



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: 0.000 mm

Calibration Date: Dec-17-2018
Date of Report: Mar-08-2019
Camera Revision: Rev01.00
Version of Report: V01



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	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

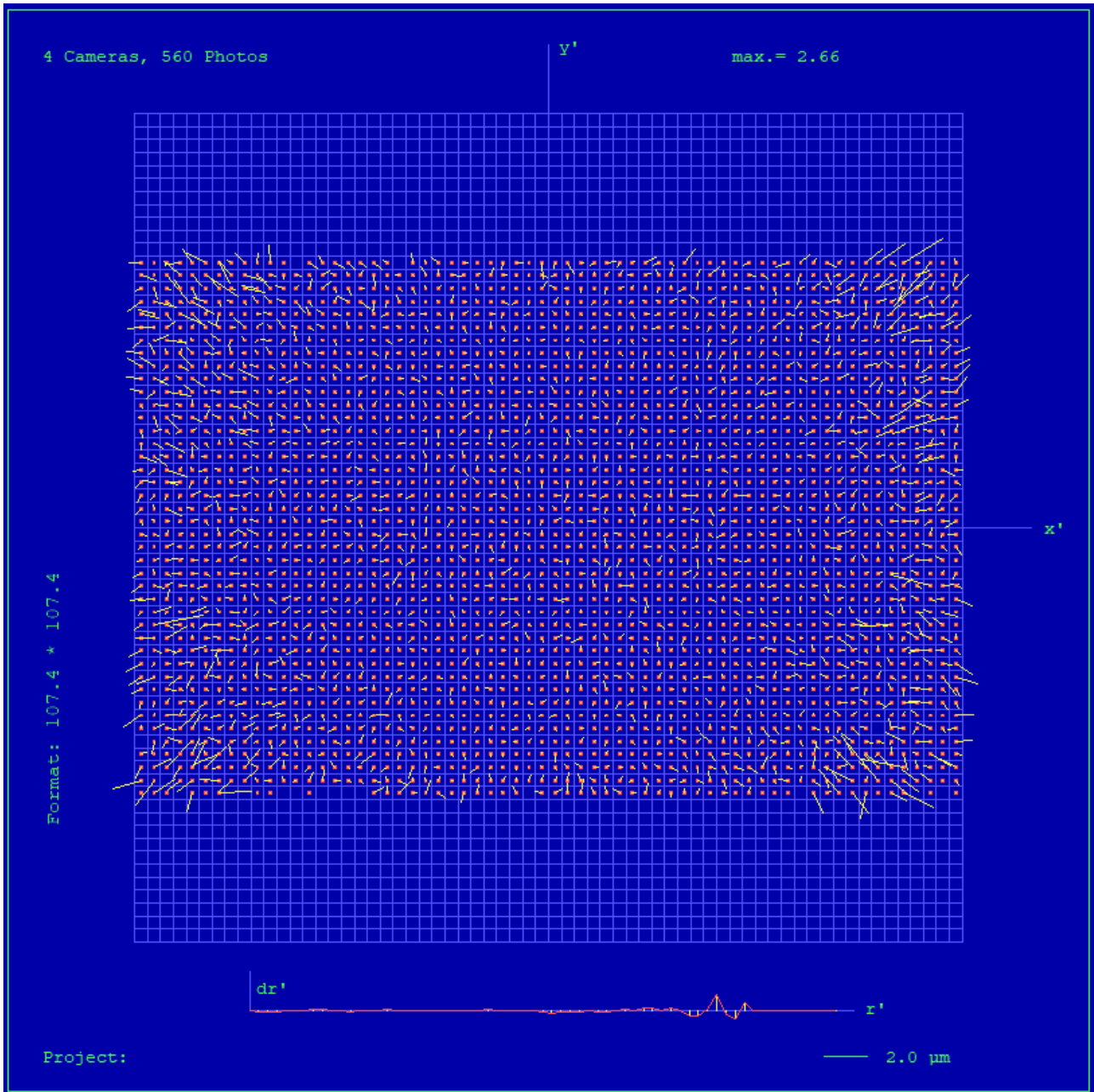
Multispectral Camera

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

Image Format	long track cross track	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	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		



