



VEXCEL
IMAGING

ULTRACAM

Calibration Report

Camera:
Serial:

UltraCam Eagle
UC-E-1-60715585-f100

Calibration Date:
Date of Report:
Camera Revision:
Version of Report:

Jan-03-2017
Jan-17-2017
Rev05.00
V01



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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-1-60715585-f100

Panchromatic Camera:	ck = 100.500 mm
Multispectral Camera:	ck = 100.500 mm

PPA Information:	X: 0.000 mm
	Y: 0.000 mm

Calibration Date:	Jan-03-2017
Date of Report:	Jan-17-2017
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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	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		

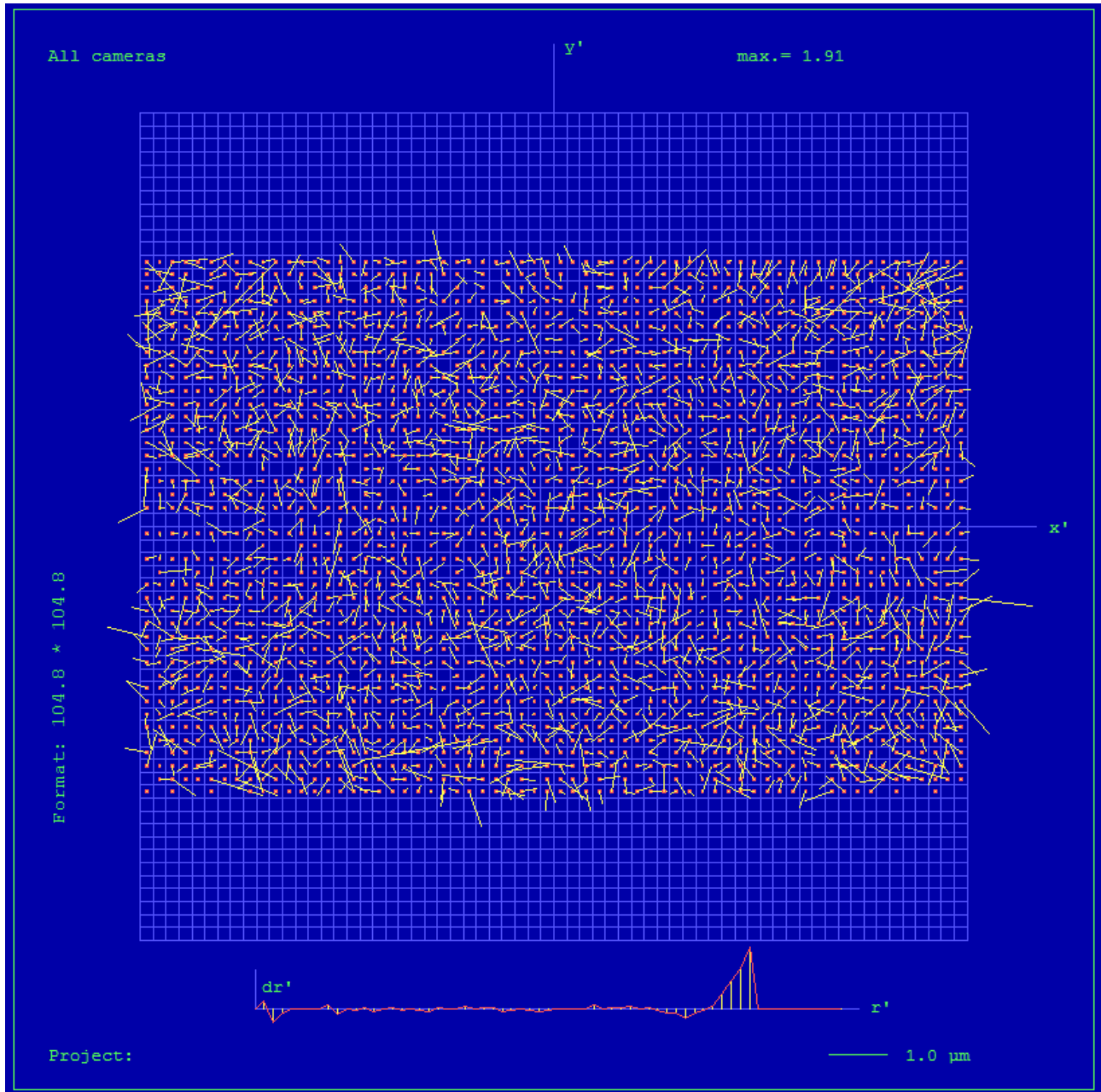
Multispectral Camera

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

Image Format	long track cross track	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	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		



