



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
Serial: UC-E-1-00518105-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: Nov-10-2016
Date of Report: Nov-15-2016
Camera Revision: Rev02.00
Version of Report: V01



Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track cross track	68.016mm 104.052mm	13080pixel 20010pixel
Image Extent		(-34.008, -52.026)mm	(34.008, 52.026)mm
Pixel Size		5.200µm*5.200µm	
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		

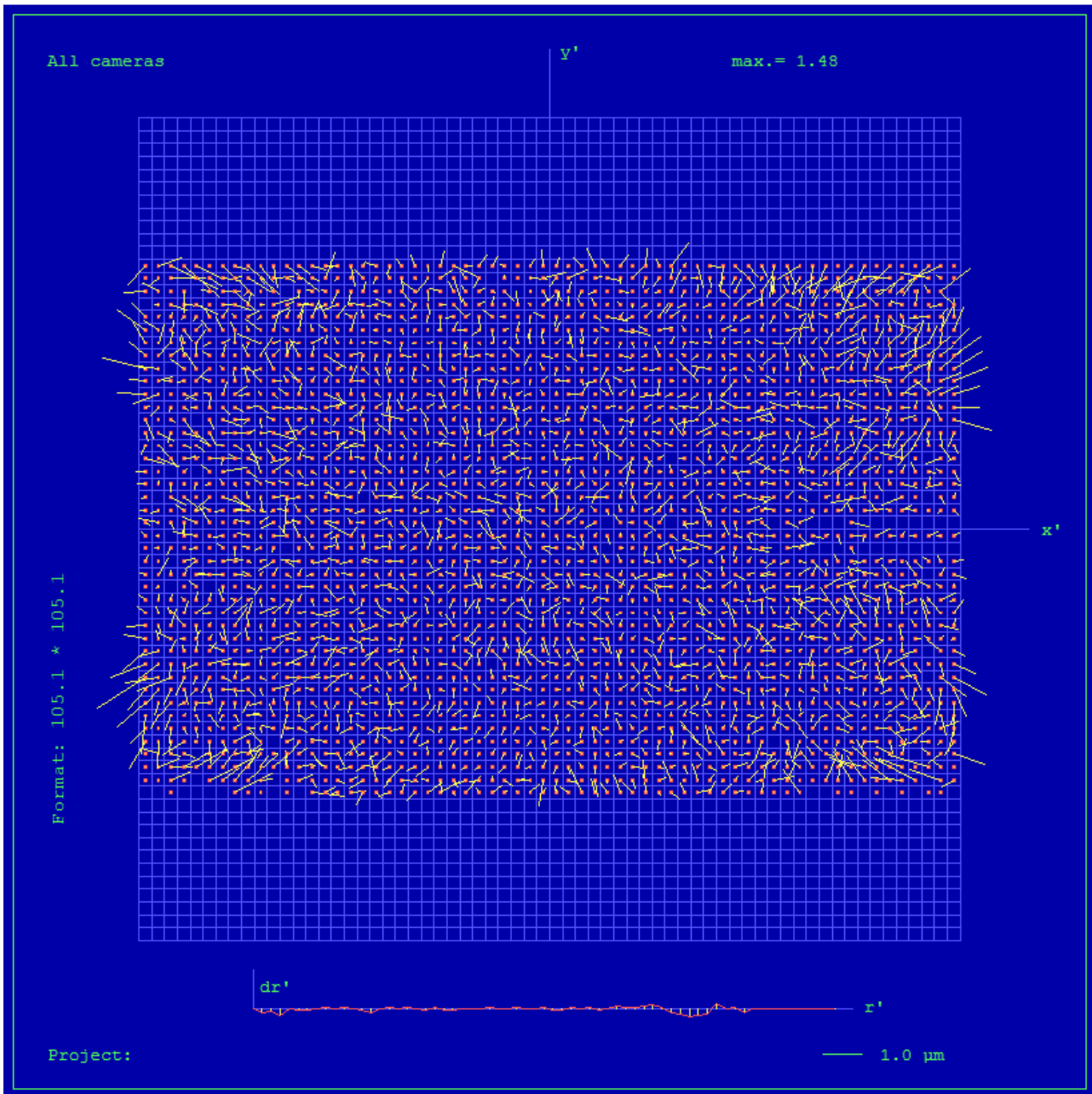
Multispectral Camera

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

Image Format	long track cross track	68.016mm 104.052mm	4360pixel 6670pixel
Image Extent		(-34.008, -52.026)mm	(34.008, 52.026)mm
Pixel Size		15.600µm*15.600µm	
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		