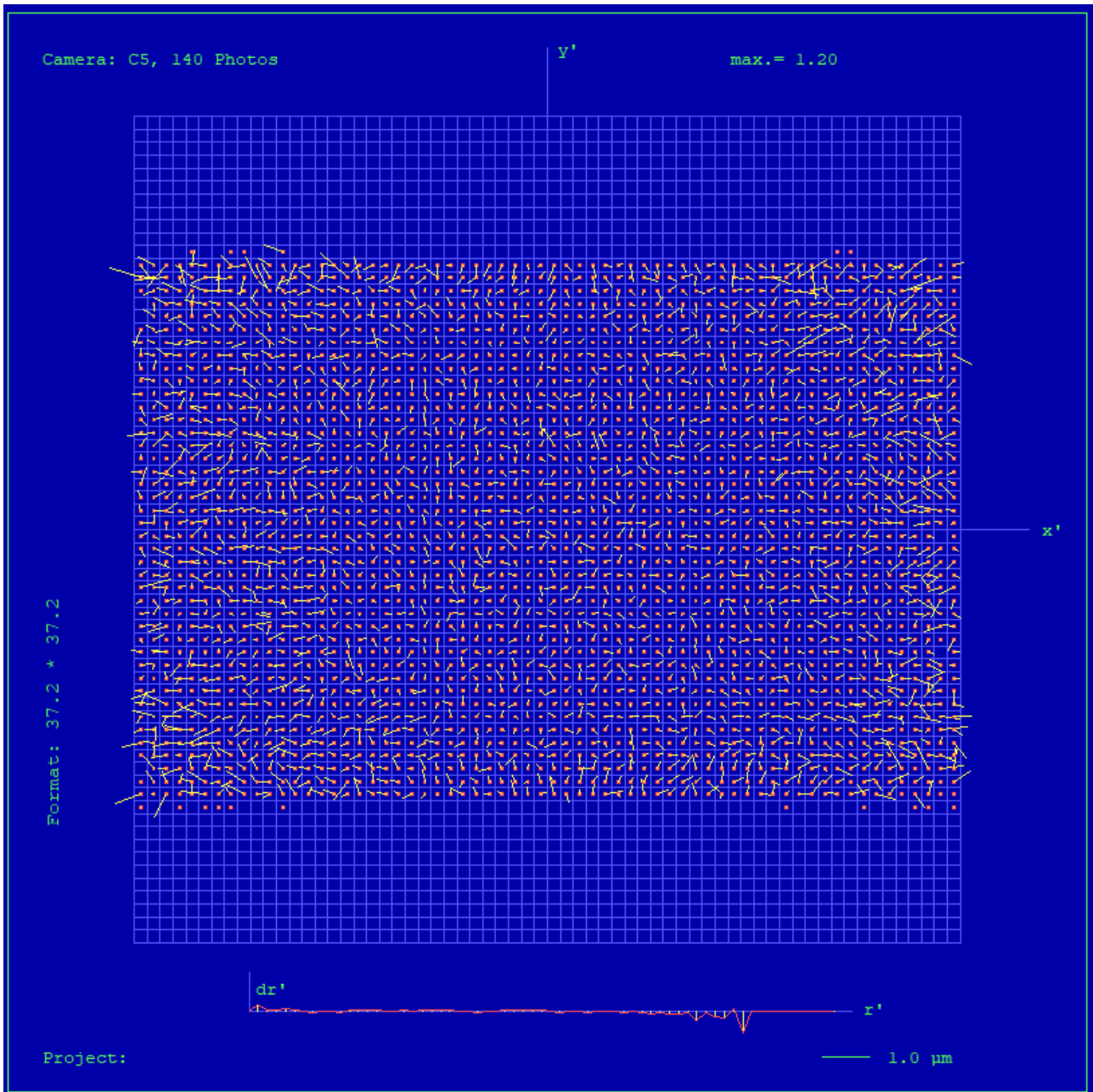
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.64 μm**



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.44 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

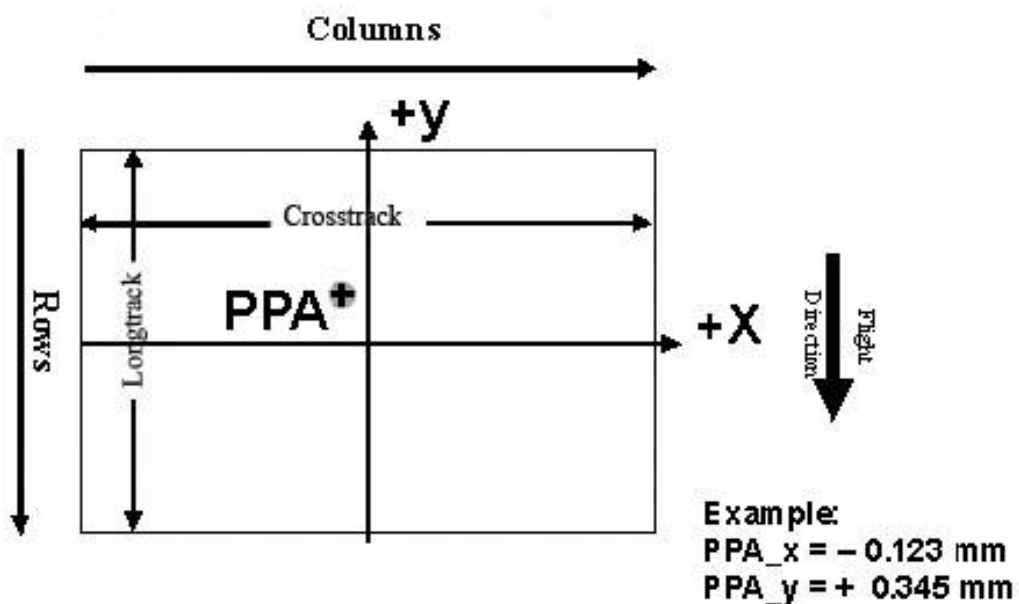
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

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

Level 2 Image Coordinate System:

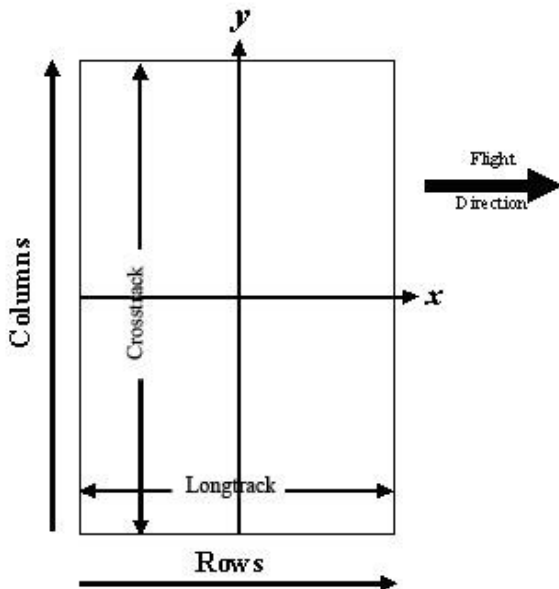
Lvl2, Camera prop. Orientation



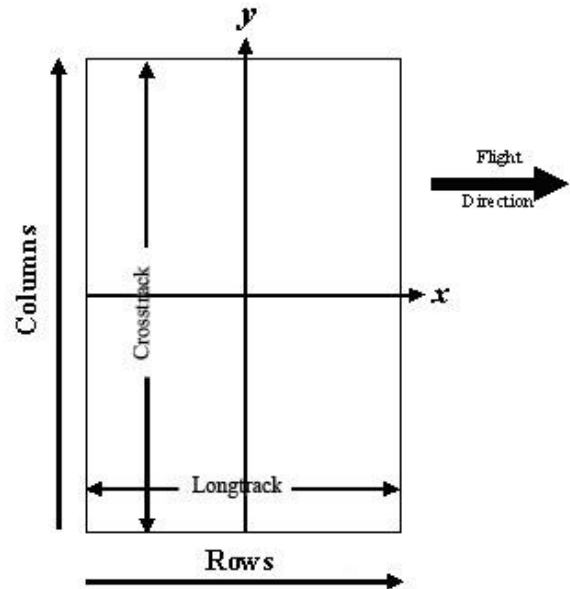
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



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



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

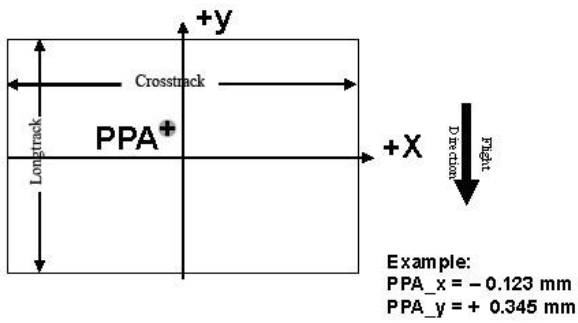
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified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