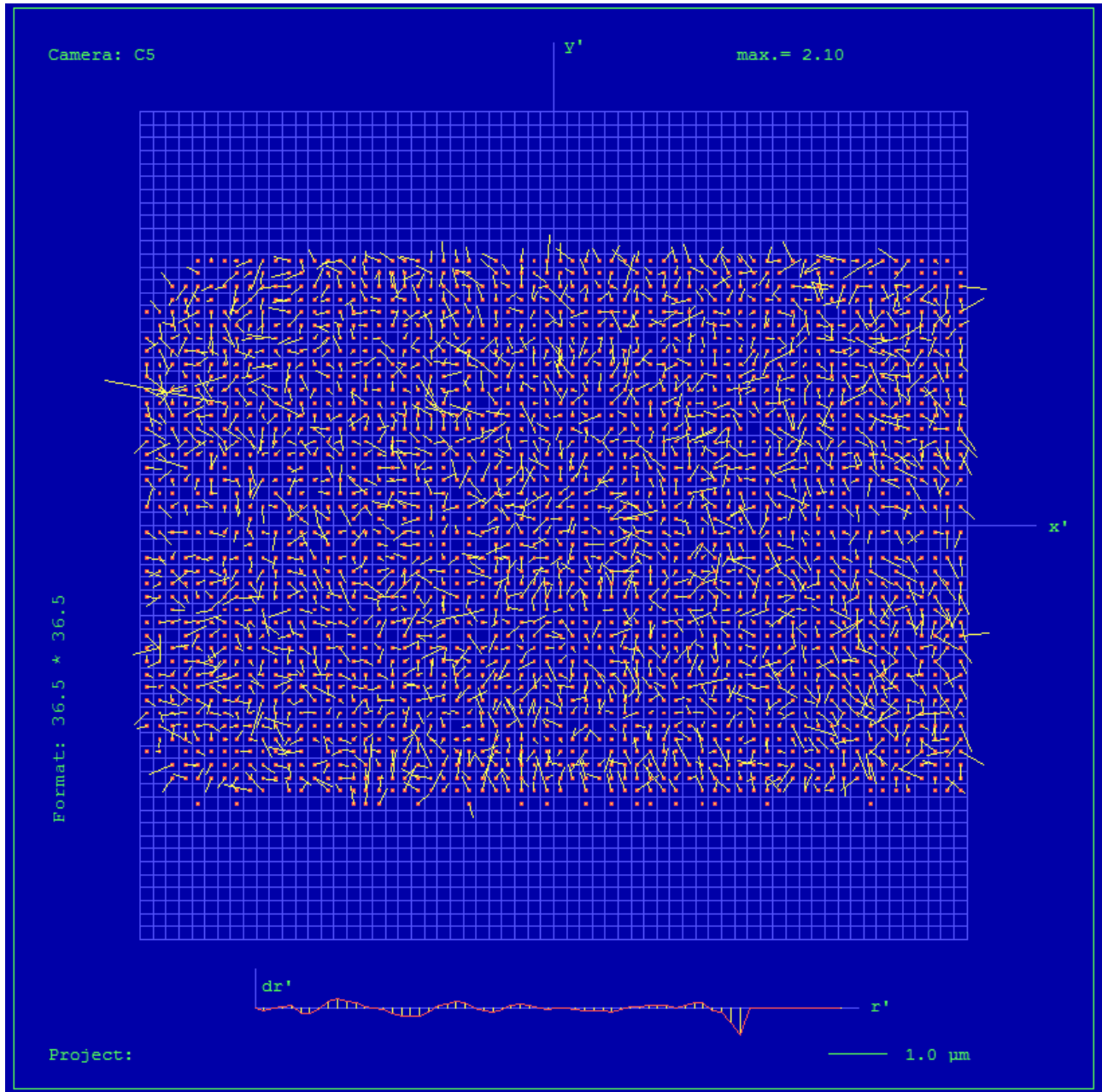
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.64 μm**



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.48 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

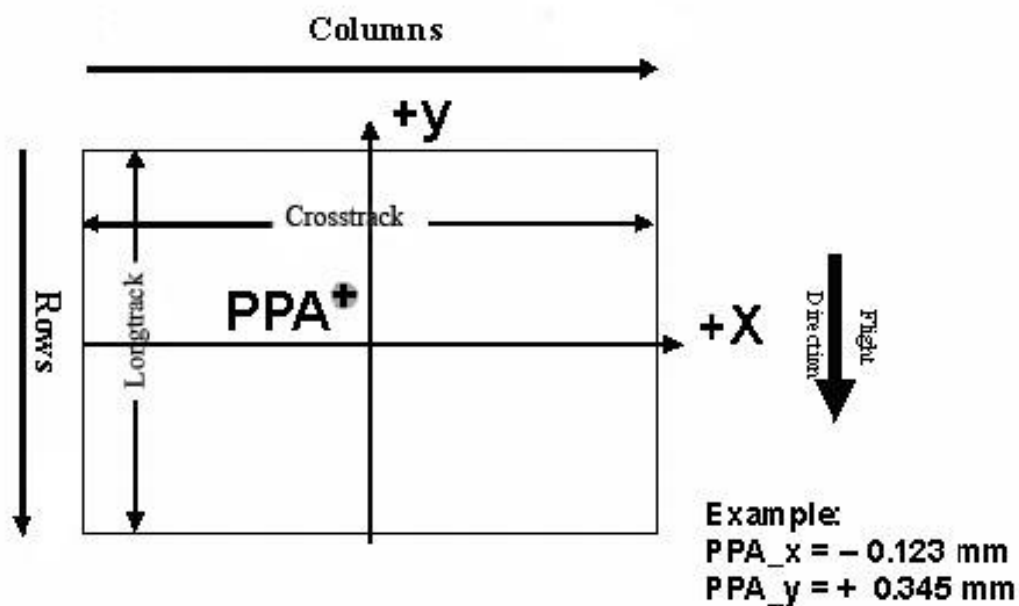
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

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

Level 2 Image Coordinate System:

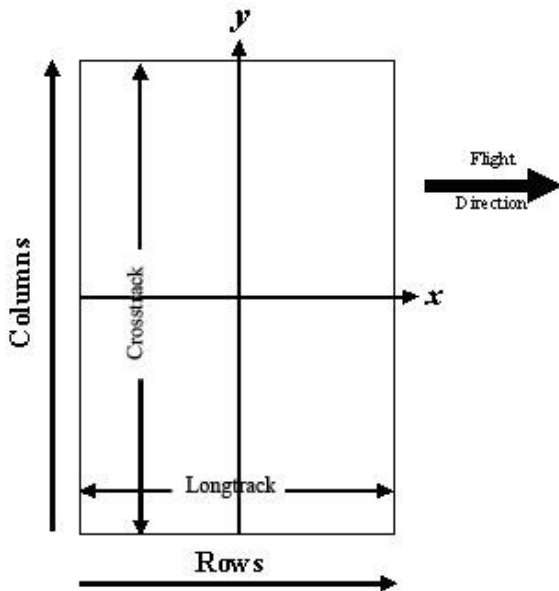
Lvl2, Camera prop. Orientation



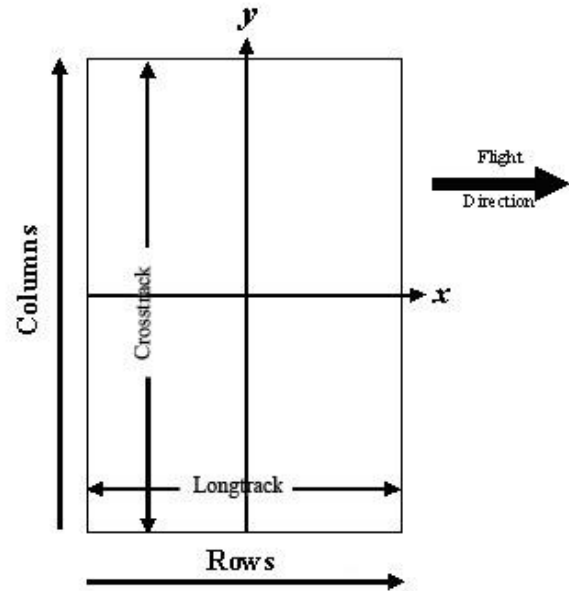
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



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



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

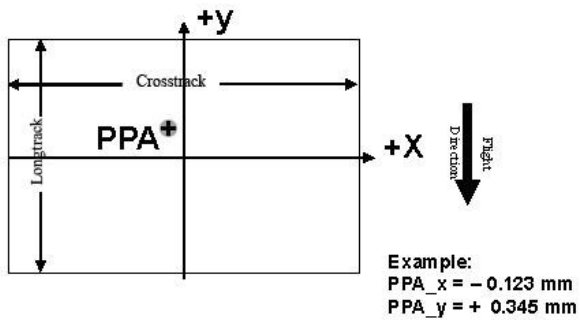
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified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

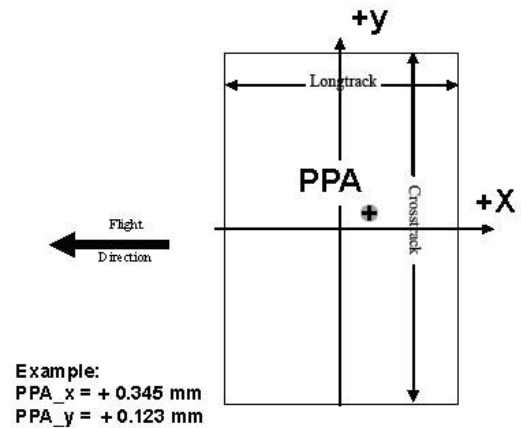


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

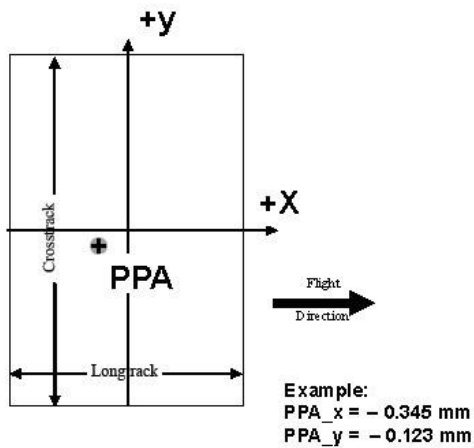
Lvl3, Rotation 0 deg clockwise



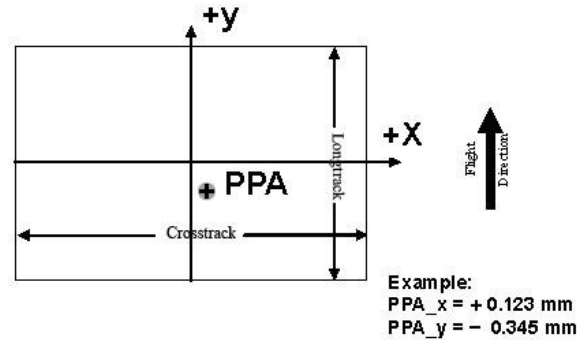
Lvl3, Rotation 90 deg clockwise



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.

