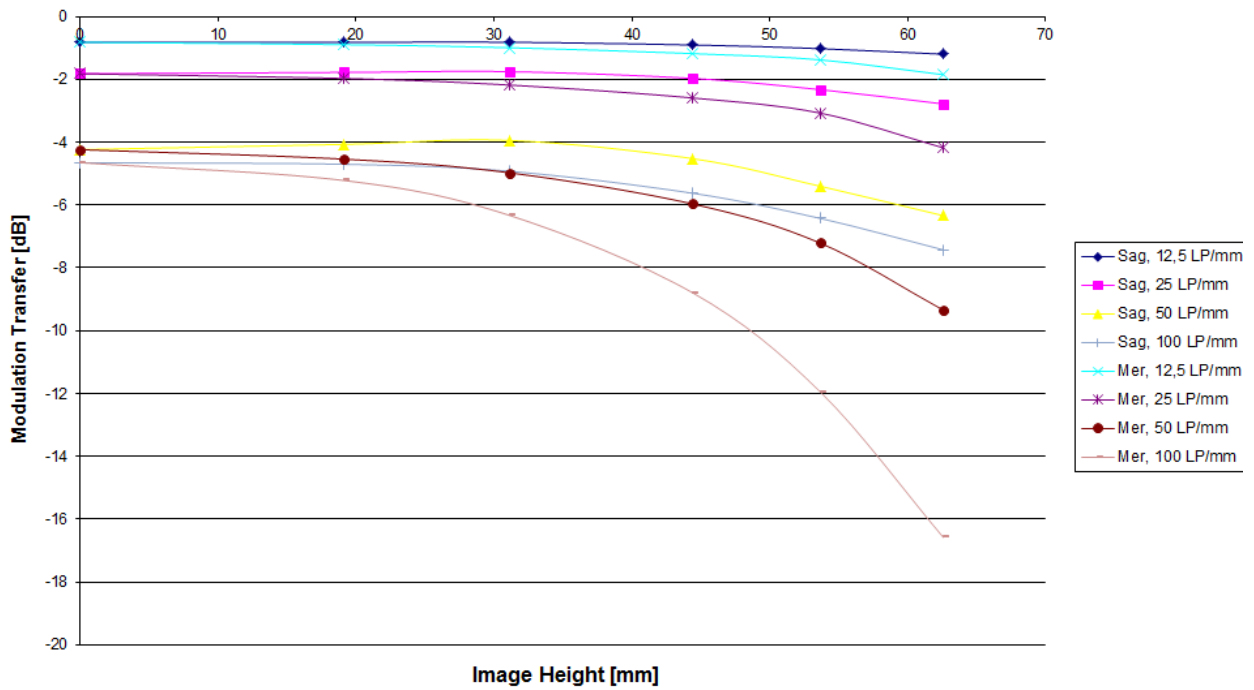




Modulation versus Image Height - Aperture f / 8

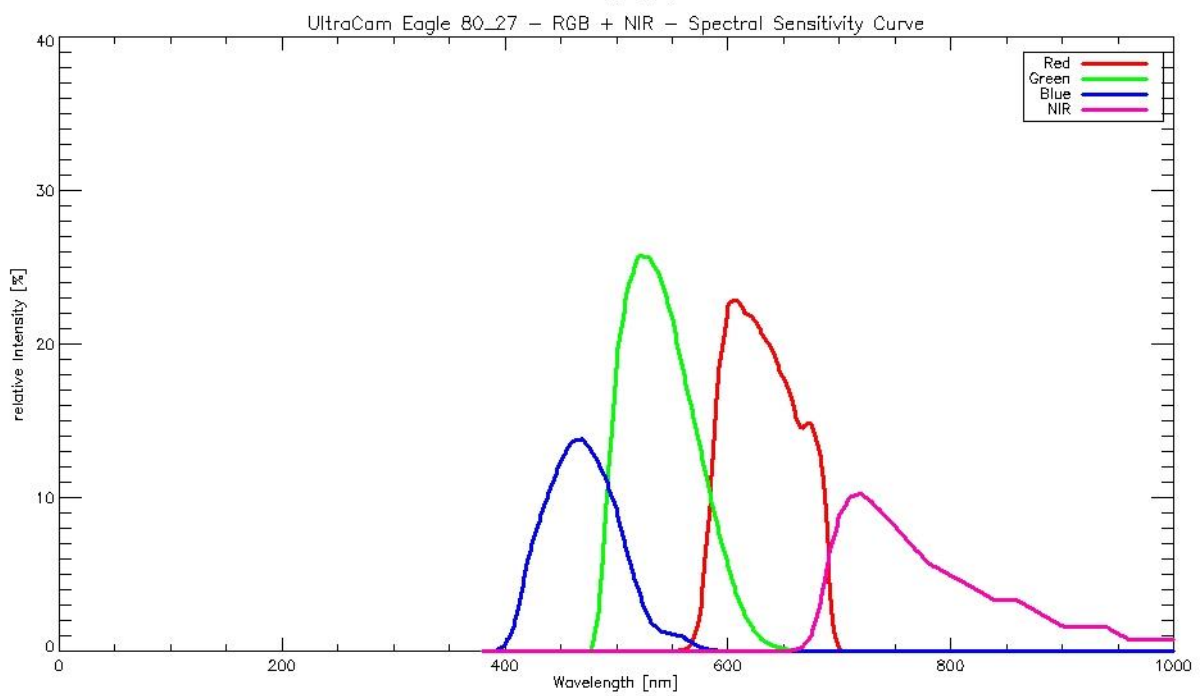
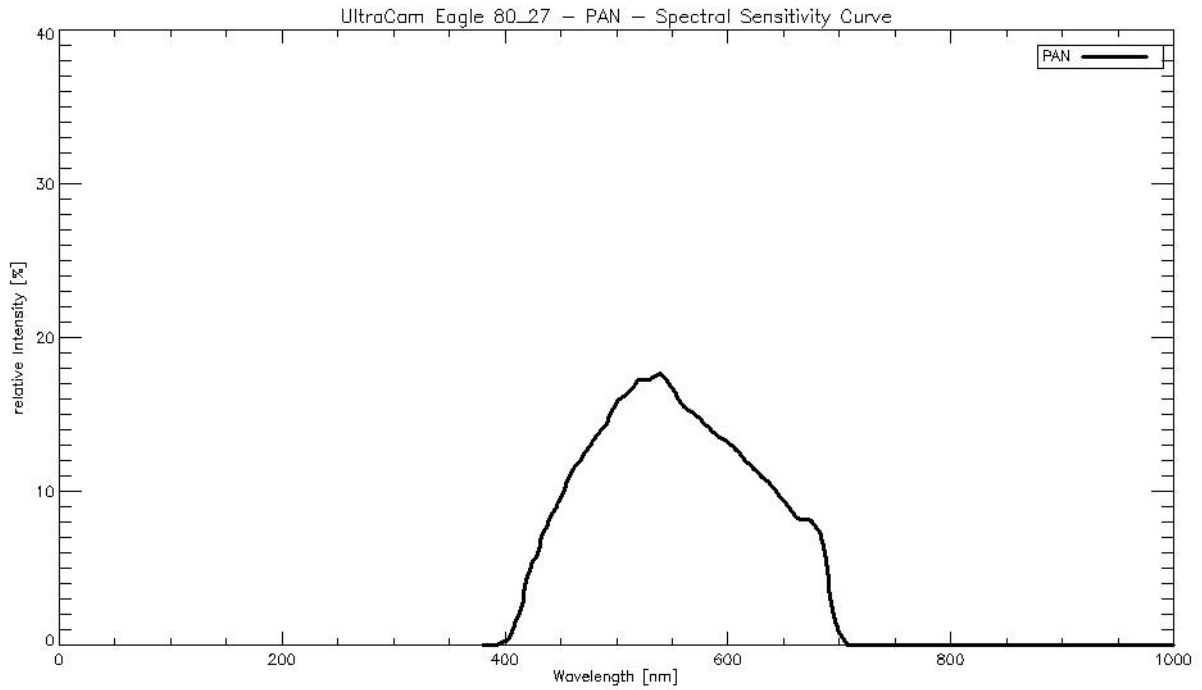


Modulation versus Image Height - Aperture f / 9.5





Spectral Sensitivity





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Radiometric Calibration

Camera: UltraCam Eagle M3
Serial: UC-EpII-1-62411397-f80

	PAN	R, G, NIR	B
Used Apertures	F5.6	F4.8	F4.8
	F6.7	F5.4	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

