VEXCEL
IMAGING

ULTRACAM

Calibration Report

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-1-20816162-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:	**Dec-19-2016**
Date of Report:	**Jan-16-2017**
Camera Revision:	**Rev02.00**
Version of Report:	**V01**

Panchromatic Camera

Large Format Panchromatic Output Image

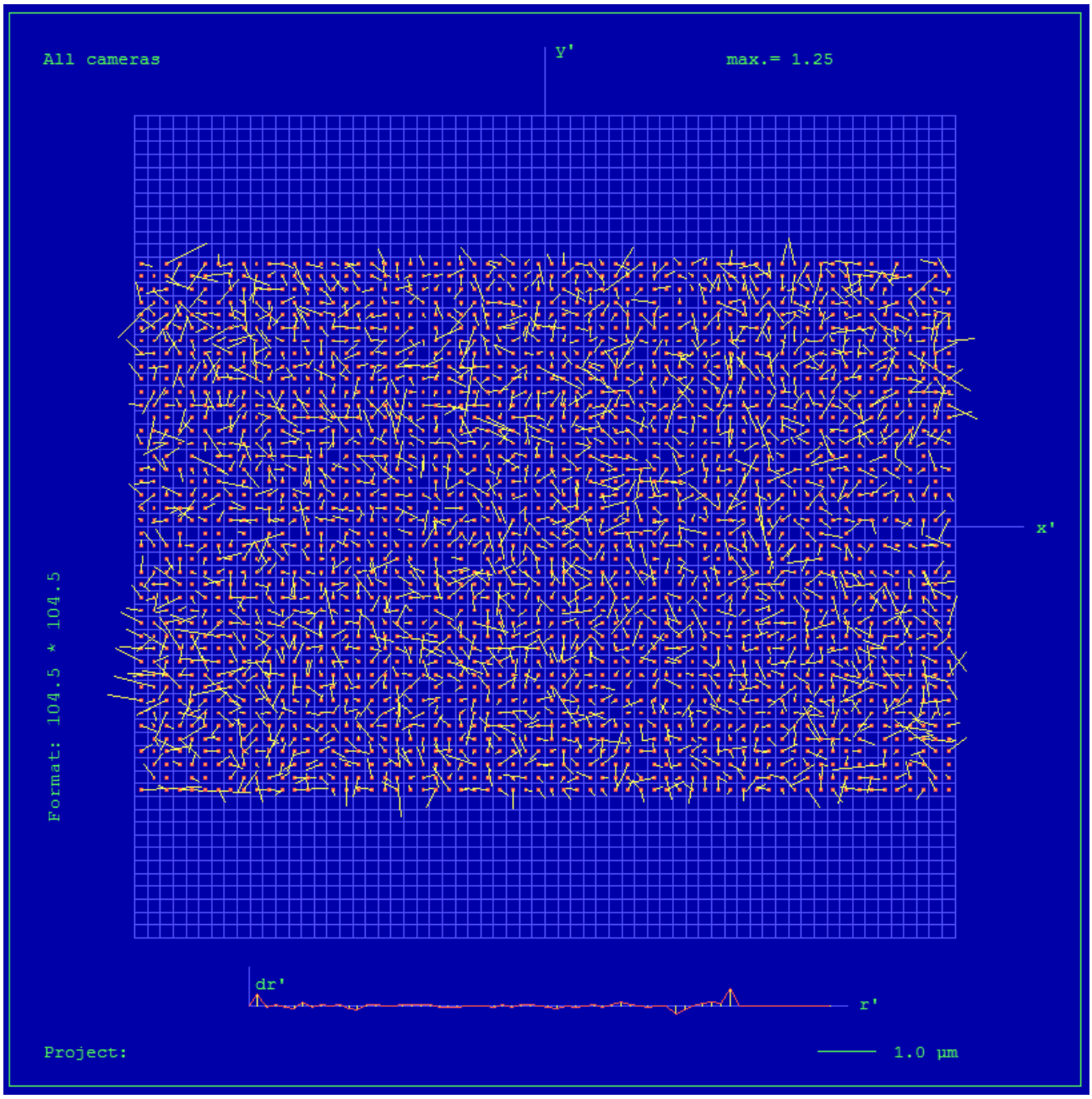
Image Format	long track cross track	68.016mm 104.052mm	13080pixel 20010pixel
Image Extent		(-34.008, -52.026)mm	(34.008, 52.026)mm
Pixel Size		5.200µm*5.200µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Multispectral Camera