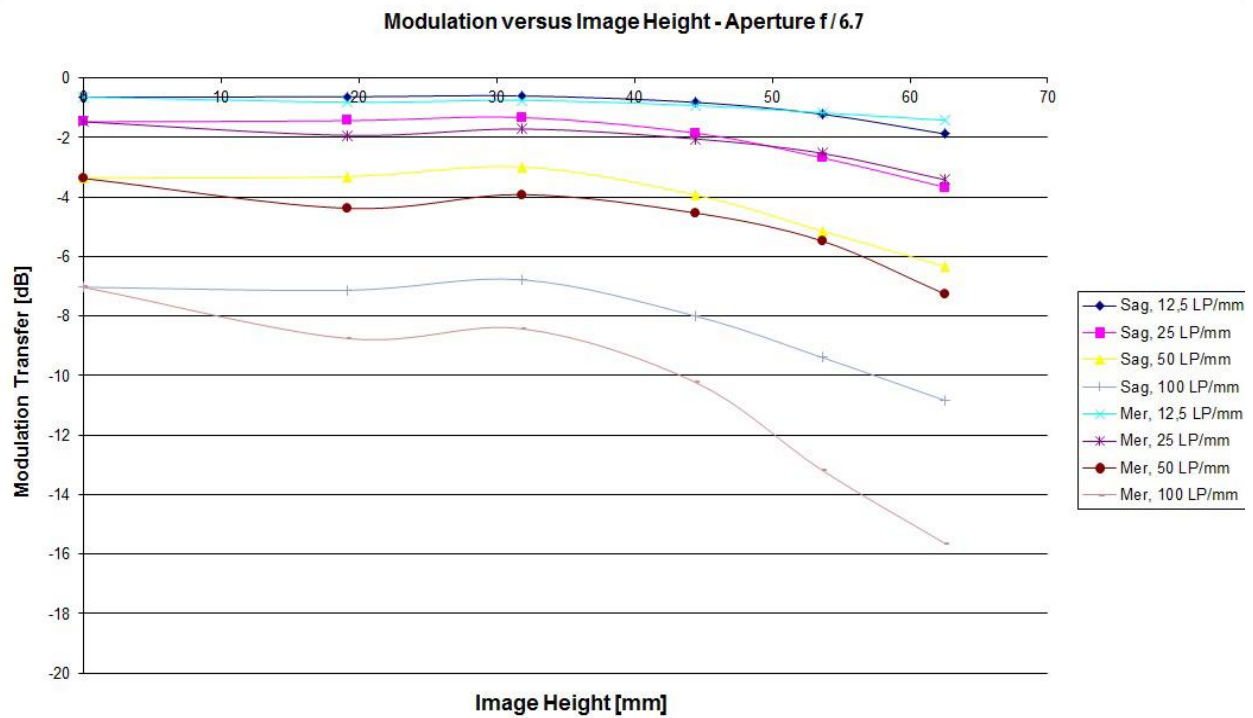
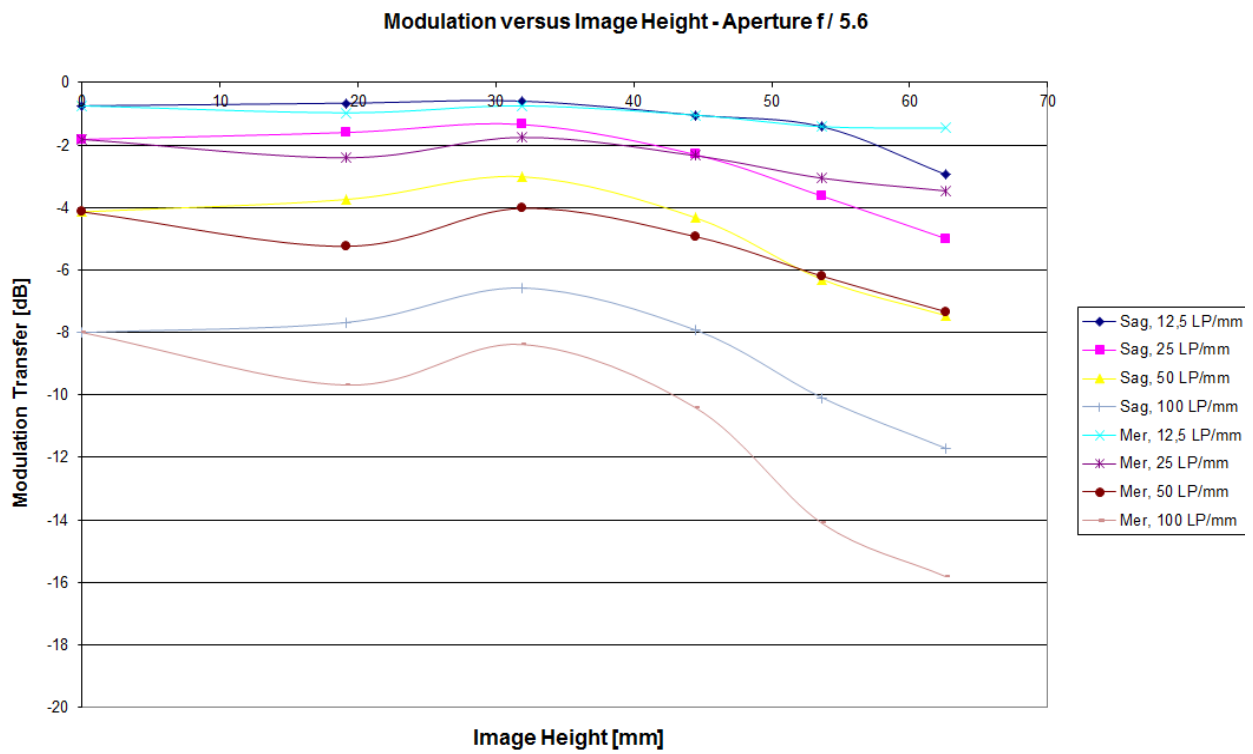
Please note that these values have been calculated and can vary up to 10% with optics from production (especially at high LP's).

The curves are given for the meridional (tangential) and 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.