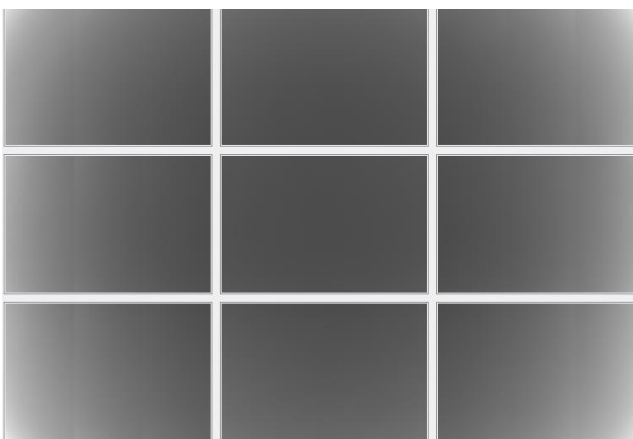
Dead Pixel Report: see Appendix I



Calibration of Vignetting for working Aperture F6.7

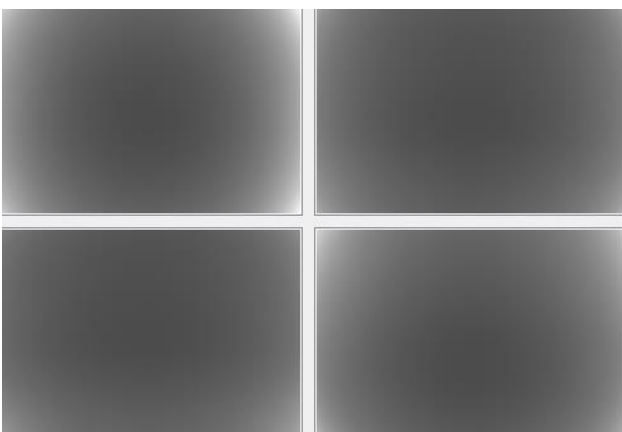
	PAN	R, G, NIR	B
Aperture	F6.7	F5.4	F4.8

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 Eagle M3
Serial: UC-EpII-1-62411397-f80

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 16 05 78	6.43	6.65	6.91	7.1	7.36	7.44	7.58	7.95	+/- 0.2
C1 (Pan)	12 16 05 84	6.68	6.93	7.18	7.4	7.56	7.75	7.96	8.18	+/- 0.2
C2 (Pan)	12 15 42 91	6.86	7.05	7.34	7.57	7.78	7.95	8.07	8.37	+/- 0.2
C3 (Pan)	12 16 05 88	6.46	6.67	6.93	7.19	7.42	7.57	7.69	7.93	+/- 0.2
C4 (Red)	12 11 00 37	7.08	7.12	7.16	7.34	7.44	7.53	7.58	7.65	+/- 0.2
C5 (Green)	12 11 00 62	7.26	7.37	7.46	7.57	7.77	7.88	7.98	8.19	+/- 0.2
C6 (Blue)	12 12 06 28	7.34	7.34	7.38	7.46	7.65	7.75	7.9	8.11	+/- 0.2
C7 (NIR)	12 15 32 05	7.68	7.68	7.84	7.99	8.1	8.13	8.2	8.38	+/- 0.2



ULTRACAM

Electronics and Sensor Calibration

Camera: UltraCam Eagle M3
Serial: UC-EpII-1-62411397-f80

Panchromatic Camera: 9 * FTF9060-M Area CCD Sensor by DALSA
Multispectral Camera: 4 * FTF9060-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]	VOG Voltage [V]
00_00	FTF9060-M	192209/001	22.20	6.58
00_01	FTF9060-M	192209/003	21.60	7.04
00_02	FTF9060-M	192209/086	22.20	6.53
00_03	FTF9060-M	192209/077	22.00	6.78
01_00	FTF9060-M	192209/085	21.60	6.62
01_01	FTF9060-M	192209/073	21.80	6.52
02_00	FTF9060-M	192209/080	22.00	6.26
02_01	FTF9060-M	192209/068	21.80	6.58
03_00	FTF9060-M	192209/059	21.80	6.34
04_00 (red)	FTF9060-M	192209/075	21.80	7.24
05_00 (green)	FTF9060-M	192209/050	22.00	6.53
06_00 (blue)	FTF9060-M	192209/084	22.00	6.22
07_00 (NIR)	FTF9060-M	192209/060	22.00	6.38