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

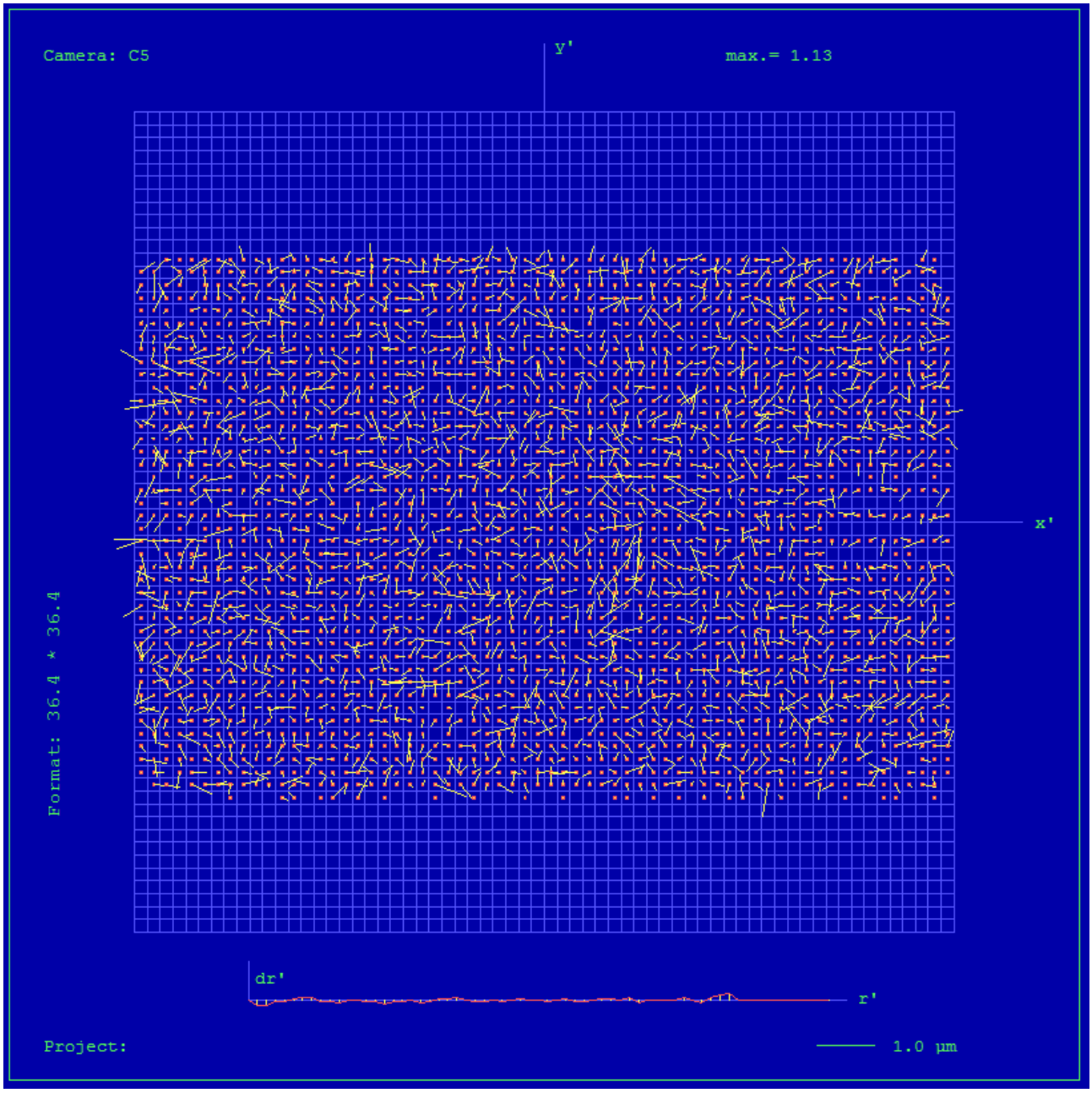
Image Format	long track cross track	68.016mm 104.052mm	4360pixel 6670pixel
Image Extent		(-34.008, -52.026)mm	(34.008, 52.026)mm
Pixel Size		15.600µm*15.600µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.57 µm**

Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.47 µm**

Explanations

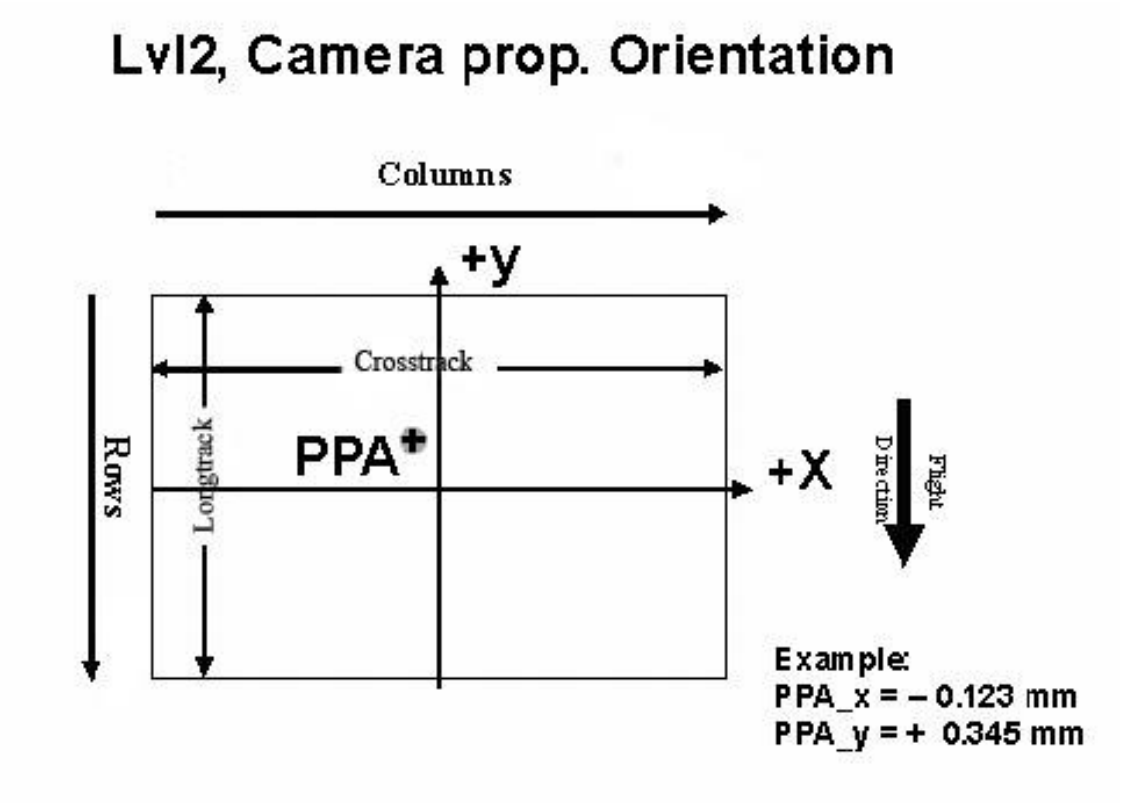
Calibration Method:

The geometric calibration is based on a set of 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

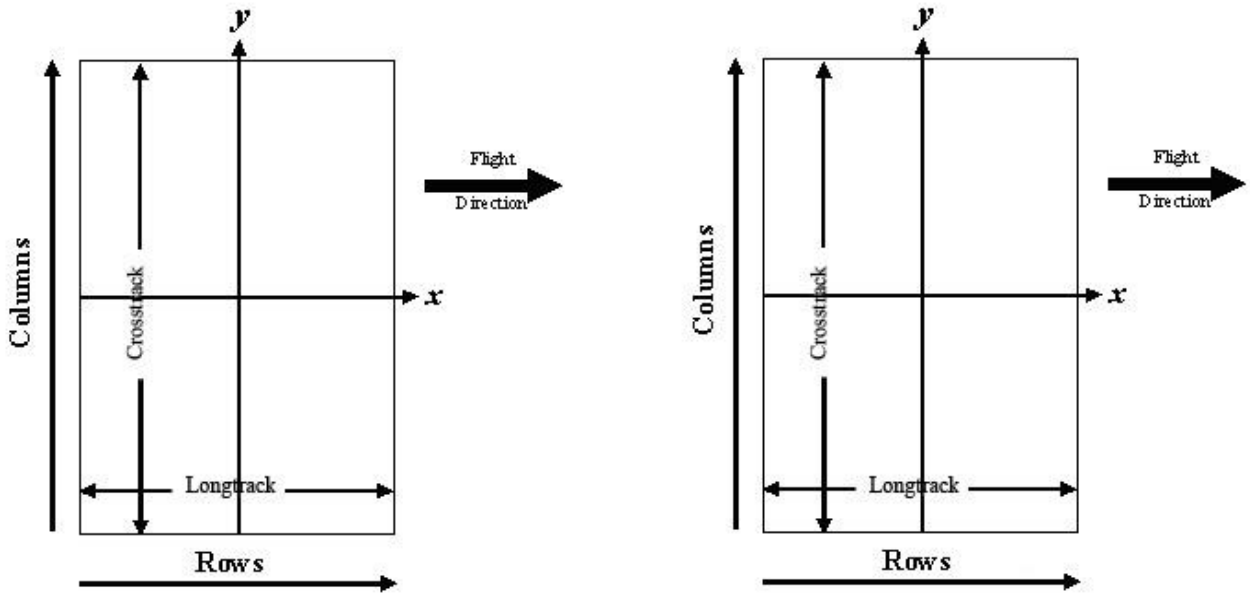
Determination of the image parameters by Least Squares Adjustment.
Software used for the adjustment: BINGO (GIP Eng. Aalen, Germany)