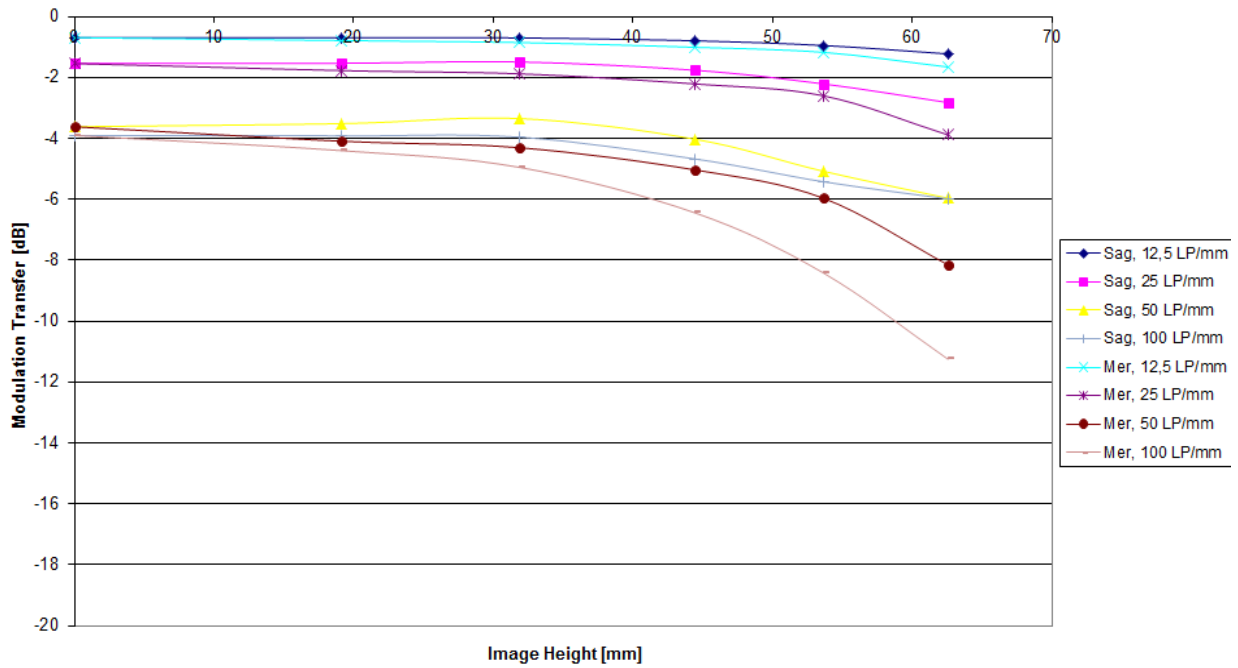
Lens types

Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic Vexcel HR Digaron 1:4/33mm, Qioptic GmbH, Germany
C5 (GREEN)	Qioptic Vexcel HR Digaron 1:4/33mm, Qioptic GmbH, Germany
C6 (BLUE)	Qioptic Vexcel HR Digaron 1:4/33mm, Qioptic GmbH, Germany
C7 (NIR)	Qioptic Vexcel HR Digaron 1:4/33mm, Qioptic GmbH, Germany