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]	
			Tap 1	Tap2
00_00	FTF9060-M	192209/001	13830	13140
00_01	FTF9060-M	192209/003	13420	12760
00_02	FTF9060-M	192209/086	13580	12970
00_03	FTF9060-M	192209/077	13600	12870
01_00	FTF9060-M	192209/085	14770	13460
01_01	FTF9060-M	192209/073	14090	13240
02_00	FTF9060-M	192209/080	13900	13160
02_01	FTF9060-M	192209/068	14150	13180
03_00	FTF9060-M	192209/059	14190	13220
04_00 (red)	FTF9060-M	192209/075	13100	12680
05_00 (green)	FTF9060-M	192209/050	14230	13200
06_00 (blue)	FTF9060-M	192209/084	13690	12900
07_00 (NIR)	FTF9060-M	192209/060	13880	12940



ULTRACAM

Summary

Camera: UltraCam Eagle M3
Serial: UC-EpII-1-62411397-f80

Laboratory Calibration Date: Jan-30-2020
Camera Revision: Rev02.00

Date of Report: Jan-30-2020
Version of Report: V01

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
Chief Scientist, Photogrammetry
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: 703/4566
PIXEL: 1117/4448
PIXEL: 1583/ 951
PIXEL: 1661/1748
PIXEL: 1767/4784
PIXEL: 2710/5443
PIXEL: 2913/2886
PIXEL: 3625/1955
PIXEL: 3646/3062
PIXEL: 3758/1925
PIXEL: 4645/3256
PIXEL: 4846/3099
PIXEL: 5273/1564
PIXEL: 6012/3189
PIXEL: 6437/3130
PIXEL: 6455/5687
PIXEL: 6662/2833
PIXEL: 7380/3283
PIXEL: 7873/5420
PIXEL: 8470/1013
PIXEL: 38/4737
PIXEL: 305/ 33
PIXEL: 388/5345
PIXEL: 388/5346
PIXEL: 1070/1902
PIXEL: 1315/ 851
PIXEL: 1704/5061
PIXEL: 5784/2981

C00-01

PIXEL: 2481/4944
PIXEL: 4628/1732
PIXEL: 4972/2499
PIXEL: 153/5626
PIXEL: 196/4647



PIXEL: 220/5775
PIXEL: 617/5196
PIXEL: 861/5622
PIXEL: 1686/5546
PIXEL: 4658/5979
PIXEL: 8071/2346
PIXEL: 8847/ 372
PIXEL: 8912/ 18

C00-02

PIXEL: 62/3490
PIXEL: 574/4962
PIXEL: 1460/1009
PIXEL: 1960/3763
PIXEL: 5186/3158
PIXEL: 6077/2799
PIXEL: 7690/3202
PIXEL: 7365/1861
PIXEL: 8429/ 98
PIXEL: 8430/ 99
PIXEL: 8431/ 98
PIXEL: 8565/ 30
PIXEL: 8782/5536
PIXEL: 8782/5537

C00-03

PIXEL: 2641/4433
PIXEL: 305/2260
PIXEL: 1058/5937
PIXEL: 3324/4171
PIXEL: 4394/2312
PIXEL: 4423/3680
PIXEL: 4777/4080
PIXEL: 4801/1183
PIXEL: 4866/4989
PIXEL: 5236/4190
PIXEL: 6052/2194
PIXEL: 6465/4260
PIXEL: 7512/ 65
PIXEL: 8219/ 334
PIXEL: 8299/ 48
PIXEL: 8793/5676
PIXEL: 88/5712
PIXEL: 456/5987
PIXEL: 592/5320
PIXEL: 1577/4942
PIXEL: 1578/4942
PIXEL: 1984/2162
PIXEL: 2641/4432
PIXEL: 2642/4432



PIXEL: 3757/3442
PIXEL: 3758/3442
PIXEL: 3758/3443
PIXEL: 3759/3442
PIXEL: 3760/3443
PIXEL: 7047/5938
PIXEL: 8518/2142
PIXEL: 8677/5526
PIXEL: 9034/ 284