Level 2 Image Coordinate System:



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

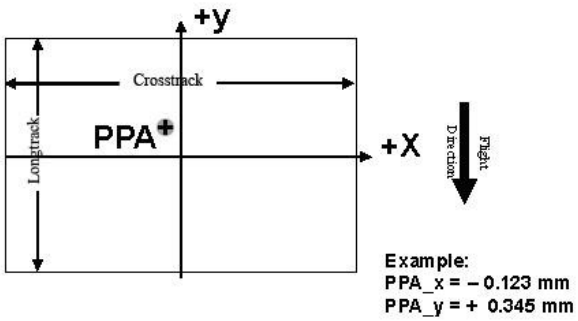
Position of Principal Point in Level 3 Image

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

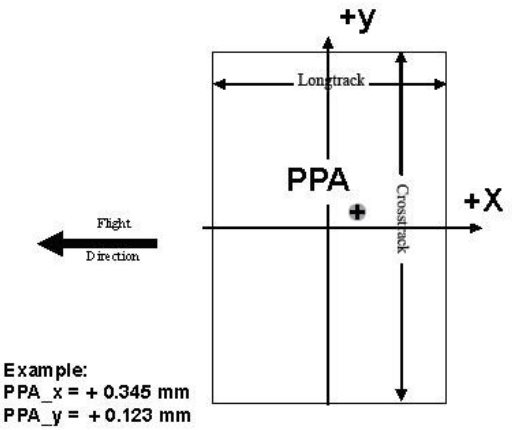
The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

Lvl3, Rotation 0 deg clockwise



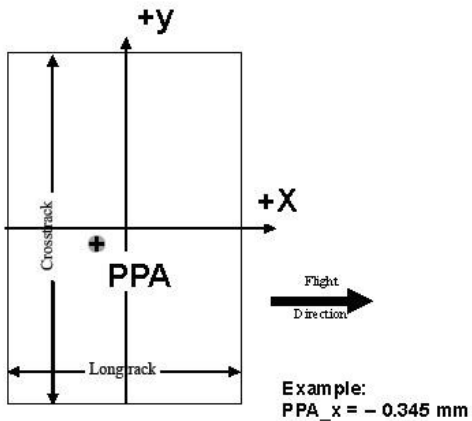
Example:
PPA_x = – 0.123 mm
PPA_y = + 0.345 mm

Lvl3, Rotation 90 deg clockwise



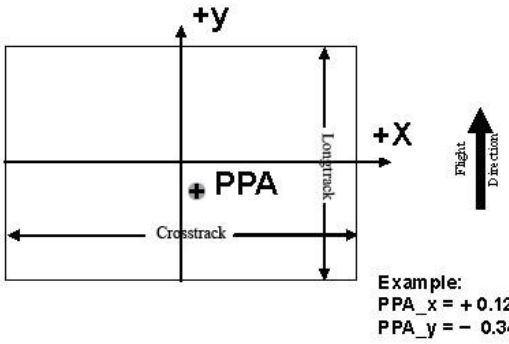
Example:
PPA_x = + 0.345 mm
PPA_y = + 0.123 mm

Lvl3, Rotation 270 deg clockwise



Example:
PPA_x = – 0.345 mm
PPA_y = – 0.123 mm

Lvl3, Rotation 180 deg clockwise



Example:
PPA_x = + 0.123 mm
PPA_y = – 0.345 mm

Lens Resolving Power

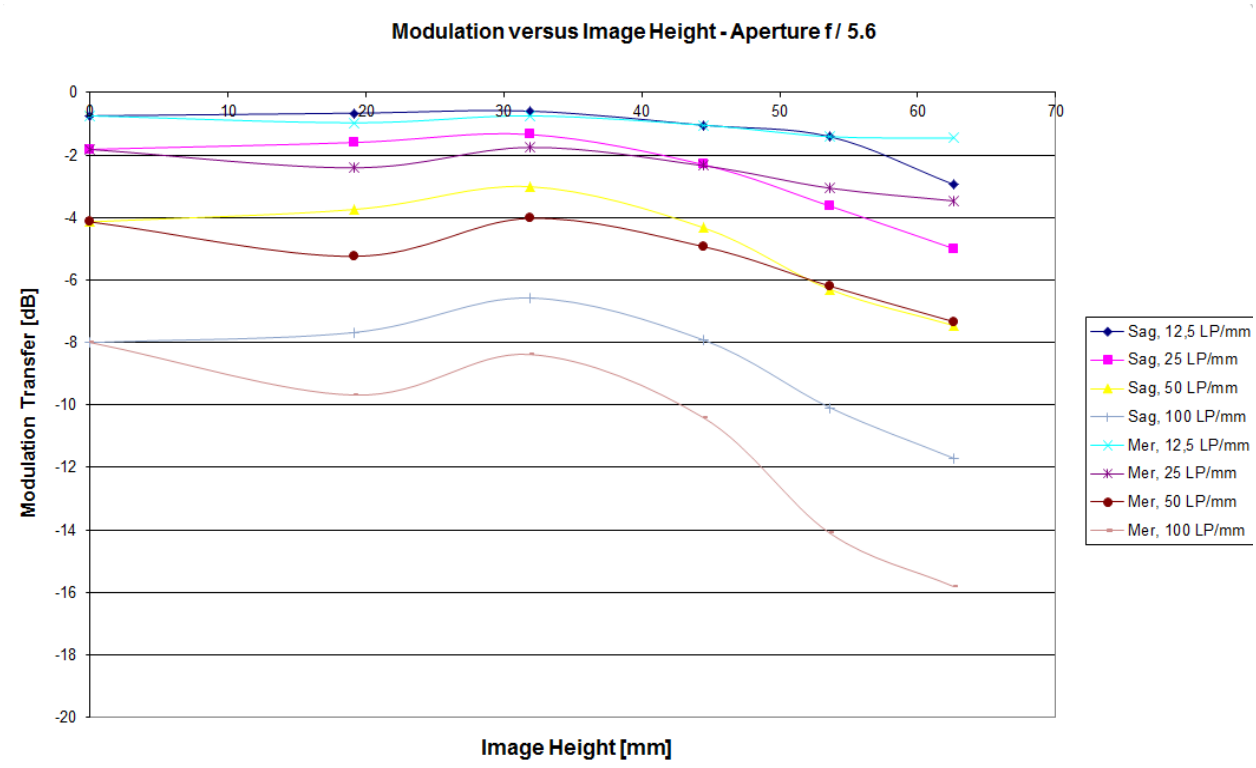
The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones.
Please note that these values have been calculated and can vary up to 10% with optics from production (especially at high LP's).