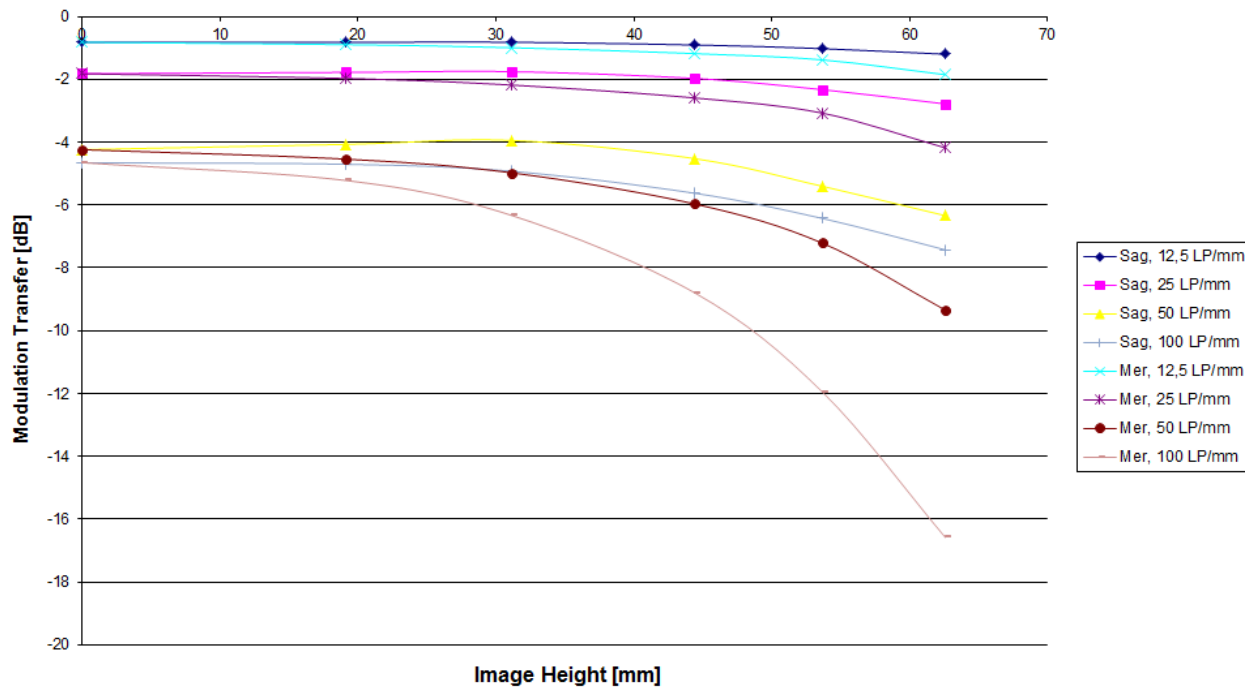




Modulation versus Image Height - Aperture f / 8

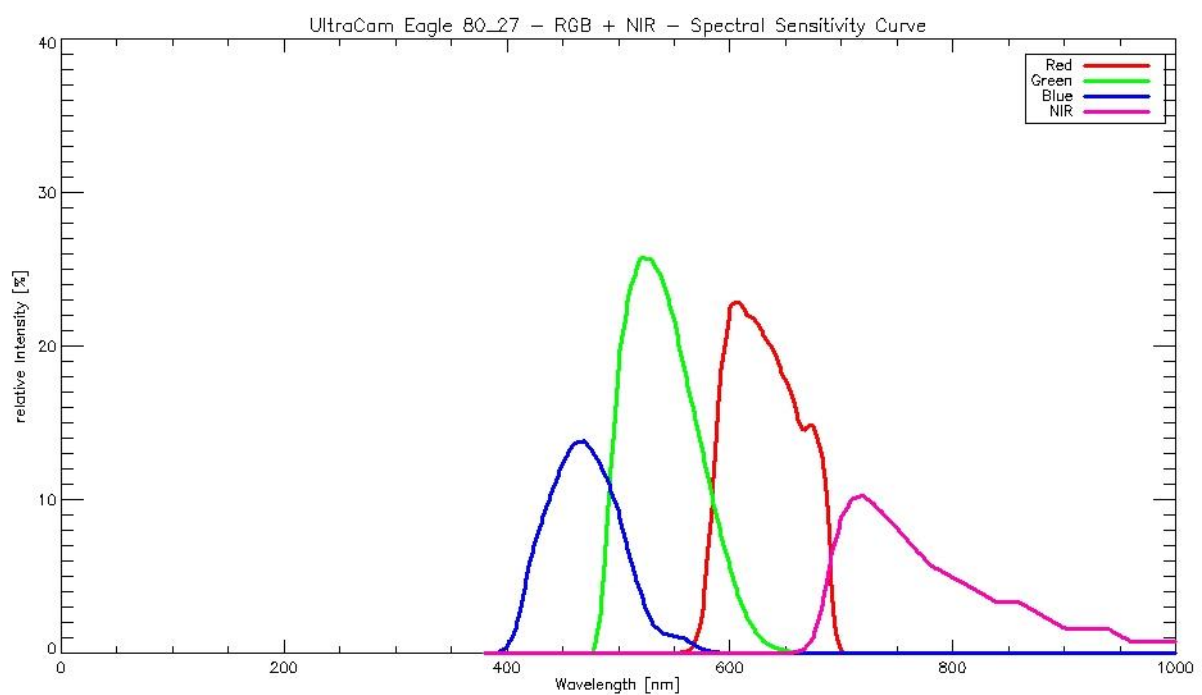
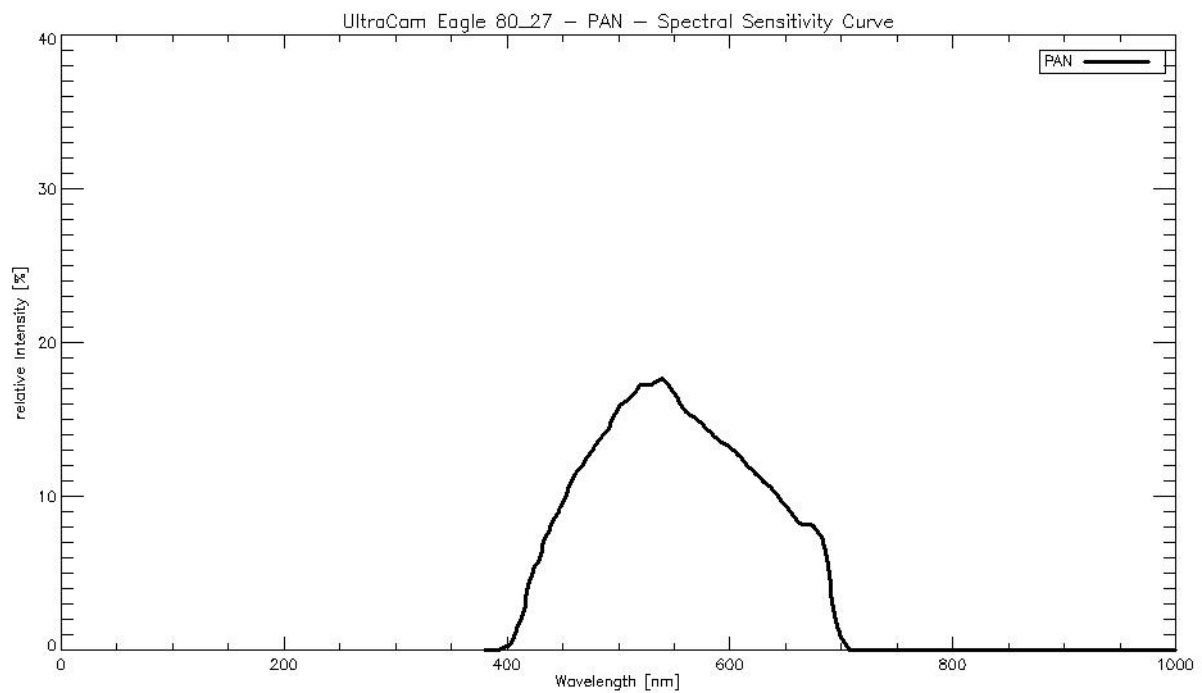


Modulation versus Image Height - Aperture f / 9.5





Spectral Sensitivity





ULTRACAM

Radiometric Calibration

Camera: UltraCam Eagle
Serial: UC-E-1-60715585-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


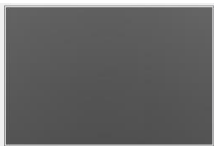

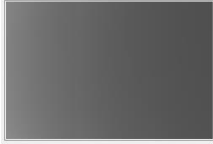
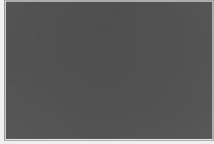
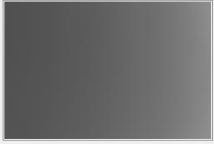
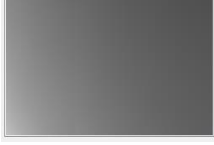
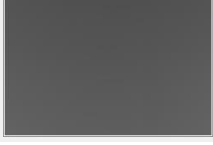
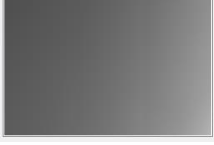
Calibration Date: Jan-03-2017
Date of Report: Jan-17-2017
Camera Revision: Rev05.00
Version of Report: V01