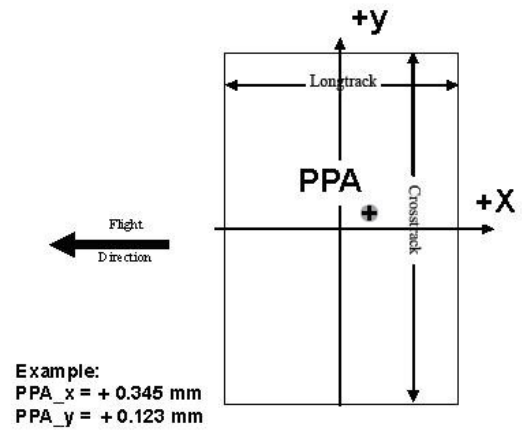


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

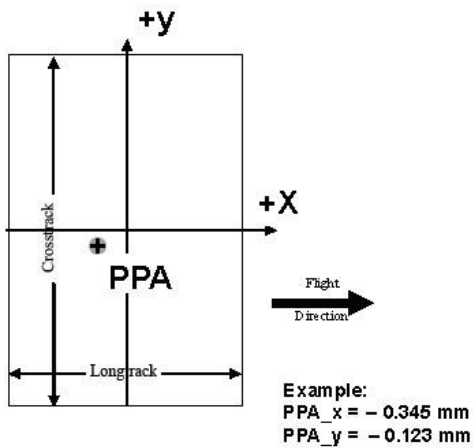
Lvl3, Rotation 0 deg clockwise



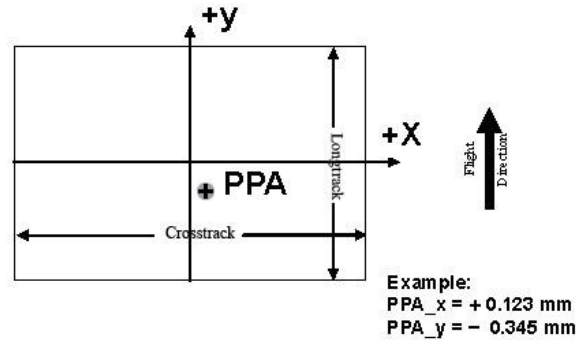
Lvl3, Rotation 90 deg clockwise



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

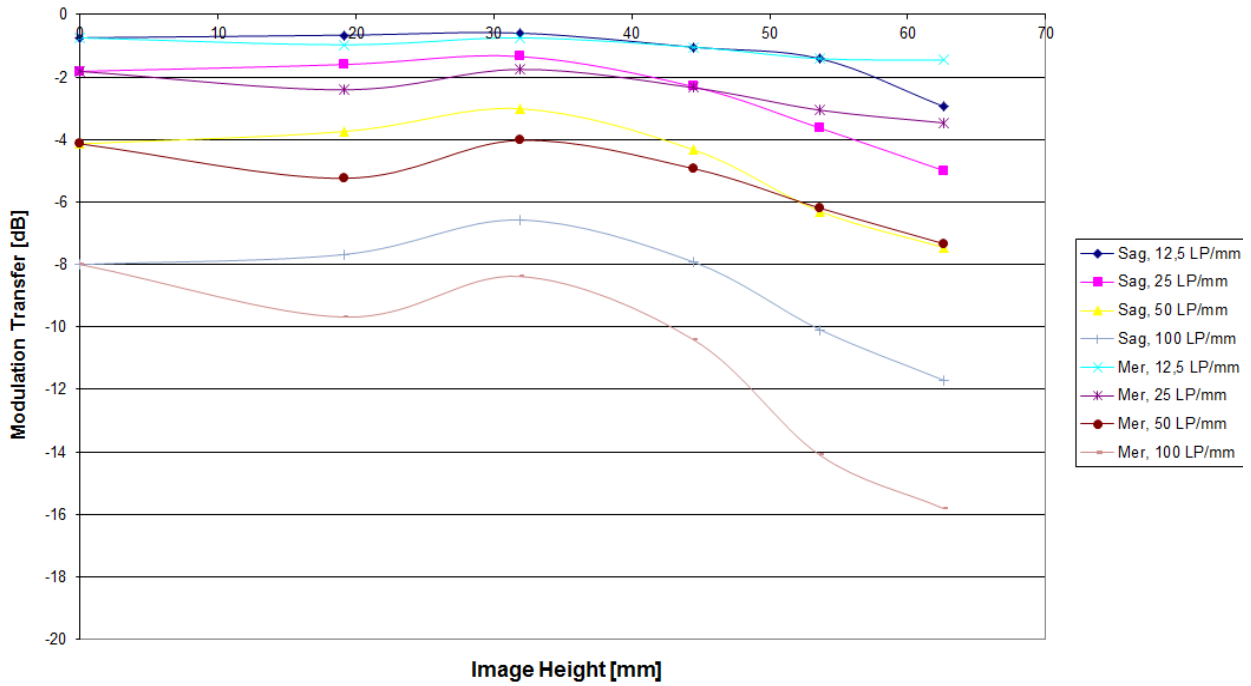
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

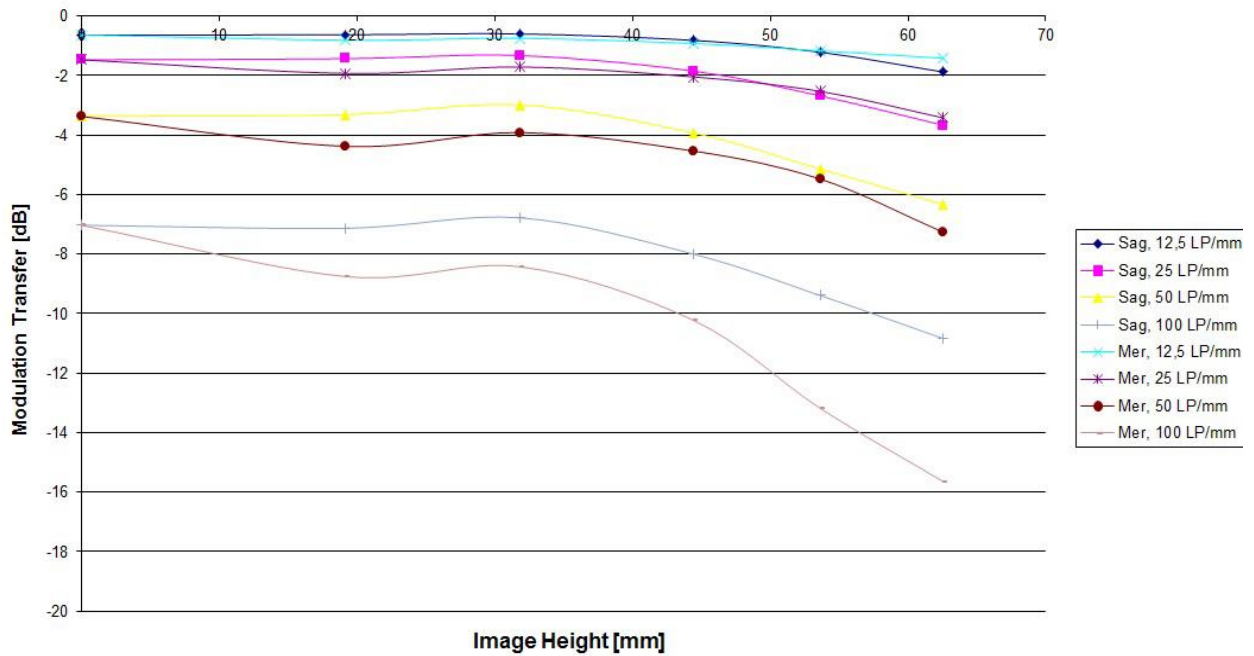
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic 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