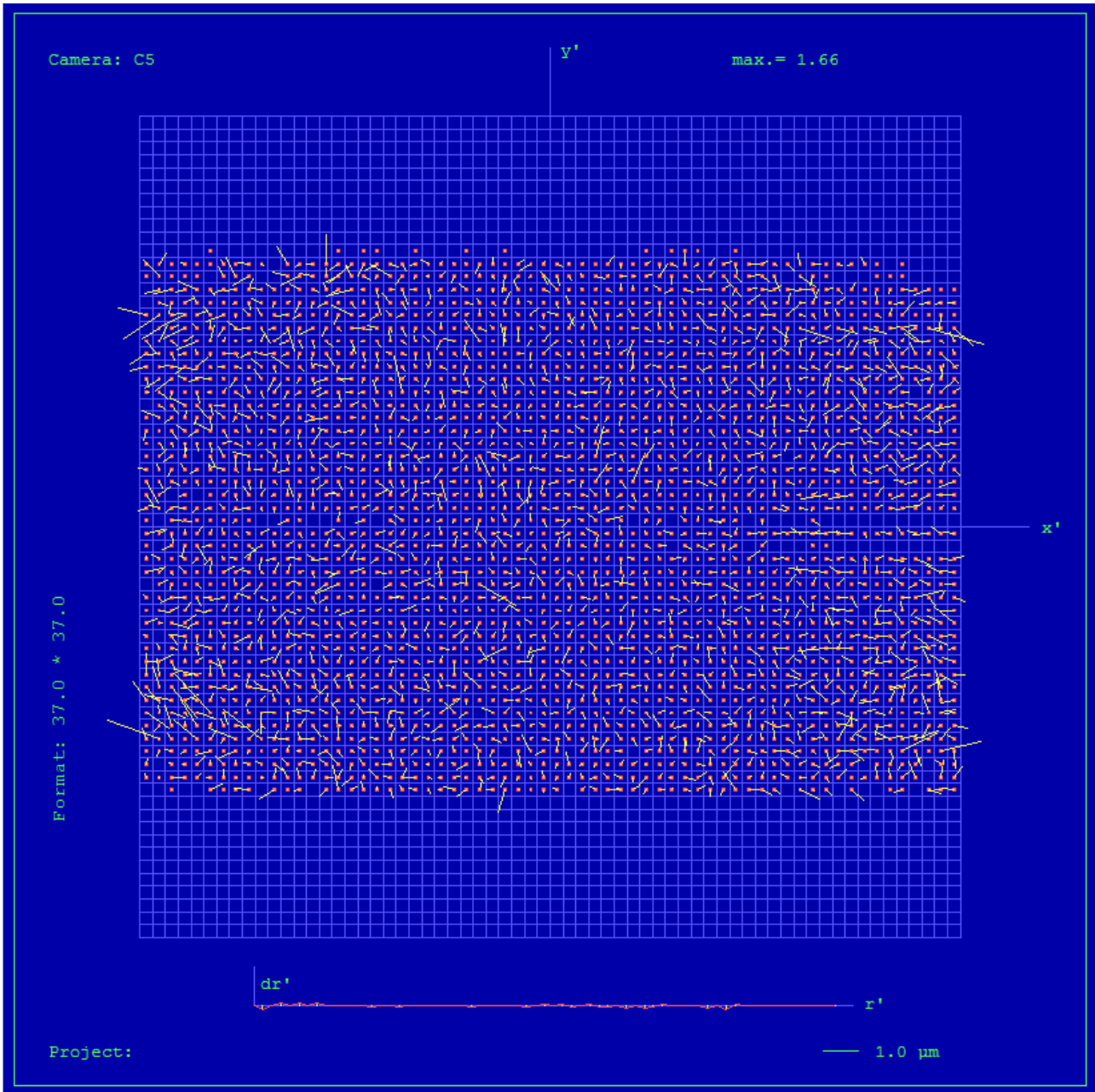
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.56 μm**



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.54 μm**



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

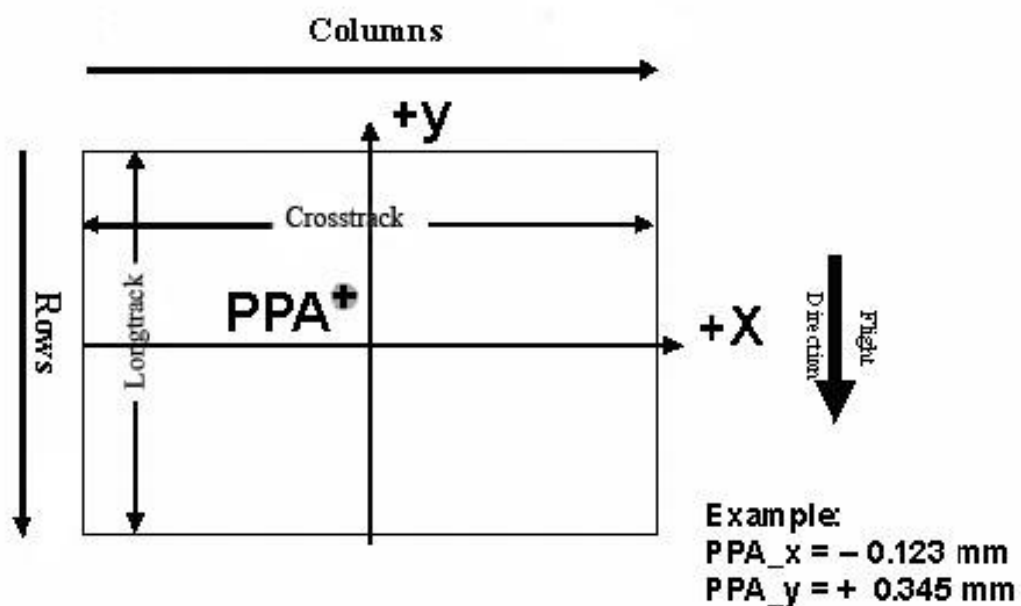
Number of point measurements for the multispectral camera: >60000

Determination of the image parameters by Least Squares Adjustment.

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

Level 2 Image Coordinate System:

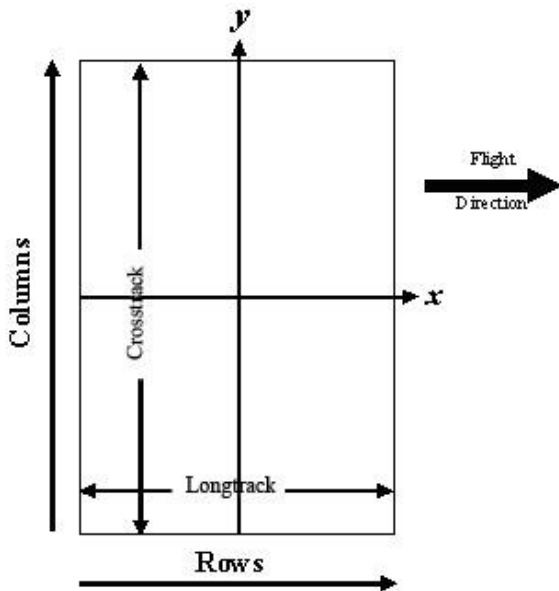
Lvl2, Camera prop. Orientation



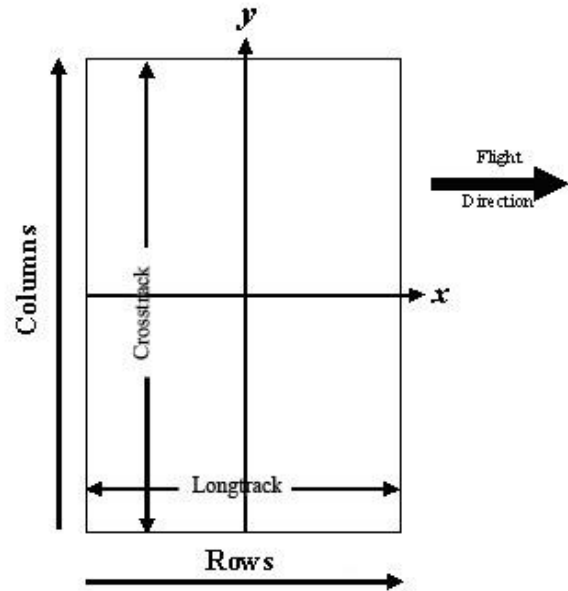
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



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



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

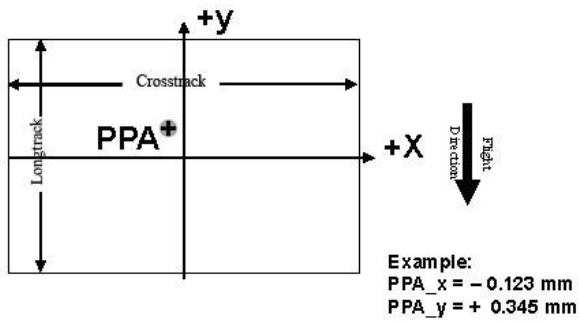
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified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

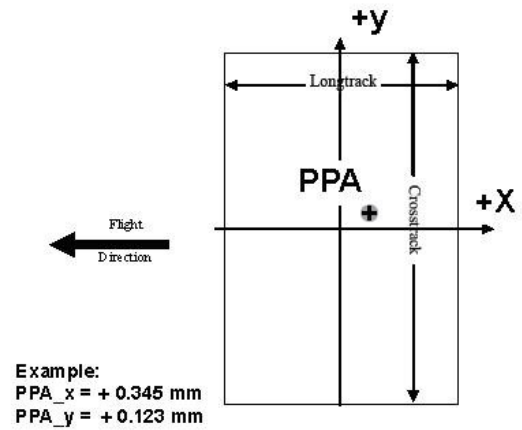


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

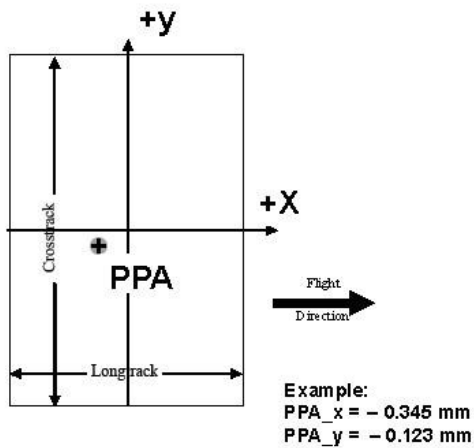
Lvl3, Rotation 0 deg clockwise



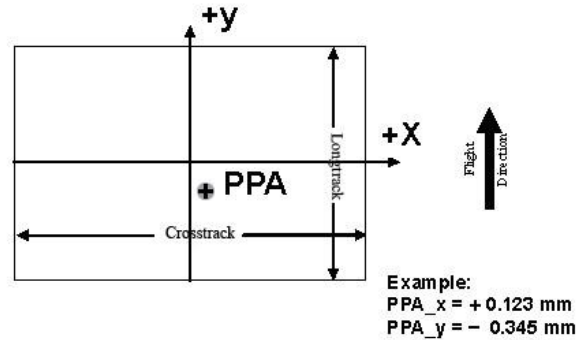
Lvl3, Rotation 90 deg clockwise



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

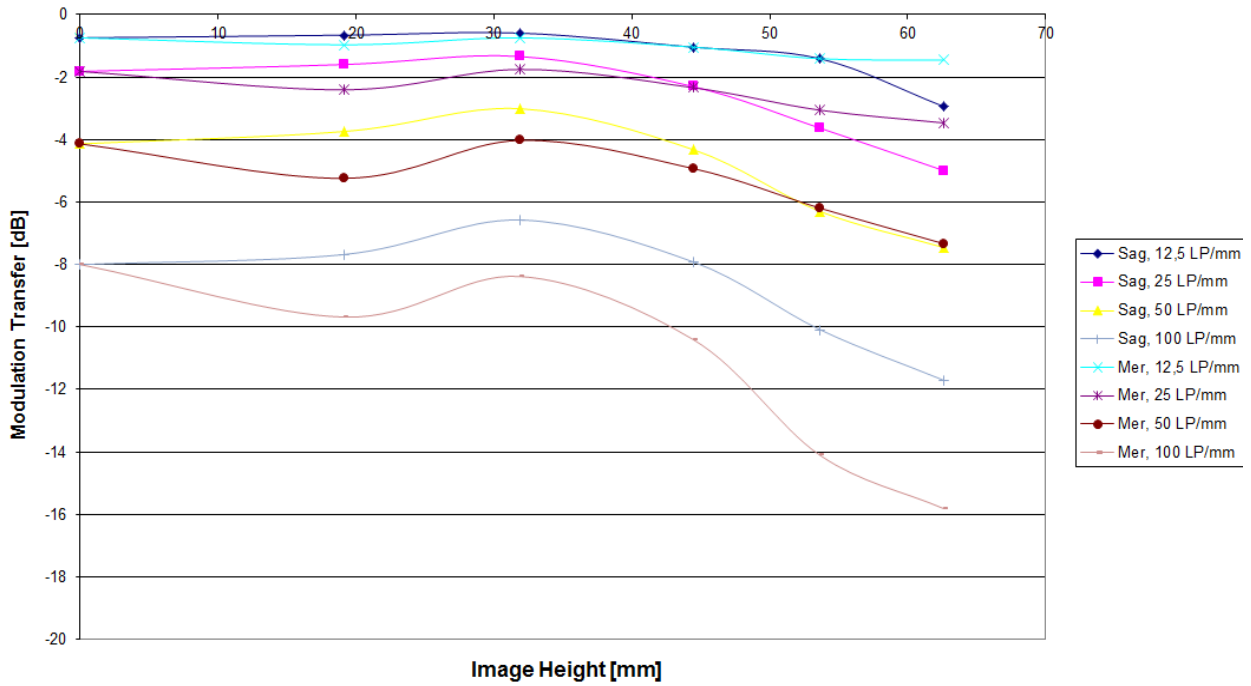
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