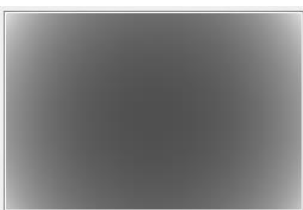
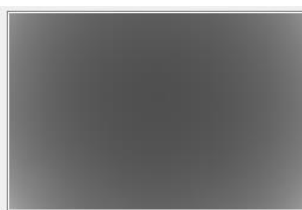
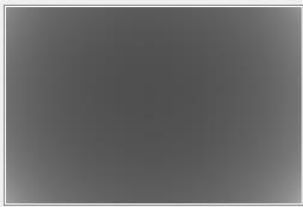
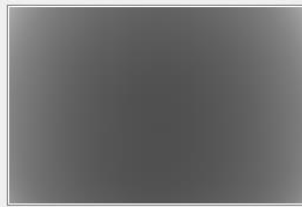
Calibration of Vignetting for working Aperture F6.7

	PAN	R, G, NIR	B
Aperture	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)



Dead Pixel Report:

Sensor number		
Anomaly type	X-Coordinate	Y-Coordinate

C00-00

PIXEL: 2672/3619
PIXEL: 5277/4592
PIXEL: 5787/1111
PIXEL: 6889/2301
PIXEL: 2845/ 780
PIXEL: 2845/ 781
PIXEL: 5079/2940
PIXEL: 5473/2048
PIXEL: 5474/2046
PIXEL: 5474/2048
PIXEL: 5866/2851
PIXEL: 6681/ 647
PIXEL: 2846/ 780
PIXEL: 5474/2049
PIXEL: 5473/2045
PIXEL: 6681/ 646

C00-01

PIXEL: 495/1158
PIXEL: 5223/1585
PIXEL: 6077/4560
PIXEL: 811/ 669
PIXEL: 1034/4065
PIXEL: 2354/2433
PIXEL: 2354/2434
PIXEL: 3937/ 464
PIXEL: 4630/2092
PIXEL: 5096/3774
PIXEL: 5275/ 645
PIXEL: 5503/4162
PIXEL: 5657/2106
PIXEL: 5657/2107
PIXEL: 5993/1950
PIXEL: 6797/4625
PIXEL: 5280/ 643
PIXEL: 5287/ 645
PIXEL: 5280/ 650

C00-02

PIXEL: 250/3047
PIXEL: 3744/1403
PIXEL: 5910/3052
PIXEL: 5899/4618
PIXEL: 5899/4619



PIXEL: 5900/4618

PIXEL: 5900/4619

C00-03

PIXEL: 340/2623

PIXEL: 2398/ 989

PIXEL: 2742/4538

PIXEL: 2780/2711

PIXEL: 6371/3050

PIXEL: 6532/1722

PIXEL: 787/1873

PIXEL: 787/1874

PIXEL: 2992/ 133

PIXEL: 5336/ 236

PIXEL: 6477/1964

PIXEL: 788/1874

C01-00

PIXEL: 495/ 646

PIXEL: 2694/4073

PIXEL: 5375/3803

PIXEL: 3665/ 707

PIXEL: 3665/ 708

PIXEL: 5064/ 30

PIXEL: 5064/ 31

PIXEL: 5065/ 30

PIXEL: 5066/ 30

PIXEL: 5066/ 31

PIXEL: 5067/ 29

PIXEL: 5067/ 31

PIXEL: 5068/ 27

PIXEL: 5068/ 28

PIXEL: 5068/ 29

PIXEL: 5069/ 27

PIXEL: 5069/ 28

PIXEL: 5069/ 29

PIXEL: 5070/ 28

C01-01

PIXEL: 65/1645

PIXEL: 191/4096

PIXEL: 1065/2352

PIXEL: 1279/2274

PIXEL: 1674/1521

PIXEL: 1921/ 288

PIXEL: 2293/1204

PIXEL: 2405/ 138

PIXEL: 2632/1934

PIXEL: 3143/3924

PIXEL: 3143/3925

PIXEL: 3743/1191

PIXEL: 4666/3145

PIXEL: 4931/2535

PIXEL: 5240/3330



PIXEL: 6086/2942
PIXEL: 6471/1351
PIXEL: 6472/1844
PIXEL: 6482/1847
PIXEL: 6704/ 850

C02-00

PIXEL: 298/4484
PIXEL: 417/1732
PIXEL: 984/1363
PIXEL: 993/4456
PIXEL: 1066/ 926
PIXEL: 1072/2670
PIXEL: 1096/ 274
PIXEL: 1300/3014
PIXEL: 1341/1716
PIXEL: 1642/2328
PIXEL: 1722/1044
PIXEL: 1820/1433
PIXEL: 2021/ 278
PIXEL: 2131/4115
PIXEL: 2429/2368
PIXEL: 2437/1632
PIXEL: 2504/4154
PIXEL: 2531/3381
PIXEL: 3022/4381
PIXEL: 3447/ 987
PIXEL: 3497/3217
PIXEL: 3772/ 972
PIXEL: 3986/3119
PIXEL: 4477/ 364
PIXEL: 4796/1241
PIXEL: 4959/3973
PIXEL: 5034/1897
PIXEL: 5723/ 234
PIXEL: 6304/3047
PIXEL: 6687/ 940
PIXEL: 325/ 128
PIXEL: 898/ 97
PIXEL: 899/ 96
PIXEL: 899/ 97
PIXEL: 900/ 96
PIXEL: 2007/1259
PIXEL: 3866/1680
PIXEL: 4606/3042
PIXEL: 4606/3043