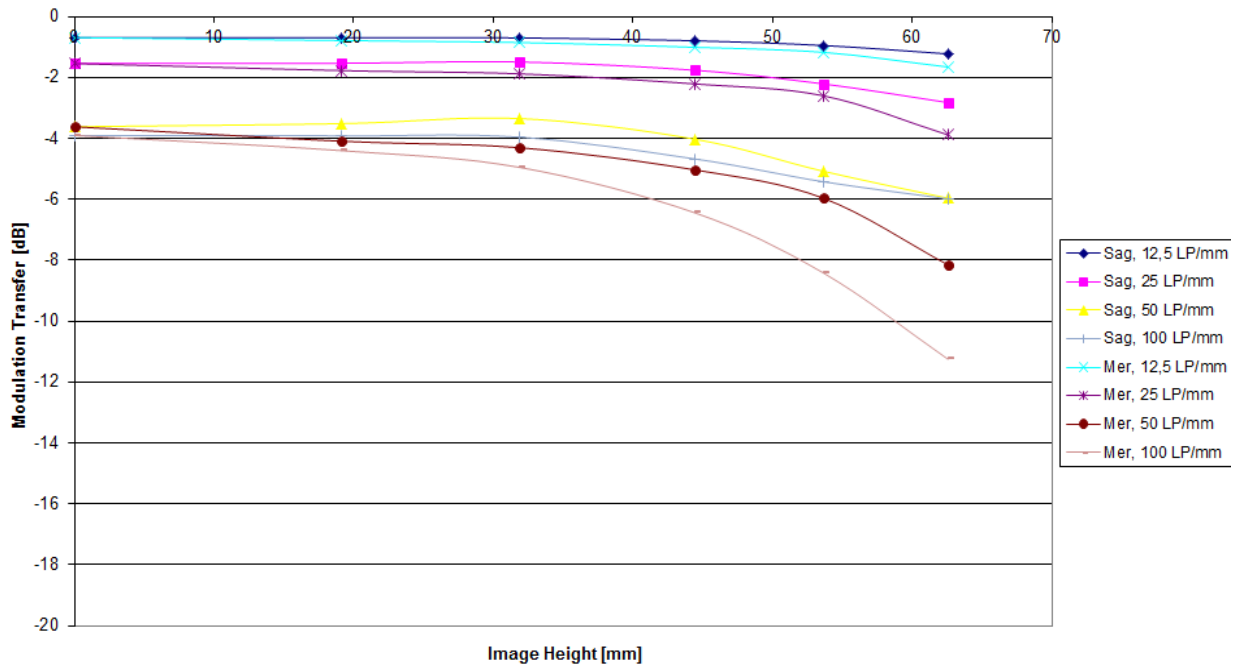


Modulation versus Image Height - Aperture f / 6.7

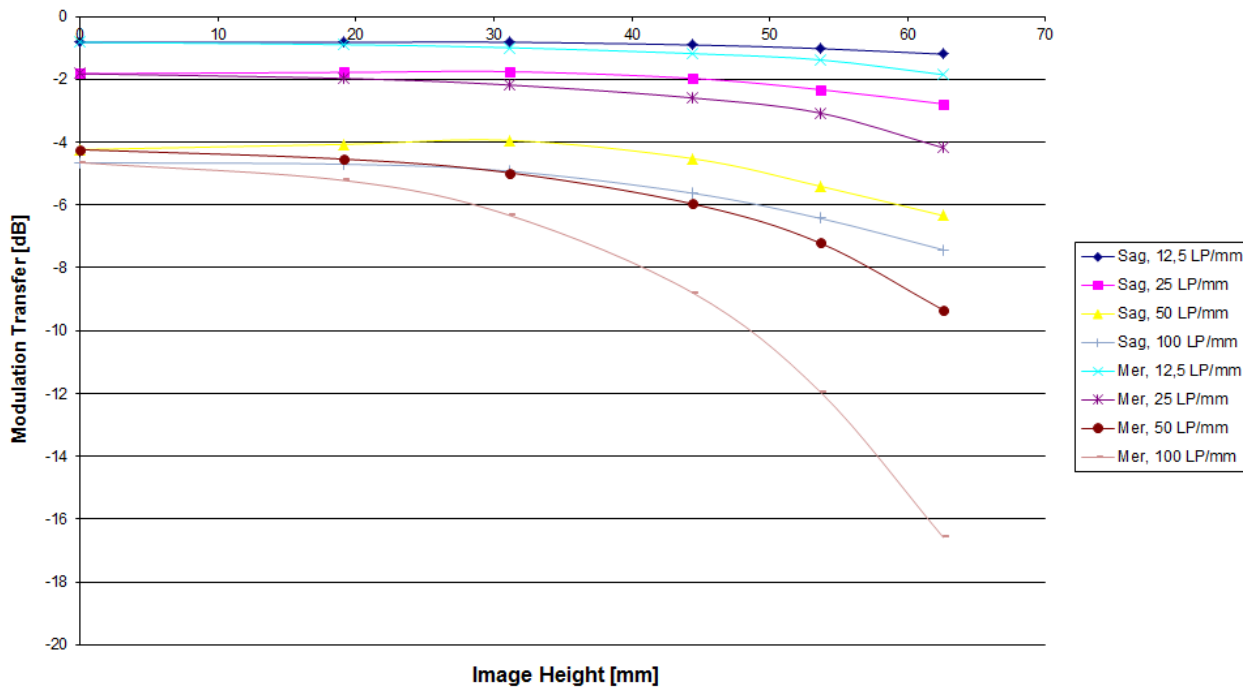