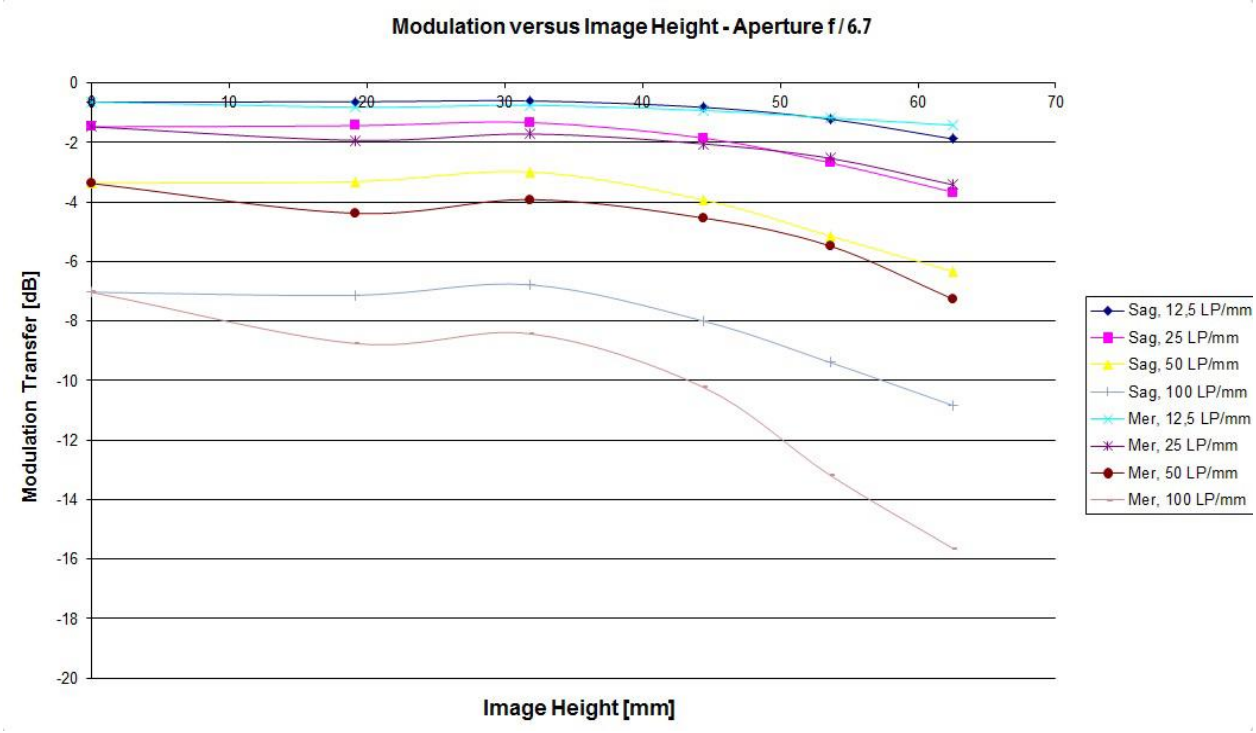
The curves are given for the meridonial (tangential) and sagital (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

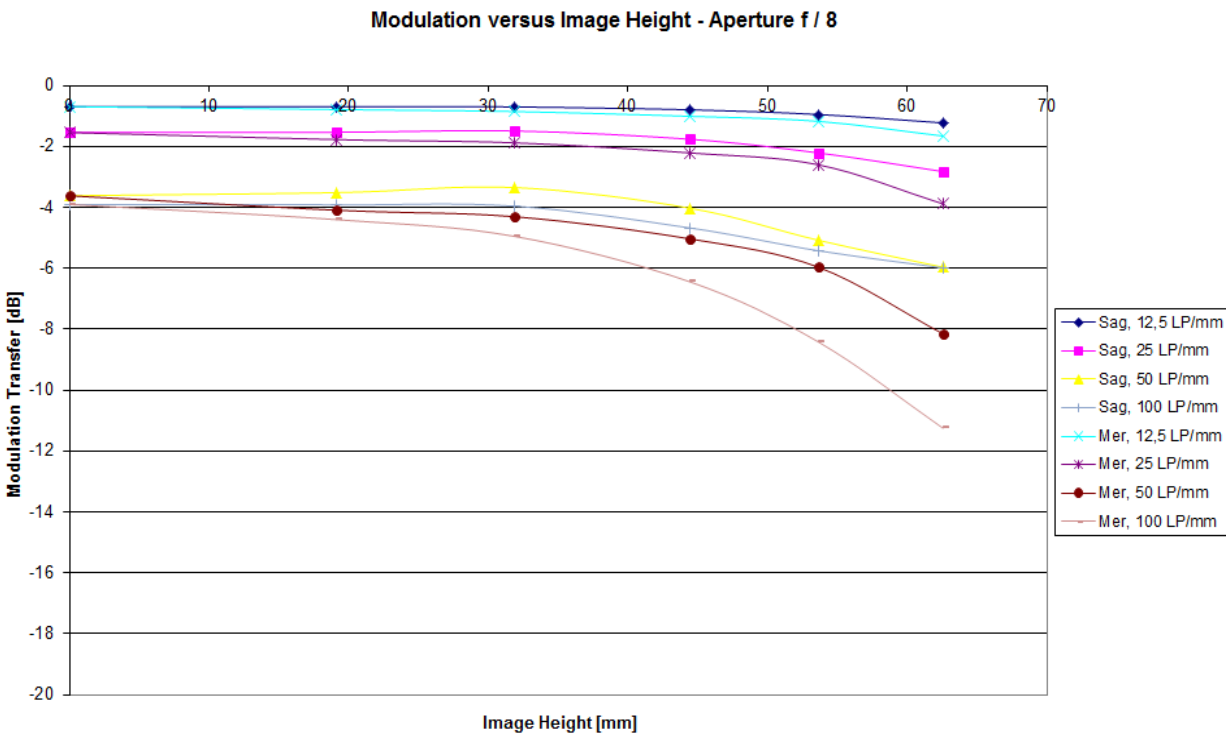
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