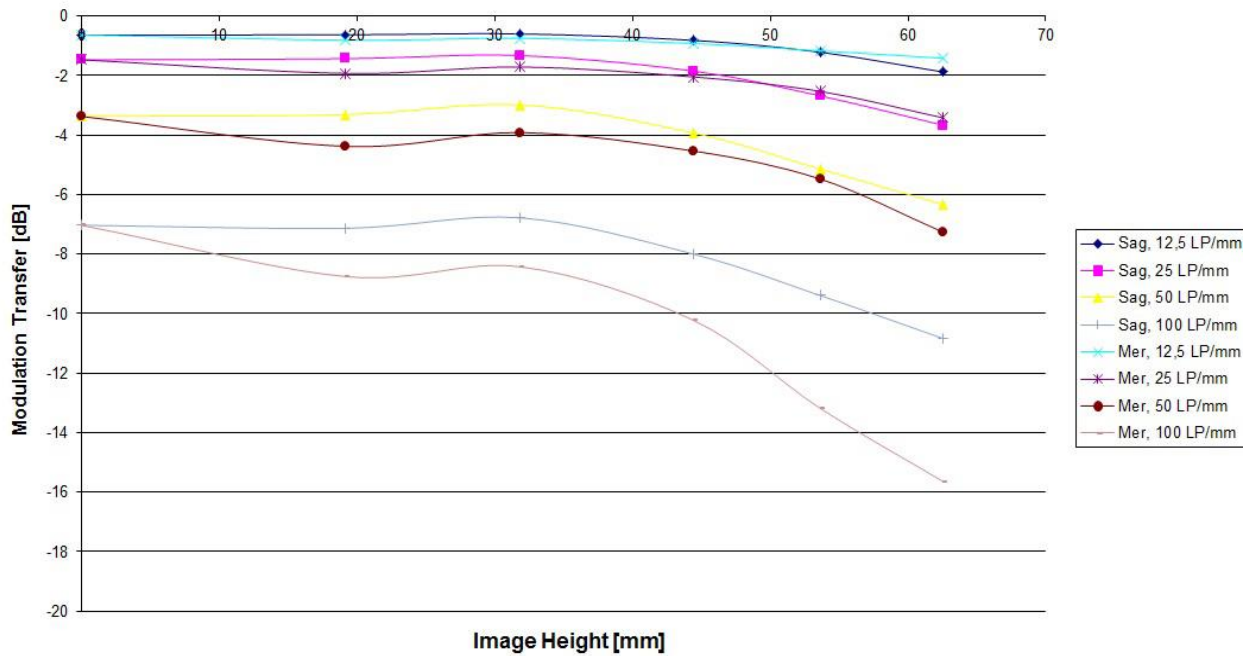
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic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