C01-00

PIXEL: 2049/5379
PIXEL: 2437/2194
PIXEL: 4852/5176
PIXEL: 403/5700
PIXEL: 419/5801
PIXEL: 2073/2821
PIXEL: 2465/1843

C01-01

PIXEL: 2670/4885
PIXEL: 4234/1479
PIXEL: 5138/ 794
PIXEL: 8345/3119
PIXEL: 3654/5500
PIXEL: 3655/5500
PIXEL: 4421/ 679
PIXEL: 4477/2379
PIXEL: 4484/2047
PIXEL: 4486/2048
PIXEL: 4488/2049
PIXEL: 4489/2048
PIXEL: 4489/2049
PIXEL: 4492/2049
COLUMN: 5691/1456

C02-00

PIXEL: 366/6017
PIXEL: 73/3994
PIXEL: 681/3862
PIXEL: 894/ 461
PIXEL: 2924/1002
PIXEL: 3021/5760
PIXEL: 3908/1527
PIXEL: 6249/5678
PIXEL: 6471/3023
PIXEL: 6761/3544
PIXEL: 7033/5323
PIXEL: 365/6017
PIXEL: 2213/5006



C02-01

- PIXEL: 651/1715
- PIXEL: 1457/ 805
- PIXEL: 2294/5398
- PIXEL: 3281/4180
- PIXEL: 4197/2440
- PIXEL: 5463/5185
- PIXEL: 5480/4892
- PIXEL: 5485/5843
- PIXEL: 6484/3777
- PIXEL: 7402/ 790
- PIXEL: 7964/1105
- PIXEL: 8105/ 278
- PIXEL: 8953/4674
- PIXEL: 1133/3158
- PIXEL: 1232/ 42
- PIXEL: 1310/ 35
- PIXEL: 8413/ 644

C03-00

- PIXEL: 1245/4678
- PIXEL: 6095/ 258
- PIXEL: 6639/2282
- PIXEL: 7616/5467
- PIXEL: 1109/ 906
- PIXEL: 4995/5805
- PIXEL: 6205/6014
- PIXEL: 8355/1851
- PIXEL: 8777/5828
- PIXEL: 221/4609

C04-00

- PIXEL: 876/2057
- PIXEL: 2527/5964
- PIXEL: 2689/5427
- PIXEL: 3375/4112
- PIXEL: 4074/4902
- PIXEL: 5683/2964
- PIXEL: 6197/2236
- PIXEL: 6223/5685
- PIXEL: 7815/2919
- PIXEL: 8145/1871
- PIXEL: 964/5858
- PIXEL: 4315/4127
- PIXEL: 4874/1464
- PIXEL: 4874/1465
- PIXEL: 4874/1466
- PIXEL: 4875/1464
- PIXEL: 4875/1465



PIXEL: 8184/ 94

C05-00

- PIXEL: 185/ 381
- PIXEL: 3105/ 385
- PIXEL: 5772/3453
- PIXEL: 6872/2460
- PIXEL: 8237/2113
- PIXEL: 417/4903
- PIXEL: 691/3703
- PIXEL: 1261/5606
- PIXEL: 1918/3721
- PIXEL: 2318/ 338
- PIXEL: 5812/ 921
- PIXEL: 6486/5017
- PIXEL: 6827/2713
- PIXEL: 6875/1317
- PIXEL: 7320/5294
- PIXEL: 7321/5294
- PIXEL: 7634/5249

C06-00

- PIXEL: 651/4504
- PIXEL: 2622/ 154
- PIXEL: 5451/5913
- PIXEL: 8180/1562
- PIXEL: 8940/4274
- PIXEL: 78/5909
- PIXEL: 269/5490
- PIXEL: 693/1202
- PIXEL: 697/5203
- PIXEL: 4137/1089
- PIXEL: 4602/ 132
- PIXEL: 6546/ 606
- PIXEL: 1992/ 576

C07-00

- PIXEL: 208/5557
- PIXEL: 1010/5207
- PIXEL: 5162/2446
- PIXEL: 208/5556
- PIXEL: 208/5558
- PIXEL: 390/5138
- PIXEL: 391/5138
- PIXEL: 474/4578
- PIXEL: 683/5933
- PIXEL: 3377/5395
- PIXEL: 4969/5066
- PIXEL: 6160/ 322



PIXEL: 6160/ 323
PIXEL: 9027/ 406

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	30.Jan.2020	30.Jan.2020	
Radiometric Calibration	30.Jan.2020	30.Jan.2020	
Shutter Calibration	30.Jan.2020	30.Jan.2020	
Electronics and Sensor Calibration	30.Jan.2020	30.Jan.2020	

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