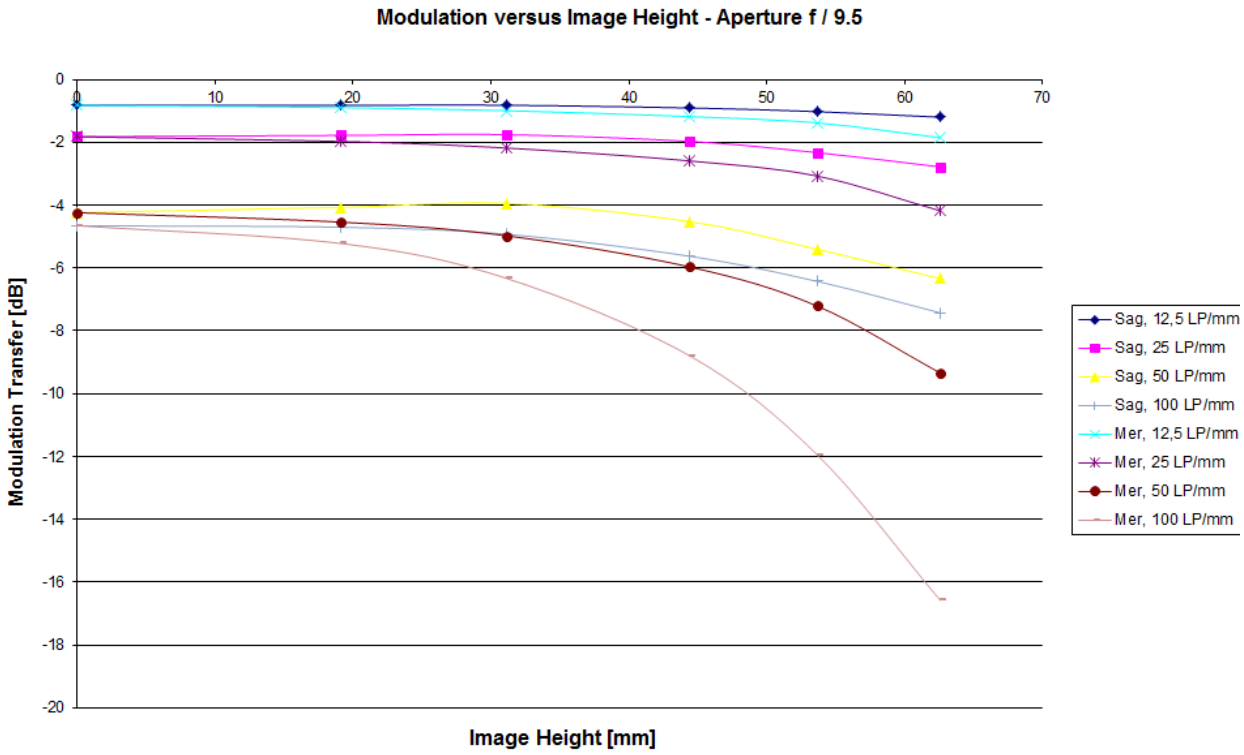
Lens types

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

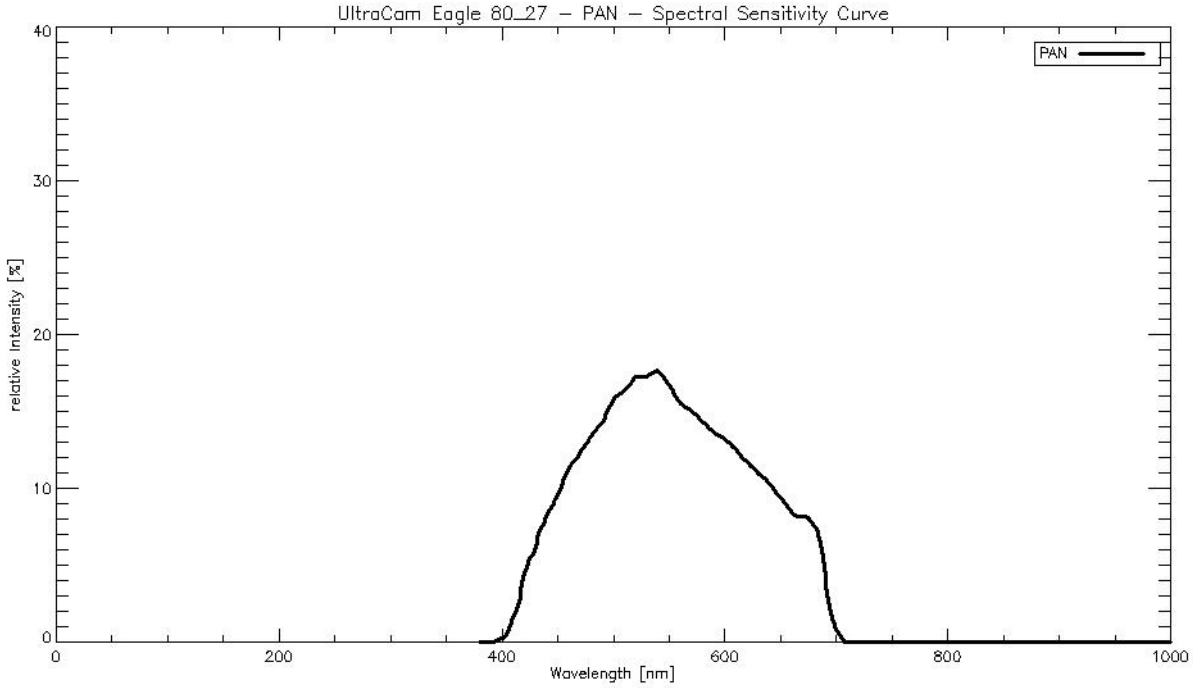

Modulation versus Image Height - Aperture f / 5.6
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm