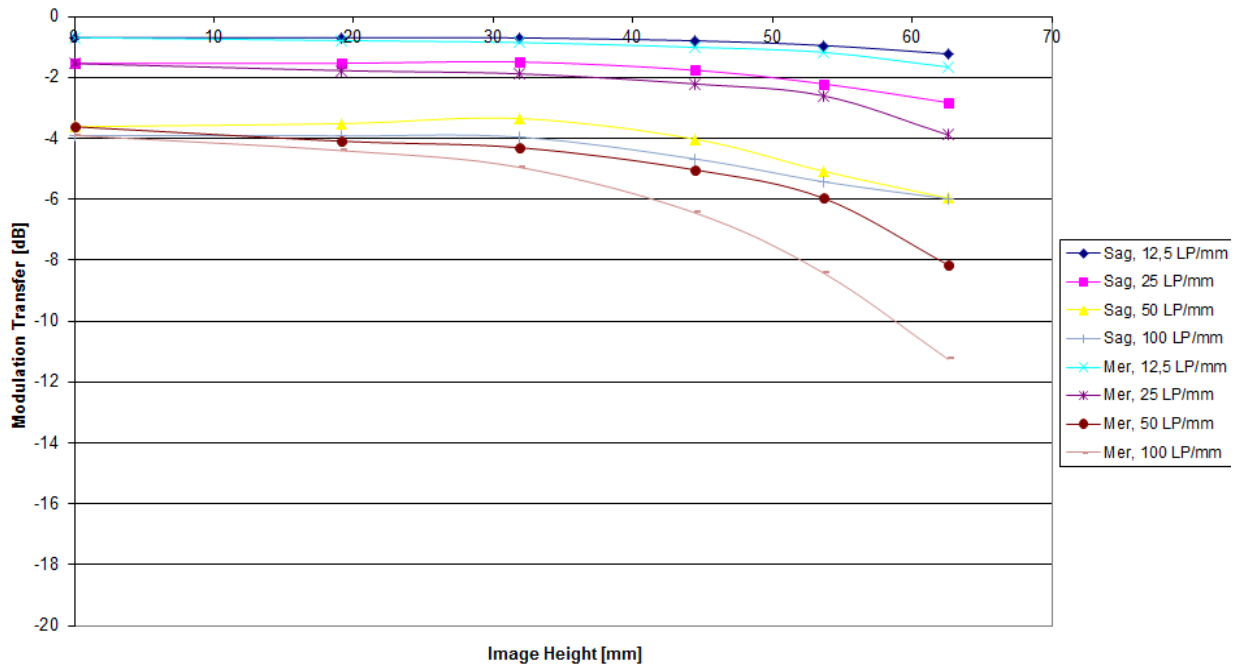


Modulation versus Image Height - Aperture f/ 6.7

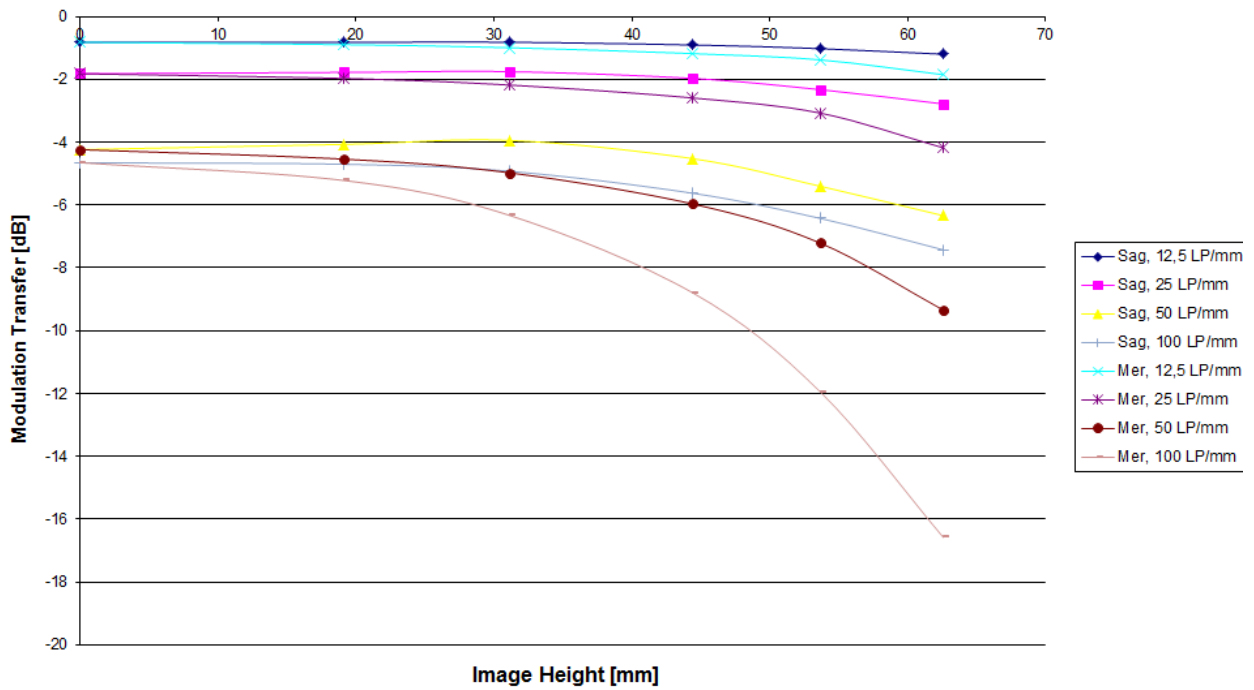




Modulation versus Image Height - Aperture f / 8

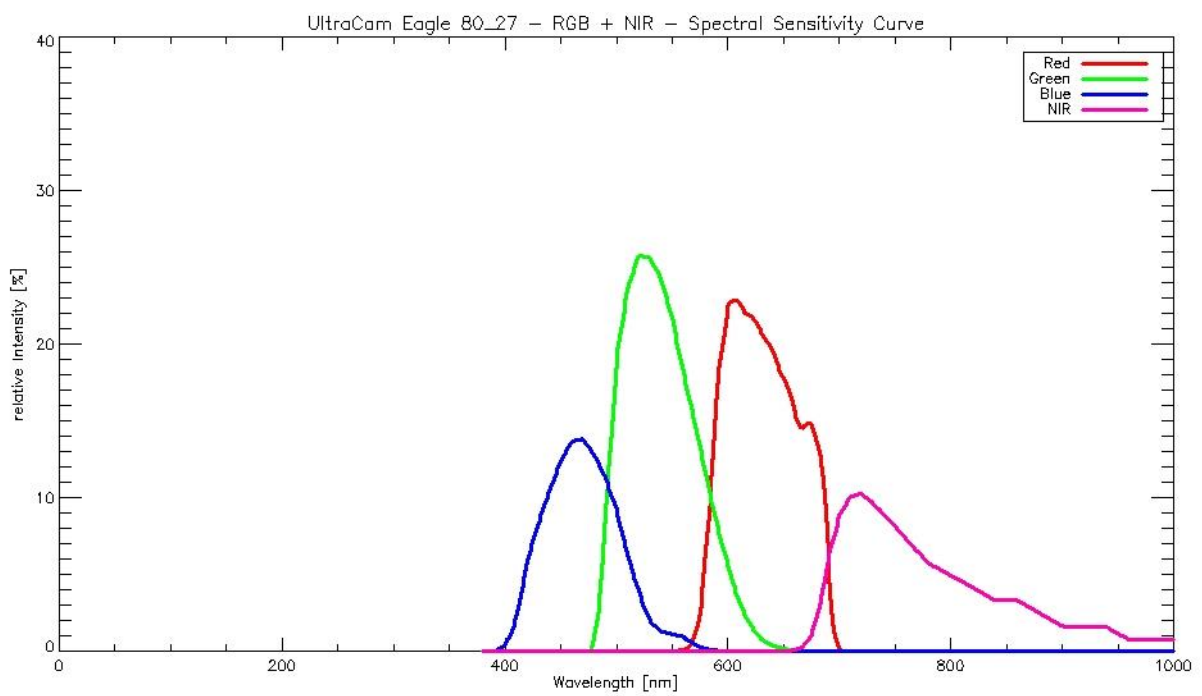
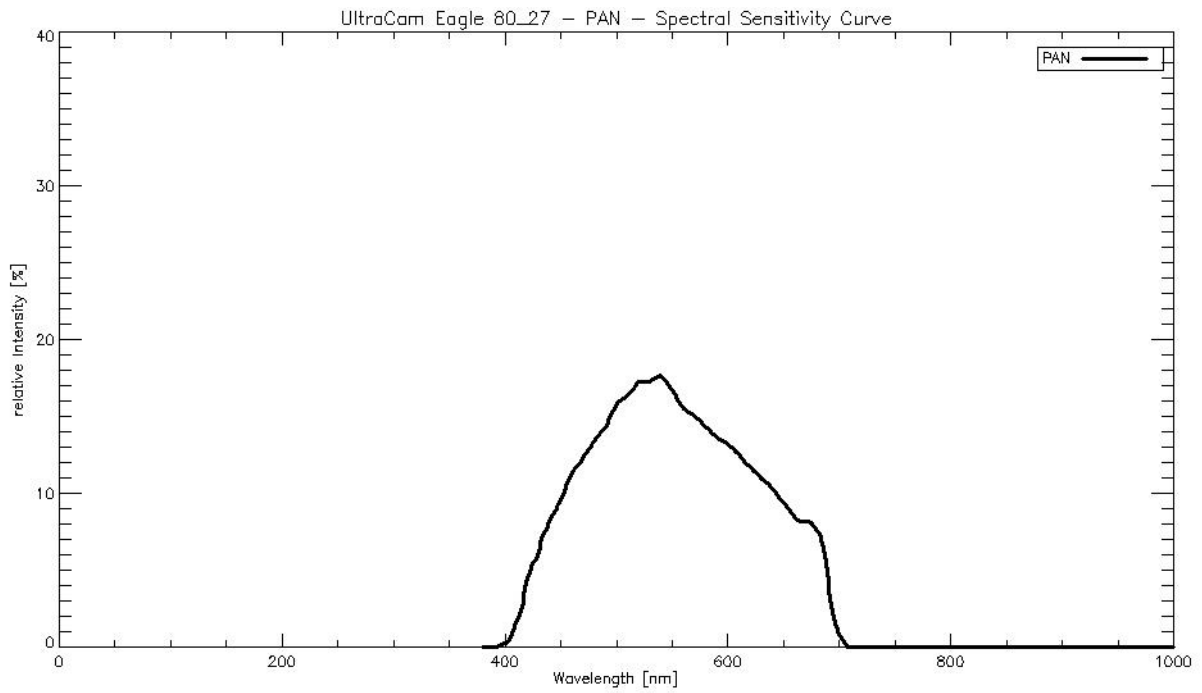