C02-01

PIXEL: 700/3140
PIXEL: 736/4378
PIXEL: 2803/ 242
PIXEL: 4806/ 117
PIXEL: 5524/4165
PIXEL: 6561/2146
PIXEL: 1058/3380



PIXEL: 1058/3381
PIXEL: 1059/3379
PIXEL: 1059/3380
PIXEL: 3537/1905
PIXEL: 3632/2333
PIXEL: 4339/ 909
PIXEL: 4340/ 909
PIXEL: 4340/ 910
PIXEL: 5718/4136
PIXEL: 4339/ 908

C03-00

PIXEL: 760/2402
PIXEL: 2053/1101
PIXEL: 3032/3678
PIXEL: 128/2959
PIXEL: 131/2960
PIXEL: 4022/1594
PIXEL: 5148/3743
PIXEL: 5148/3744
PIXEL: 5147/3743
PIXEL: 5147/3744

C04-00

PIXEL: 118/1795
PIXEL: 1186/3090
PIXEL: 2031/4475
PIXEL: 3660/1147
PIXEL: 1199/4208
PIXEL: 1199/4209
PIXEL: 3212/1583
PIXEL: 3212/1584
PIXEL: 3628/1509
PIXEL: 4878/1456
PIXEL: 6515/ 612
PIXEL: 6515/ 613
PIXEL: 6516/ 614
PIXEL: 6517/ 614

C05-00

PIXEL: 1498/1347
PIXEL: 5518/4554
PIXEL: 5772/1083
PIXEL: 5572/3831

C06-00

PIXEL: 586/2919
PIXEL: 4496/ 632
PIXEL: 6040/ 597
PIXEL: 2217/2566
PIXEL: 4962/4196
PIXEL: 5419/4604
PIXEL: 5838/2209
PIXEL: 6157/4412



PIXEL: 6515/1472
PIXEL: 6515/1473
PIXEL: 6777/1402
PIXEL: 6778/1402
PIXEL: 6158/4412
PIXEL: 6159/4411
PIXEL: 6778/1403
PIXEL: 6777/1403

C07-00

PIXEL: 757/3489
PIXEL: 1100/1890
PIXEL: 1260/3021
PIXEL: 2152/4478
PIXEL: 2576/ 542
PIXEL: 2763/ 905
PIXEL: 3149/ 289
PIXEL: 3574/4556
PIXEL: 3777/1005
PIXEL: 3843/1730
PIXEL: 4262/ 79
PIXEL: 4463/4616
PIXEL: 4520/1485
PIXEL: 4784/3404
PIXEL: 4949/1961
PIXEL: 5273/1134
PIXEL: 5770/3483
PIXEL: 6644/ 49
PIXEL: 6846/2749

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-1-60715585-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 Date: Jan-03-2017
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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 27 38 31	6.65	6.87	7.16	7.42	7.71	7.84	7.96	8.24	+/- 0.2
C1 (Pan)	12 27 38 40	6.69	6.94	7.25	7.46	7.69	7.86	7.95	8.13	+/- 0.2
C2 (Pan)	12 27 38 29	6.68	6.81	7.11	7.35	7.51	7.68	7.83	7.98	+/- 0.2
C3 (Pan)	12 27 38 42	6.08	6.26	6.54	6.78	6.98	7.08	7.18	7.37	+/- 0.2
C4 (Red)	12 24 50 18	6.65	6.77	6.90	6.99	7.19	7.19	7.21	7.41	+/- 0.2
C5 (Green)	12 24 50 20	7.44	7.57	7.74	7.87	8.01	8.07	8.07	8.24	+/- 0.2
C6 (Blue)	12 23 11 73	6.84	6.84	6.87	6.95	7.12	7.27	7.38	7.38	+/- 0.2
C7 (NIR)	12 23 11 77	6.68	6.75	6.93	7.06	7.20	7.28	7.28	7.27	+/- 0.2



ULTRACAM

Electronics and Sensor Calibration

Camera: UltraCam Eagle
Serial: UC-E-1-60715585-f100

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

Calibration Date: Jan-03-2017
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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	15 7349/050	24.40
00_01	FTF7046-M	16 0872/086	24.00
00_02	FTF7046-M	16 0872/116	24.00
00_03	FTF7046-M	16 0872/069	23.80
01_00	FTF7046-M	16 0872/088	24.00
01_01	FTF7046-M	16 2469/031	24.40
02_00	FTF7046-M	16 0872/128	24.00
02_01	FTF7046-M	16 0872/073	23.80
03_00	FTF7046-M	16 0872/117	24.00
04_00 (red)	FTF7046-M	16 2469/064	24.40
05_00 (green)	FTF7046-M	16 0872/111	24.00
06_00 (blue)	FTF7046-M	16 0872/097	24.00
07_00 (NIR)	FTF7046-M	16 2469/010	24.60



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	15 7349/050	13730
00_01	FTF7046-M	16 0872/086	13270
00_02	FTF7046-M	16 0872/116	12700
00_03	FTF7046-M	16 0872/069	13380
01_00	FTF7046-M	16 0872/088	13150
01_01	FTF7046-M	16 2469/031	13330
02_00	FTF7046-M	16 0872/128	12390
02_01	FTF7046-M	16 0872/073	12770
03_00	FTF7046-M	16 0872/117	12570
04_00 (red)	FTF7046-M	16 2469/064	13230
05_00 (green)	FTF7046-M	16 0872/111	12870
06_00 (blue)	FTF7046-M	16 0872/097	12790
07_00 (NIR)	FTF7046-M	16 2469/010	13930



ULTRACAM

Summary

Camera:	UltraCam Eagle
Serial:	UC-E-1-60715585-f100
Calibration Date:	Jan-03-2017
Date of Report:	Jan-17-2017
Camera Revision:	Rev05.00
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.

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