Modulation versus Image Height - Aperture f / 8

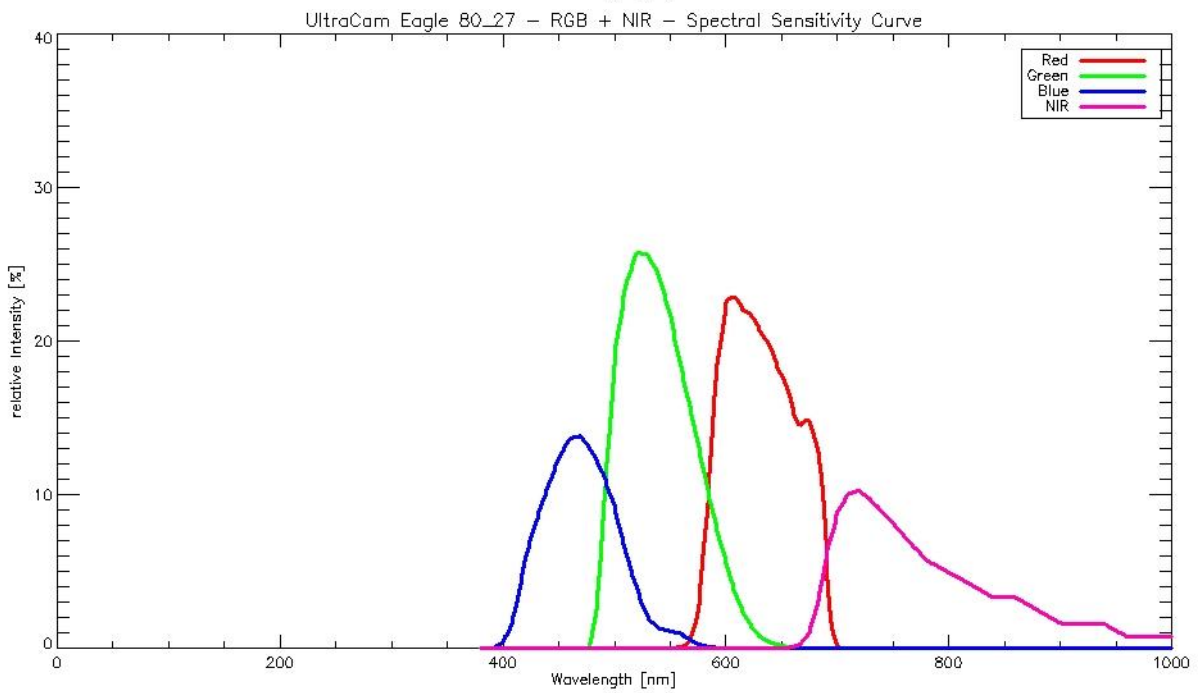
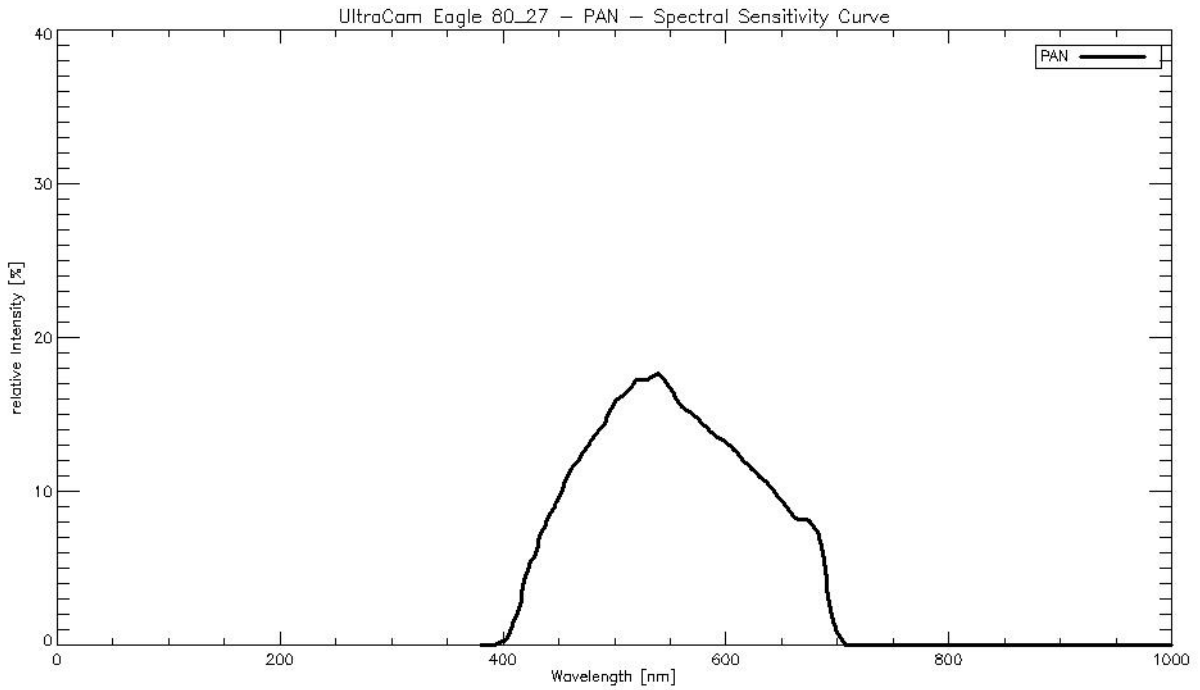