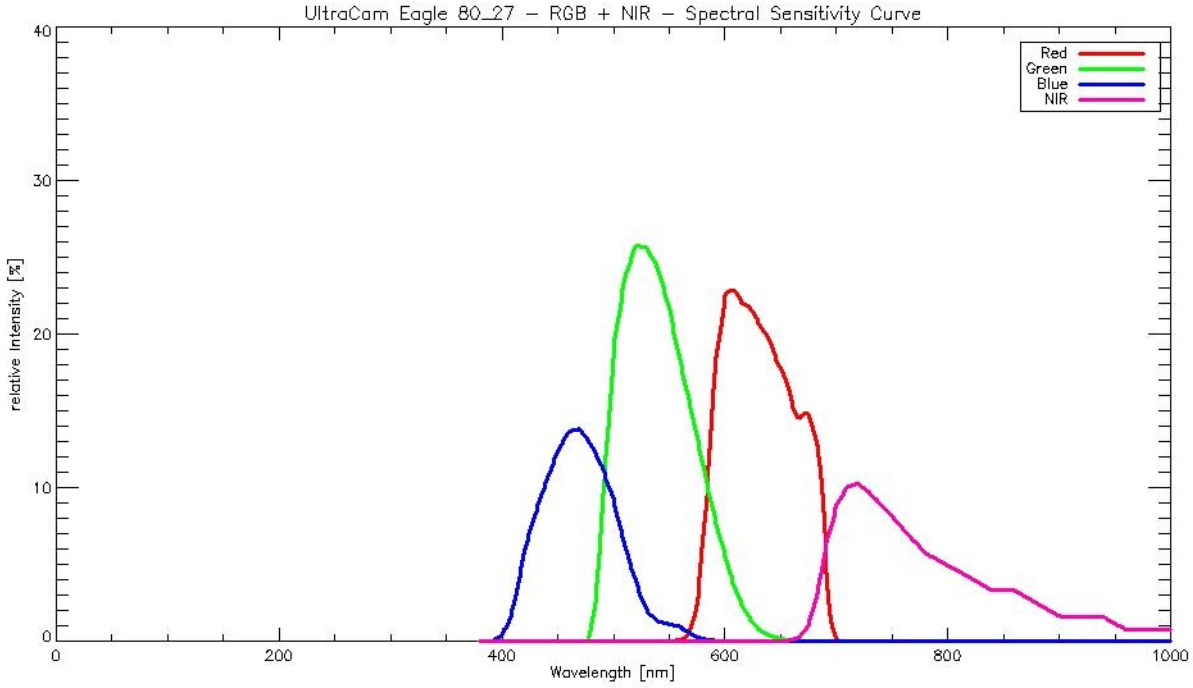

Modulation versus Image Height - Aperture f / 6.7
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm


Modulation versus Image Height - Aperture f / 8
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm


Modulation versus Image Height - Aperture f / 9.5
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm

Spectral Sensitivity





ULTRACAM

Radiometric Calibration

Camera: **UltraCam Eagle**
Serial: **UC-E-1-20816162-f100**

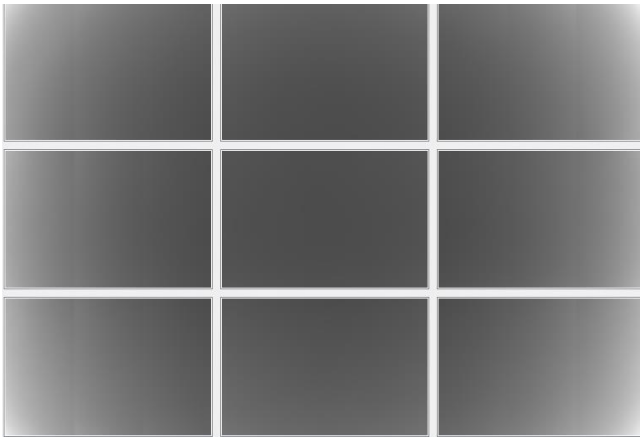
	PAN	R, G, NIR	B
Used Apertures	F5.6	F4.8	F4.8
	F6.7	F5.6	F4.8
	F8	F6.7	F4.8
	F9.5	F8	F5.6
	F11	F9.5	F6.7
	F13	F11	F8
	F16	F13	F9.5
	F22	F19	F13

Calibration Date: **Dec-19-2016**
Date of Report: **Jan-16-2017**
Camera Revision: **Rev02.00**
Version of Report: **V01**

Calibration of Vignetting for working Aperture F6.7

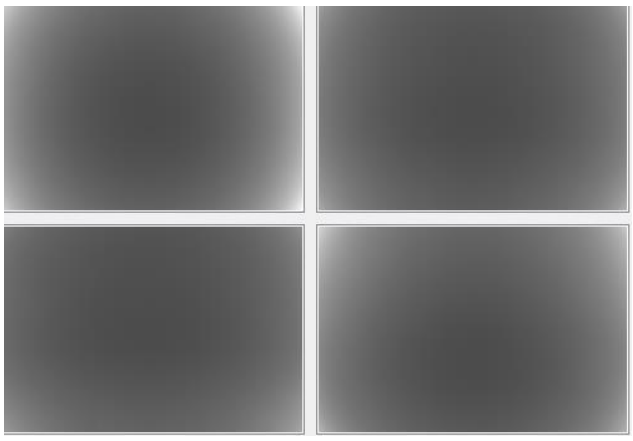
	PAN	R, G, NIR	B
Aperture	F6.7	F5.6	F4.8

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: 424/3635
PIXEL: 1323/1615
PIXEL: 1544/ 552
PIXEL: 1803/4046
PIXEL: 1821/4223
PIXEL: 2321/1995
PIXEL: 3224/ 816
PIXEL: 3238/2961
PIXEL: 4399/3762
PIXEL: 4883/2495
PIXEL: 5919/4205
PIXEL: 6839/1624
PIXEL: 86/2354
PIXEL: 86/2355
PIXEL: 2930/3125
PIXEL: 3137/3218
PIXEL: 2874/3118
PIXEL: 2874/3119
PIXEL: 2930/3126