Modulation versus Image Height - Aperture f / 9.5





Spectral Sensitivity





ULTRACAM

Radiometric Calibration

Camera: UltraCam Eagle
Serial: UC-E-1-00518105-f80

	PAN	R, G, NIR	B
Used Apertures	F5.6	F4.8	F4.8
	F6.5	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

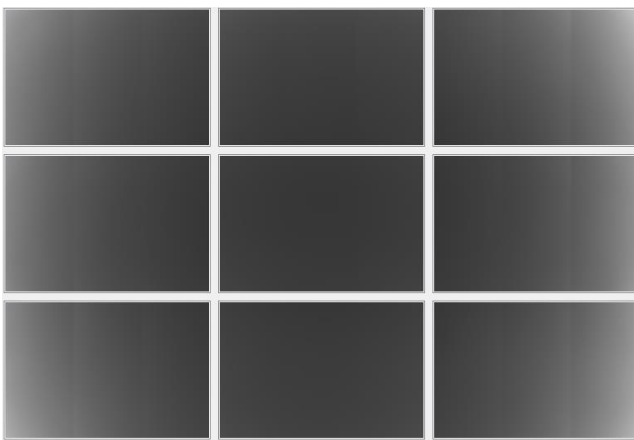
Calibration Date: Nov-10-2016
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Version of Report: V01



Calibration of Vignetting for working Aperture F6.7

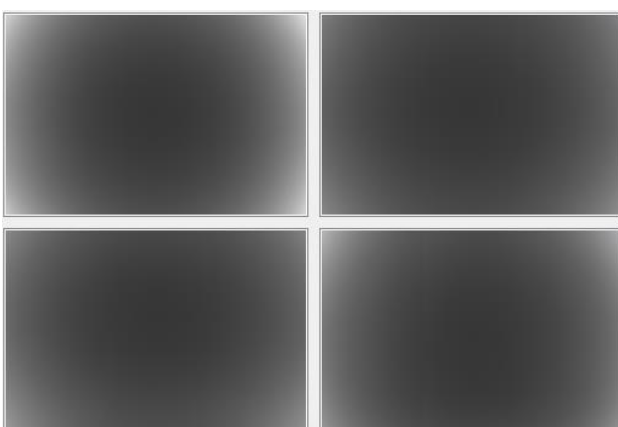
	PAN	R, G, NIR	B
Aperture	F6.5	F5.4	F4.8

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)



Dead Pixel Report:

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

C00-00

- PIXEL: 719/1576
- PIXEL: 897/1099
- PIXEL: 1282/2389
- PIXEL: 1304/3823
- PIXEL: 1540/3278
- PIXEL: 2208/2008
- PIXEL: 2447/2219
- PIXEL: 3095/1903
- PIXEL: 3095/1904
- PIXEL: 3430/3020
- PIXEL: 3524/1096
- PIXEL: 3735/ 914
- PIXEL: 4162/1771
- PIXEL: 5120/3586
- PIXEL: 5707/4376
- PIXEL: 5948/2760
- PIXEL: 6085/3127
- PIXEL: 6301/2203
- PIXEL: 6301/2204
- PIXEL: 6863/1776
- PIXEL: 2290/4385
- PIXEL: 2290/4386
- PIXEL: 3491/ 20
- PIXEL: 3492/ 21
- PIXEL: 6880/3643
- PIXEL: 2289/4385
- PIXEL: 2290/4387
- PIXEL: 2289/4387
- PIXEL: 3493/ 21