Modulation versus Image Height - Aperture f / 9.5





Spectral Sensitivity





ULTRACAM

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

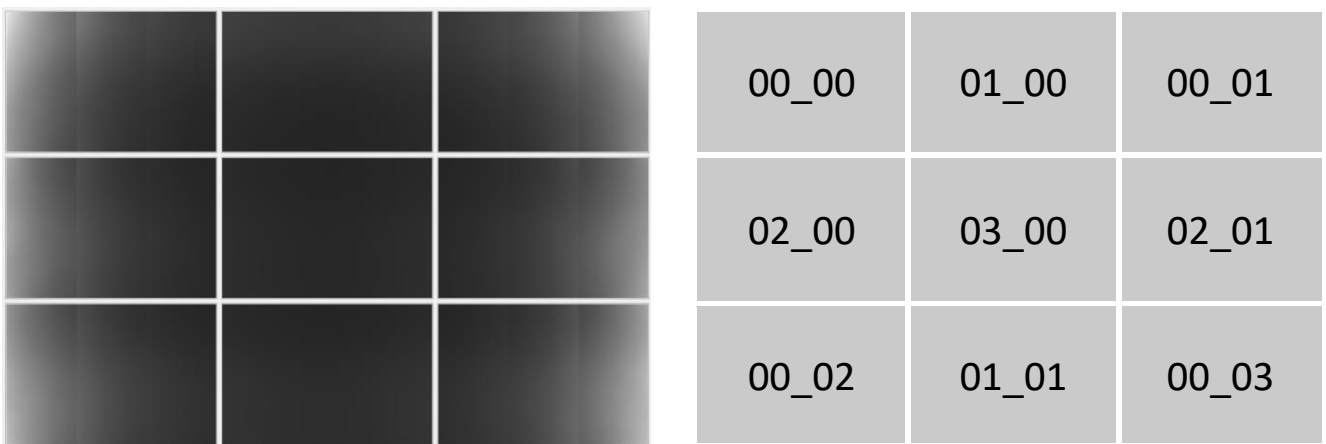
Calibration Date: Dec-17-2018
Date of Report: Mar-08-2019
Camera Revision: Rev01.00
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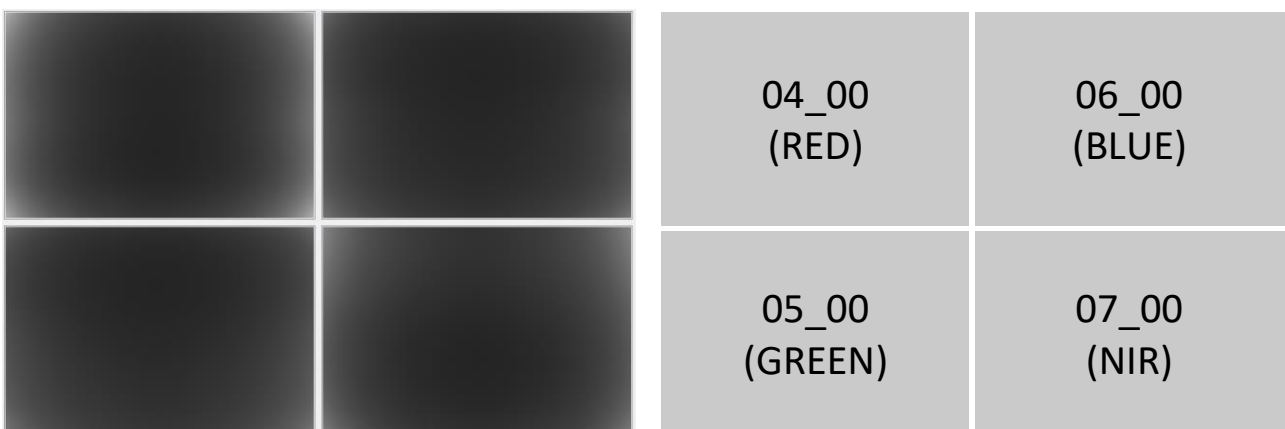
Calibration of Vignetting for working Aperture F6.7

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

Graphical Overview of Pan Sensors:



Graphical Overview of Multispectral Sensors:





Dead Pixel Report:

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

- PIXEL: 38/4737
- PIXEL: 1661/1748
- PIXEL: 3625/1955
- PIXEL: 4117/ 917
- PIXEL: 4846/3099
- PIXEL: 5273/1564
- PIXEL: 6437/3130
- PIXEL: 6455/5687
- PIXEL: 6662/2833
- PIXEL: 7873/5420
- PIXEL: 8593/3714
- PIXEL: 305/ 33
- PIXEL: 388/5345
- PIXEL: 388/5346
- PIXEL: 553/ 937
- PIXEL: 967/1056
- PIXEL: 1070/1902
- PIXEL: 1289/1001
- PIXEL: 1315/ 851
- PIXEL: 1704/5061
- PIXEL: 5784/2981
- PIXEL: 389/5344
- PIXEL: 1316/ 851

C00-01

- PIXEL: 1586/4773
- PIXEL: 2481/4944
- 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: 8662/ 655
- PIXEL: 8823/ 274
- PIXEL: 8847/ 372
- PIXEL: 8912/ 18
- PIXEL: 1686/5547
- PIXEL: 45/6012



C00-02

- PIXEL: 574/4962
- PIXEL: 1460/1009
- PIXEL: 1596/2318
- PIXEL: 4130/2876
- PIXEL: 8814/3339
- PIXEL: 163/1688
- PIXEL: 214/ 99
- PIXEL: 709/3241
- PIXEL: 835/2933
- PIXEL: 7365/1861
- PIXEL: 8429/ 98
- PIXEL: 8430/ 99
- PIXEL: 8431/ 98
- PIXEL: 8565/ 30
- PIXEL: 8782/5536
- PIXEL: 8782/5537
- PIXEL: 8428/ 98
- PIXEL: 8430/ 97

C00-03

- PIXEL: 2641/4433
- PIXEL: 222/5247
- PIXEL: 305/2260
- PIXEL: 426/3189
- PIXEL: 1015/4493
- PIXEL: 1058/5937
- PIXEL: 1088/3598
- PIXEL: 1210/4978
- PIXEL: 1913/1890
- PIXEL: 3161/ 410
- PIXEL: 3702/1167
- PIXEL: 4385/5491
- PIXEL: 4389/5495
- PIXEL: 4392/5499
- PIXEL: 4439/4377
- PIXEL: 4439/4378
- PIXEL: 4444/4370
- PIXEL: 4444/4371
- PIXEL: 4445/4370
- PIXEL: 4866/4989
- PIXEL: 5236/4190
- PIXEL: 5671/5261
- PIXEL: 7512/ 65
- PIXEL: 8065/3660
- 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: 6765/2759
PIXEL: 7047/5938
PIXEL: 8219/ 334
PIXEL: 8518/2142
PIXEL: 8677/5526
PIXEL: 8971/5833
PIXEL: 8975/2708
PIXEL: 9034/ 284