C00-01

PIXEL: 6200/2138

C00-02

PIXEL: 138/ 595
PIXEL: 1270/4563
PIXEL: 3784/2837
PIXEL: 4368/3482
PIXEL: 5475/2242
PIXEL: 1150/3204
PIXEL: 5024/3037
PIXEL: 5026/3037
PIXEL: 5026/3038
PIXEL: 5586/4591
PIXEL: 5586/4592
PIXEL: 5586/4593
PIXEL: 5587/4592
PIXEL: 5587/4593
PIXEL: 5587/4594
PIXEL: 6581/4333
PIXEL: 5024/3039
PIXEL: 5026/3039
PIXEL: 6580/4333

C00-03

PIXEL: 24/ 367
PIXEL: 774/3751
PIXEL: 1111/ 114
PIXEL: 1568/4200
PIXEL: 2128/2891
PIXEL: 2284/1762
PIXEL: 2695/ 264
PIXEL: 3089/1703
PIXEL: 3330/2217
PIXEL: 3894/ 537
PIXEL: 3906/2510
PIXEL: 4021/3201
PIXEL: 4055/ 67
PIXEL: 4141/ 563
PIXEL: 4243/2586
PIXEL: 4977/ 485
PIXEL: 5135/4121
PIXEL: 5348/2419
PIXEL: 5680/2450
PIXEL: 2858/4477
PIXEL: 4609/2461
PIXEL: 4610/2461
PIXEL: 4610/2462
PIXEL: 4611/2462
PIXEL: 4609/2462
PIXEL: 4608/2461
PIXEL: 4609/2460
PIXEL: 4609/2463
PIXEL: 4611/2461

C01-00

PIXEL: 1651/3759
PIXEL: 1742/ 414
PIXEL: 3039/1416
PIXEL: 3810/1748
PIXEL: 4732/1716
PIXEL: 4910/3901
PIXEL: 5852/ 726
PIXEL: 6119/ 567
PIXEL: 6627/4294
PIXEL: 3522/3398
PIXEL: 4055/ 779
PIXEL: 4684/3994
PIXEL: 4759/3159
PIXEL: 4760/3159
PIXEL: 4760/3160
PIXEL: 5783/2418
PIXEL: 6935/1725
PIXEL: 3521/3398
PIXEL: 3523/3397
PIXEL: 3521/3397
PIXEL: 3522/3397
PIXEL: 3522/3396
PIXEL: 4684/3995

C01-01

PIXEL: 367/3120
PIXEL: 647/ 310
PIXEL: 3981/2705
PIXEL: 3990/1072
PIXEL: 4163/4148
PIXEL: 4245/ 411
PIXEL: 4600/3619
PIXEL: 3803/4372
PIXEL: 3804/4372
PIXEL: 3804/4373
PIXEL: 3805/4372
PIXEL: 3805/4374
PIXEL: 4717/3076
PIXEL: 4717/3077
PIXEL: 4718/3076
PIXEL: 4718/3077
PIXEL: 5003/4248
PIXEL: 5004/4248
PIXEL: 5480/1306
PIXEL: 5481/1305
PIXEL: 5481/1306
PIXEL: 5830/2510
PIXEL: 5831/2507
PIXEL: 5832/2508
PIXEL: 3806/4373
PIXEL: 3803/4373
PIXEL: 3803/4374
PIXEL: 4716/3076
PIXEL: 4716/3077
PIXEL: 4719/3076
PIXEL: 4717/3078
PIXEL: 4719/3077
PIXEL: 4718/3078
PIXEL: 5830/2507
PIXEL: 5829/2508
PIXEL: 5829/2509
PIXEL: 5831/2511
PIXEL: 5832/2509
PIXEL: 5832/2511
PIXEL: 5833/2510

C02-00

PIXEL: 922/2491
PIXEL: 1330/3948
PIXEL: 1371/3894
PIXEL: 1542/4608
PIXEL: 1868/1723
PIXEL: 1884/2098
PIXEL: 2469/4497
PIXEL: 2639/ 596
PIXEL: 2917/4329
PIXEL: 3635/3508
PIXEL: 3893/3583
PIXEL: 4327/ 135
PIXEL: 5385/ 602
PIXEL: 6028/2088
PIXEL: 6563/3933
PIXEL: 6633/2800
PIXEL: 1098/1695
PIXEL: 1099/1695
PIXEL: 2152/1886
PIXEL: 2153/1885
PIXEL: 2153/1886
PIXEL: 1099/1694
PIXEL: 1100/1695
PIXEL: 1098/1694
PIXEL: 2152/1887
PIXEL: 2151/1886
PIXEL: 2152/1885
PIXEL: 2151/1885
PIXEL: 2153/1887

C02-01

PIXEL: 82/4074
PIXEL: 163/ 859
PIXEL: 257/2518
PIXEL: 980/2472
PIXEL: 1159/1206
PIXEL: 1261/3663
PIXEL: 1949/4438
PIXEL: 2034/1172
PIXEL: 2731/ 848
PIXEL: 3004/ 17
PIXEL: 3179/3941
PIXEL: 3377/3498
PIXEL: 4741/ 183
PIXEL: 5027/4438
PIXEL: 5395/2147
PIXEL: 5564/4162
PIXEL: 5973/2756
PIXEL: 6928/4522

C03-00

PIXEL: 1149/3133
PIXEL: 1944/2058
PIXEL: 2017/3421
PIXEL: 2181/ 261
PIXEL: 2422/ 824
PIXEL: 3071/2001
PIXEL: 6693/3055
PIXEL: 6751/2456
PIXEL: 1403/2761
PIXEL: 1403/2762
PIXEL: 1404/2761
PIXEL: 1404/2762
PIXEL: 2562/1547
PIXEL: 3426/2564
PIXEL: 5733/2503
PIXEL: 5733/2504
PIXEL: 6883/4535
PIXEL: 6883/4536
PIXEL: 5732/2503
PIXEL: 5732/2504
PIXEL: 6884/4536

C04-00

PIXEL: 1517/3396
PIXEL: 3188/1745
PIXEL: 5878/4451
PIXEL: 6041/1796
PIXEL: 4543/1803
PIXEL: 6944/ 40
PIXEL: 6832/ 82
PIXEL: 6944/ 39
PIXEL: 6943/ 40

C05-00

PIXEL: 288/2408
PIXEL: 571/1027
PIXEL: 1081/1603
PIXEL: 3011/2047
PIXEL: 4436/3668
PIXEL: 2978/2708
PIXEL: 2978/2710
PIXEL: 2979/2708
PIXEL: 3507/3565
PIXEL: 3507/3566
PIXEL: 3507/3567
PIXEL: 4149/3025
PIXEL: 5616/ 321
PIXEL: 5664/2621
PIXEL: 5842/ 255
PIXEL: 6173/3125
PIXEL: 6397/ 155
PIXEL: 6705/ 540
PIXEL: 6721/ 465