C00-01

- PIXEL: 208/2136
- PIXEL: 672/2795
- PIXEL: 730/3888
- PIXEL: 2270/3088
- PIXEL: 2498/3196
- PIXEL: 2928/3757
- PIXEL: 3541/2851
- PIXEL: 4728/ 321
- PIXEL: 5127/2215



PIXEL: 6544/ 506
PIXEL: 3524/1373
PIXEL: 3524/1374
PIXEL: 4013/3651
PIXEL: 6714/1658
PIXEL: 3525/1373
PIXEL: 3525/1374

C00-02

PIXEL: 45/ 718
PIXEL: 1377/3762
PIXEL: 1545/1246
PIXEL: 1952/4256
PIXEL: 2656/2063
PIXEL: 2874/1638
PIXEL: 3232/1819
PIXEL: 3608/1375
PIXEL: 4490/3384
PIXEL: 4963/1960
PIXEL: 4963/1976
PIXEL: 5443/3218
PIXEL: 5641/ 71
PIXEL: 5722/1588
PIXEL: 6557/2783
PIXEL: 6859/3859
PIXEL: 1883/4224
PIXEL: 1898/ 863
PIXEL: 2164/1170
PIXEL: 2345/1546
PIXEL: 2346/1546
PIXEL: 2346/1547
PIXEL: 2694/4394
PIXEL: 2805/ 356
PIXEL: 3244/2323
PIXEL: 3282/2880
PIXEL: 3894/1414
PIXEL: 3927/ 674
PIXEL: 4846/4569
PIXEL: 4868/1526
PIXEL: 5039/2679
PIXEL: 6798/4337
PIXEL: 2345/1548
PIXEL: 2346/1548
PIXEL: 2344/1546
PIXEL: 3894/1415
PIXEL: 3893/1414
PIXEL: 4846/4568



C00-03

- PIXEL: 347/ 767
- PIXEL: 670/1853
- PIXEL: 1327/4206
- PIXEL: 1673/2293
- PIXEL: 1698/3629
- PIXEL: 2009/2556
- PIXEL: 2120/1426
- PIXEL: 2417/3648
- PIXEL: 2627/2783
- PIXEL: 2813/4425
- PIXEL: 3722/1181
- PIXEL: 3959/ 417
- PIXEL: 4482/3748
- PIXEL: 4751/4037
- PIXEL: 4861/3268
- PIXEL: 5692/3599
- PIXEL: 55/ 254
- PIXEL: 1414/1319
- PIXEL: 1414/1320
- PIXEL: 1415/1318
- PIXEL: 1416/1320
- PIXEL: 1902/1198
- PIXEL: 2834/4205
- PIXEL: 5088/ 621
- PIXEL: 1416/1318
- PIXEL: 1417/1319
- PIXEL: 1902/1199
- PIXEL: 1903/1198
- PIXEL: 1902/1197

C01-00

- PIXEL: 32/ 908
- PIXEL: 1814/3163
- PIXEL: 2318/3124
- PIXEL: 2880/2555
- PIXEL: 2937/3105
- PIXEL: 6899/ 660
- PIXEL: 1316/ 217
- PIXEL: 1317/ 217
- PIXEL: 2332/1708
- PIXEL: 3206/1630
- PIXEL: 3526/2182
- PIXEL: 5434/2448
- PIXEL: 5434/2449
- PIXEL: 5435/2448
- PIXEL: 5435/2449
- PIXEL: 5527/1878
- PIXEL: 5839/ 57
- PIXEL: 5840/ 57



PIXEL: 6662/ 43
PIXEL: 6662/ 44
PIXEL: 6662/ 45
PIXEL: 6663/ 44
PIXEL: 5436/2448
PIXEL: 5841/ 56
PIXEL: 5838/ 56
PIXEL: 5840/ 55
PIXEL: 5839/ 55

C01-01

PIXEL: 1388/1511
PIXEL: 2661/3236
PIXEL: 4488/2126
PIXEL: 4754/ 334
PIXEL: 3656/3617
PIXEL: 3656/3618
PIXEL: 3657/3618
PIXEL: 3826/4598
PIXEL: 3655/3617
PIXEL: 3825/4597
PIXEL: 3825/4598

C02-00

PIXEL: 778/1003
PIXEL: 2423/2786
PIXEL: 3185/1647
PIXEL: 6341/ 473
PIXEL: 6372/4090
PIXEL: 6669/2140
PIXEL: 6958/4125
PIXEL: 2318/1548
PIXEL: 3023/1850
PIXEL: 2319/1547
PIXEL: 2318/1547
PIXEL: 2319/1548

C02-01

PIXEL: 814/1230
PIXEL: 913/4544
PIXEL: 1281/ 963
PIXEL: 1405/4209
PIXEL: 2046/2171
PIXEL: 3025/ 669
PIXEL: 3313/3127
PIXEL: 3363/3517
PIXEL: 5491/2300
PIXEL: 5708/4587
PIXEL: 6783/3706
PIXEL: 1752/2299



PIXEL: 1752/2300
PIXEL: 1748/2298

C03-00

PIXEL: 193/2635
PIXEL: 1045/ 187
PIXEL: 2872/4079
PIXEL: 3687/3159
PIXEL: 4140/4443
PIXEL: 4828/1579
PIXEL: 5563/3252
PIXEL: 6030/3708
PIXEL: 792/4051
PIXEL: 1162/ 876
PIXEL: 1345/3388
PIXEL: 1346/3388
PIXEL: 1777/3800
PIXEL: 1778/3800
PIXEL: 1778/3801
PIXEL: 3058/ 177
PIXEL: 4860/1650
PIXEL: 793/4050
PIXEL: 1345/3389
PIXEL: 1778/3799

C04-00

PIXEL: 578/2805
PIXEL: 758/3241
PIXEL: 841/1691
PIXEL: 1208/4212
PIXEL: 2731/3198
PIXEL: 2883/4496
PIXEL: 3591/4582
PIXEL: 3599/1834
PIXEL: 4220/1627
PIXEL: 6473/ 56
PIXEL: 6483/3450
PIXEL: 508/2380
PIXEL: 508/2381
PIXEL: 508/2382
PIXEL: 827/2569
PIXEL: 1097/1666
PIXEL: 1097/1667
PIXEL: 3487/ 925
PIXEL: 5639/1660
PIXEL: 5639/1663
PIXEL: 5640/1659
PIXEL: 5640/1663
PIXEL: 507/2380
PIXEL: 507/2382