C01-00

PIXEL: 1203/4287
PIXEL: 1222/5585
PIXEL: 2049/5379
PIXEL: 4089/2444
PIXEL: 4846/2368
PIXEL: 7305/5788
PIXEL: 7834/2712
PIXEL: 7835/2712
PIXEL: 7837/2709
PIXEL: 8993/5466
PIXEL: 403/5700
PIXEL: 419/5801
PIXEL: 2073/2821
PIXEL: 2465/1843
PIXEL: 2465/1842
PIXEL: 2466/1843

C01-01

PIXEL: 3753/4822
PIXEL: 3755/4038
PIXEL: 4234/1479
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



PIXEL: 4483/2047
PIXEL: 2670/4885

C02-00

PIXEL: 366/6017
PIXEL: 328/5674
PIXEL: 821/5854
PIXEL: 7033/5323
PIXEL: 8297/1759
PIXEL: 365/6017
PIXEL: 2213/5006

C02-01

PIXEL: 651/1715
PIXEL: 2294/5398
PIXEL: 5463/5185
PIXEL: 7402/ 790
PIXEL: 1133/3158
PIXEL: 1232/ 42
PIXEL: 1310/ 35
PIXEL: 8413/ 644
PIXEL: 8414/ 644
PIXEL: 8414/ 643

C03-00

PIXEL: 1116/5224
PIXEL: 7616/5467
PIXEL: 1109/ 906
PIXEL: 4995/5805
PIXEL: 6205/6014
PIXEL: 8355/1851
PIXEL: 1108/ 906
PIXEL: 1108/ 905

C04-00

PIXEL: 1844/4447
PIXEL: 7391/5767
PIXEL: 7815/2919
PIXEL: 8321/1549
PIXEL: 964/5858
PIXEL: 4315/4127
PIXEL: 4874/1464
PIXEL: 4874/1465
PIXEL: 4874/1466
PIXEL: 4875/1464
PIXEL: 4875/1465
PIXEL: 8184/ 94
PIXEL: 964/5857
PIXEL: 8183/ 94



C05-00

PIXEL: 1464/2666
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
PIXEL: 417/4902
PIXEL: 691/3702
PIXEL: 2319/ 338
PIXEL: 2319/ 339
PIXEL: 6487/5017
PIXEL: 6485/5017
PIXEL: 7321/5295

C06-00

PIXEL: 78/5909
PIXEL: 651/4504
PIXEL: 5366/5393
PIXEL: 5431/1951
PIXEL: 5451/5913
PIXEL: 8940/4274
PIXEL: 269/5490
PIXEL: 693/1202
PIXEL: 697/5203
PIXEL: 4137/1089
PIXEL: 4602/ 132
PIXEL: 6546/ 606
PIXEL: 694/1202
PIXEL: 4137/1088
PIXEL: 4601/ 132
PIXEL: 6547/ 606
COLUMN: 1992/ 576

C07-00

PIXEL: 208/5557
PIXEL: 1562/5107
PIXEL: 5246/1916
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
PIXEL: 209/5557
PIXEL: 6159/ 322

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).



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 Date: Dec-17-2018
Date of Report: Mar-08-2019
Camera Revision: Rev01.00
Version of Report: V01



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.

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	6.36	6.53	6.84	6.99	7.19	7.28	7.43	7.76	+/- 0.2
C1 (Pan)	12 16 05 84	6.56	6.72	7.01	7.23	7.40	7.53	7.62	7.98	+/- 0.2
C2 (Pan)	12 15 42 91	6.71	6.86	7.20	7.37	7.54	7.63	7.73	8.01	+/- 0.2
C3 (Pan)	12 16 05 88	6.51	6.62	6.94	7.13	7.29	7.39	7.54	7.77	+/- 0.2
C4 (Red)	12 11 00 37	7.10	7.10	7.34	7.41	7.45	7.45	7.60	7.68	+/- 0.2
C5 (Green)	12 11 00 62	7.13	7.21	7.39	7.53	7.53	7.57	7.78	7.98	+/- 0.2
C6 (Blue)	12 12 06 28	7.13	7.15	7.21	7.27	7.44	7.55	7.58	7.95	+/- 0.2
C7 (NIR)	12 15 32 05	7.54	7.54	7.59	7.81	8.02	8.06	8.13	8.54	+/- 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 Date: Dec-17-2018
Date of Report: Mar-08-2019
Camera Revision: Rev01.00
Version of Report: V01



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.

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.

Cone_Sensor	Sensor Type	Sensor Serial Number	Intensity Threshold [DN]	
			Tap 1	Tap2
00_00	FTF9060-M	192209/001	14070	13320
00_01	FTF9060-M	192209/003	13600	12970
00_02	FTF9060-M	192209/086	13830	13170
00_03	FTF9060-M	192209/077	13820	13110
01_00	FTF9060-M	192209/085	14950	13610
01_01	FTF9060-M	192209/073	14300	13430
02_00	FTF9060-M	192209/080	14120	13350
02_01	FTF9060-M	192209/068	14340	13400
03_00	FTF9060-M	192209/059	14350	13350
04_00 (red)	FTF9060-M	192209/075	13300	12850
05_00 (green)	FTF9060-M	192209/050	14400	13340
06_00 (blue)	FTF9060-M	192209/084	13920	13140
07_00 (NIR)	FTF9060-M	192209/060	13950	13050



ULTRACAM

Summary

Camera:	UltraCam Eagle M3
Serial:	UC-EpII-1-62411397-f80
Calibration Date:	Dec-17-2018
Date of Report:	Mar-08-2019
Camera Revision:	Rev01.00
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

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