PIXEL: 6743/1190
PIXEL: 6766/ 446
PIXEL: 6900/ 316
PIXEL: 2977/2709
PIXEL: 2979/2709
PIXEL: 2979/2710
PIXEL: 2977/2710
PIXEL: 6400/ 178
PIXEL: 6902/ 315
PIXEL: 6904/ 312
PIXEL: 6904/ 313
PIXEL: 6903/ 313
PIXEL: 6900/ 314
PIXEL: 6899/ 314
PIXEL: 6902/ 316
PIXEL: 6904/ 314
PIXEL: 6900/ 315
PIXEL: 6901/ 316
PIXEL: 6903/ 315

C06-00

PIXEL: 2306/2450
PIXEL: 2772/3087
PIXEL: 2974/4422
PIXEL: 3005/2368
PIXEL: 4449/4173
PIXEL: 4663/2124
PIXEL: 4729/4425
PIXEL: 4798/ 438
PIXEL: 5270/3746
PIXEL: 5851/2679
PIXEL: 6168/4237
PIXEL: 3069/1181
PIXEL: 3070/1178
PIXEL: 3070/1179
PIXEL: 3070/1180
PIXEL: 3071/1178
PIXEL: 3071/1182
PIXEL: 3072/1178
PIXEL: 3072/1179
PIXEL: 3072/1180
PIXEL: 3073/1179
PIXEL: 3073/1180
PIXEL: 3073/1182
PIXEL: 3073/1183
PIXEL: 3074/1178
PIXEL: 3074/1179
PIXEL: 5698/3375
PIXEL: 5698/3376
PIXEL: 3071/1181
PIXEL: 3074/1177
PIXEL: 3072/1181

C07-00

PIXEL: 278/1784
PIXEL: 343/1052
PIXEL: 872/1168
PIXEL: 1535/3623
PIXEL: 2149/2364
PIXEL: 2661/ 567
PIXEL: 3233/3337
PIXEL: 3233/3338
PIXEL: 3511/1043
PIXEL: 4477/3253
PIXEL: 4837/2293
PIXEL: 4837/2294
PIXEL: 4837/3120
PIXEL: 4837/3327
PIXEL: 4837/3838
PIXEL: 6260/4432
PIXEL: 1176/4206
PIXEL: 1177/4206
PIXEL: 1178/4207
PIXEL: 1177/4207
PIXEL: 1176/4208
PIXEL: 1177/4208
PIXEL: 1178/4208

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-1-20816162-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:	**Dec-19-2016**
Date of Report:	**Jan-16-2017**
Camera Revision:	**Rev02.00**
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 23 55 22	6.61	6.93	7.15	7.44	7.61	7.65	7.83	8.06	+/- 0.2
C1 (Pan)	12 23 55 05	6.40	6.63	6.87	7.12	7.27	7.50	7.55	7.79	+/- 0.2
C2 (Pan)	12 23 55 16	6.36	6.63	6.84	7.09	7.18	7.39	7.45	7.64	+/- 0.2
C3 (Pan)	12 23 55 14	6.33	6.53	6.83	7.09	7.24	7.36	7.40	7.67	+/- 0.2
C4 (Red)	12 23 11 68	7.63	7.64	7.76	7.87	7.87	8.14	8.14	8.15	+/- 0.2
C5 (Green)	12 23 11 71	7.66	7.81	7.88	7.98	8.14	8.20	8.20	8.43	+/- 0.2
C6 (Blue)	12 23 11 74	6.54	6.58	6.58	6.69	6.82	6.90	6.97	7.12	+/- 0.2
C7 (NIR)	12 23 11 81	6.26	6.42	6.53	6.72	6.72	6.80	6.88	6.92	+/- 0.2

ULTRACAM

Electronics and Sensor Calibration

Camera:	**UltraCam Eagle**
Serial:	**UC-E-1-20816162-f100**
Panchromatic Camera:	**9 * FTF7046-M Area CCD Sensor by DALSA**
Multispectral Camera:	**4 * FTF7046-M Area CCD Sensor by DALSA**
Calibration Date:	**Dec-19-2016**
Date of Report:	**Jan-16-2017**
Camera Revision:	**Rev02.00**
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]
00_00	FTF7046-M	14 8937/027	24.60
00_01	FTF7046-M	14 8709/029	24.60
00_02	FTF7046-M	14 8611/035	25.20
00_03	FTF7046-M	14 8937/009	24.60
01_00	FTF7046-M	14 8709/001	24.60
01_01	FTF7046-M	14 8611/037	24.80
02_00	FTF7046-M	14 8611/036	25.20
02_01	FTF7046-M	14 8937/025	24.80
03_00	FTF7046-M	14 8493/031	24.80
04_00 (red)	FTF7046-M	14 8937/031	24.80
05_00 (green)	FTF7046-M	14 8709/004	25.00
06_00 (blue)	FTF7046-M	14 8709/003	24.60
07_00 (NIR)	FTF7046-M	14 8937/033	24.40

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	14 8937/027	13180
00_01	FTF7046-M	14 8709/029	13750
00_02	FTF7046-M	14 8611/035	13440
00_03	FTF7046-M	14 8937/009	13310
01_00	FTF7046-M	14 8709/001	13230
01_01	FTF7046-M	14 8611/037	13670
02_00	FTF7046-M	14 8611/036	14170
02_01	FTF7046-M	14 8937/025	13790
03_00	FTF7046-M	14 8493/031	11840
04_00 (red)	FTF7046-M	14 8937/031	13670
05_00 (green)	FTF7046-M	14 8709/004	13100
06_00 (blue)	FTF7046-M	14 8709/003	13690
07_00 (NIR)	FTF7046-M	14 8937/033	13360

ULTRACAM

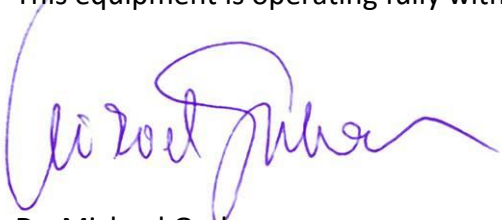
Summary

Camera:	**UltraCam Eagle**
Serial:	**UC-E-1-20816162-f100**
Calibration Date:	**Dec-19-2016**
Date of Report:	**Jan-16-2017**
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.



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