PIXEL: 1096/1666
PIXEL: 3487/ 924
PIXEL: 3489/ 925
PIXEL: 3488/ 923
PIXEL: 3490/ 924
PIXEL: 3490/ 925
PIXEL: 3491/ 923
PIXEL: 5641/1660
PIXEL: 5638/1661
PIXEL: 5641/1662

C05-00

PIXEL: 143/1947
PIXEL: 676/3403
PIXEL: 1448/2060
PIXEL: 1779/2186
PIXEL: 2055/4415
PIXEL: 2932/ 539
PIXEL: 3742/2842
PIXEL: 4983/ 692
PIXEL: 5673/2845
PIXEL: 6846/ 812
PIXEL: 72/2889
PIXEL: 72/2890
PIXEL: 73/2889
PIXEL: 271/ 624
PIXEL: 271/ 625
PIXEL: 314/ 448
PIXEL: 1238/3538
PIXEL: 1238/3539
PIXEL: 2440/ 67
PIXEL: 2441/ 71
PIXEL: 4474/1139
PIXEL: 4475/1138
PIXEL: 4475/1139
PIXEL: 4476/1137
PIXEL: 4476/1138
PIXEL: 4477/1136
PIXEL: 5645/4074
PIXEL: 6034/4622
PIXEL: 73/2890
PIXEL: 71/2889
PIXEL: 314/ 447
PIXEL: 1237/3538
PIXEL: 1239/3538
PIXEL: 4474/1138

C06-00

PIXEL: 1219/4120
PIXEL: 2162/ 102



PIXEL: 3743/2495
PIXEL: 6609/2604
PIXEL: 2428/ 945

C07-00

PIXEL: 365/4334
PIXEL: 1510/3874
PIXEL: 1536/2147
PIXEL: 1569/3162
PIXEL: 2084/ 989
PIXEL: 3003/2618
PIXEL: 3300/2330
PIXEL: 6621/ 115

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
Serial: UC-E-1-00518105-f80

Panchromatic Camera: 4 * Prontor Magnetic 0
Prontor-Werk Alfred Gauthier GmbH, Germany

Multispectral Camera: 4 * Prontor Magnetic 0
Prontor-Werk Alfred Gauthier GmbH, Germany

Calibration Date: Nov-10-2016
Date of Report: Nov-15-2016
Camera Revision: Rev02.00
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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 10 09 95	9.87	10.20	10.68	11.04	11.24	11.46	11.71	12.10	+/- 0.2
C1 (Pan)	12 10 09 83	10.68	10.99	11.43	11.86	12.13	12.36	12.56	13.10	+/- 0.2
C2 (Pan)	12 10 09 80	9.57	9.89	10.35	10.68	10.97	11.20	11.36	11.81	+/- 0.2
C3 (Pan)	12 10 09 88	9.99	10.28	10.78	11.15	11.45	11.68	11.79	12.26	+/- 0.2
C4 (Red)	12 10 16 37	11.63	11.74	11.96	12.16	12.24	12.45	12.46	12.62	+/- 0.2
C5 (Green)	12 10 16 17	11.54	11.66	12.02	12.19	12.30	12.37	12.41	12.86	+/- 0.2
C6 (Blue)	12 10 16 20	11.46	11.46	11.49	11.61	11.85	12.05	12.21	12.50	+/- 0.2
C7 (NIR)	12 10 16 27	11.06	11.22	11.46	11.74	11.85	11.91	12.11	12.12	+/- 0.2



ULTRACAM

Electronics and Sensor Calibration

Camera: UltraCam Eagle
Serial: UC-E-1-00518105-f80

Panchromatic Camera: 9 * FTF7046-M Area CCD Sensor by DALSA
Multispectral Camera: 4 * FTF7046-M Area CCD Sensor by DALSA

Calibration Date: Nov-10-2016
Date of Report: Nov-15-2016
Camera Revision: Rev02.00
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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]
00_00	FTF7046-M	148611/055	24.60
00_01	FTF7046-M	148611/050	24.80
00_02	FTF7046-M	148424/025	24.80
00_03	FTF7046-M	148611/042	24.80
01_00	FTF7046-M	148611/056	24.40
01_01	FTF7046-M	148611/061	24.60
02_00	FTF7046-M	148611/063	24.60
02_01	FTF7046-M	148611/064	25.20
03_00	FTF7046-M	148611/057	24.40
04_00 (red)	FTF7046-M	148611/021	24.60
05_00 (green)	FTF7046-M	148611/049	24.80
06_00 (blue)	FTF7046-M	148611/045	24.60
07_00 (NIR)	FTF7046-M	148611/052	24.80



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]
00_00	FTF7046-M	148611/055	13420
00_01	FTF7046-M	148611/050	13540
00_02	FTF7046-M	148424/025	13900
00_03	FTF7046-M	148611/042	13030
01_00	FTF7046-M	148611/056	13660
01_01	FTF7046-M	148611/061	13630
02_00	FTF7046-M	148611/063	14080
02_01	FTF7046-M	148611/064	13730
03_00	FTF7046-M	148611/057	13610
04_00 (red)	FTF7046-M	148611/021	13270
05_00 (green)	FTF7046-M	148611/049	13380
06_00 (blue)	FTF7046-M	148611/045	13440
07_00 (NIR)	FTF7046-M	148611/052	13660



ULTRACAM

Summary

Camera:	UltraCam Eagle
Serial:	UC-E-1-00518105-f80
Calibration Date:	Nov-10-2016
Date of Report:	Nov-15-2016
Camera Revision:	Rev02.00
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

Dipl. Ing. (FH) Helmut Jauk
Senior Project Specialist
Vexcel Imaging GmbH