



# ULTRACAM

## Calibration Report

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Bahia, Brasil 2013

Photo on page 1 courtesy of Hiparc Geotecnologia, Brasil

[www.hiparc.com](http://www.hiparc.com)

UltraCam Lp, GSD25 cm, RGB



# **ULTRACAM**

## Geometric Calibration

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**Camera:** UltraCam Eagle M3  
**Serial:** 431S61680X916102-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:** May-11-2018  
**Date of Report:** Nov-08-2018  
**Camera Revision:** Rev01.01  
**Version of Report:** V01



## Panchromatic Camera

### Large Format Panchromatic Output Image

<b>Image Format</b>	long track cross track	68.016mm 105.840mm	17004pixel 26460pixel
<b>Image Extent</b>		(-34.008, -52.920)mm	(34.008, 52.920)mm
<b>Pixel Size</b>		4.000µm*4.000µm	
<b>Focal Length</b>	ck	100.500mm	± 0.002mm
<b>Principal Point (Level 2)</b>	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
<b>Lens Distortion</b>	Remaining Distortion less than 0.002mm		

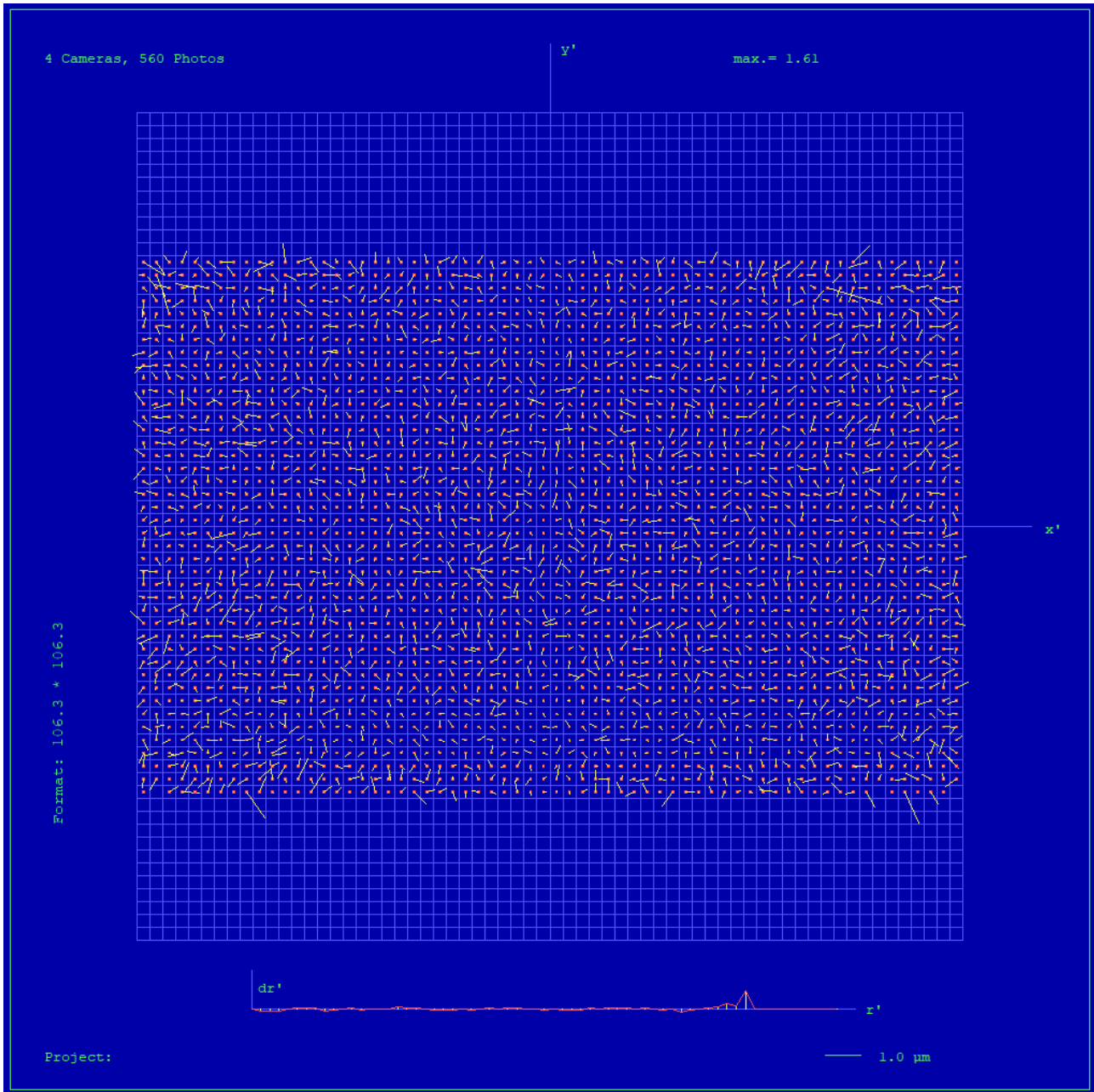
## Multispectral Camera

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

<b>Image Format</b>	long track cross track	68.016mm 105.840mm	5668pixel 8820pixel
<b>Image Extent</b>		(-34.008, -52.920)mm	(34.008, 52.920)mm
<b>Pixel Size</b>		12.000µm*12.000µm	
<b>Focal Length</b>	ck	100.500mm	± 0.002mm
<b>Principal Point (Level 2)</b>	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
<b>Lens Distortion</b>	Remaining Distortion less than 0.002mm		



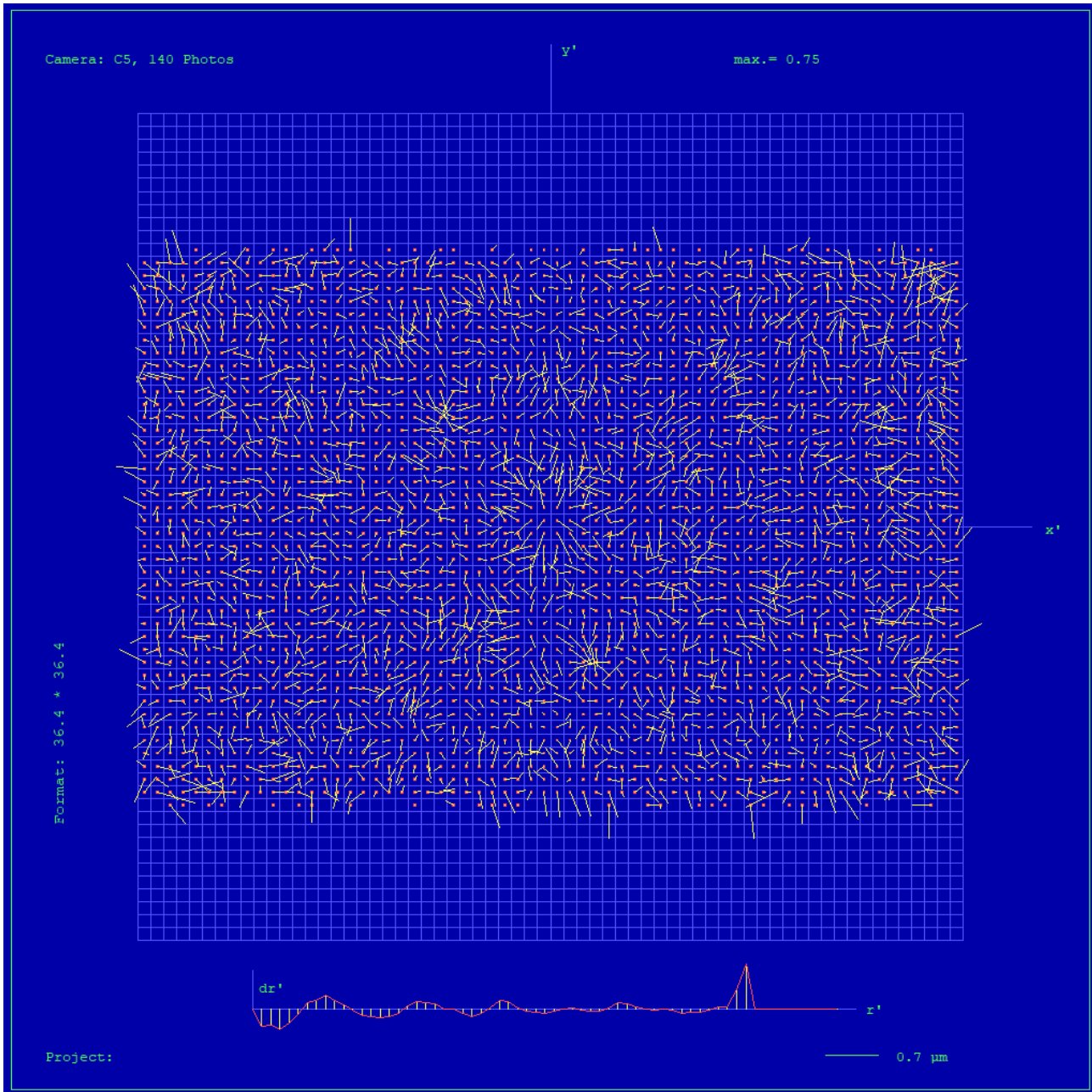
# Full Panchromatic Image, Residual Error Diagram



**Residual Error (RMS):**            **0.50 μm**



## Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS):            0.39  $\mu\text{m}$



## 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

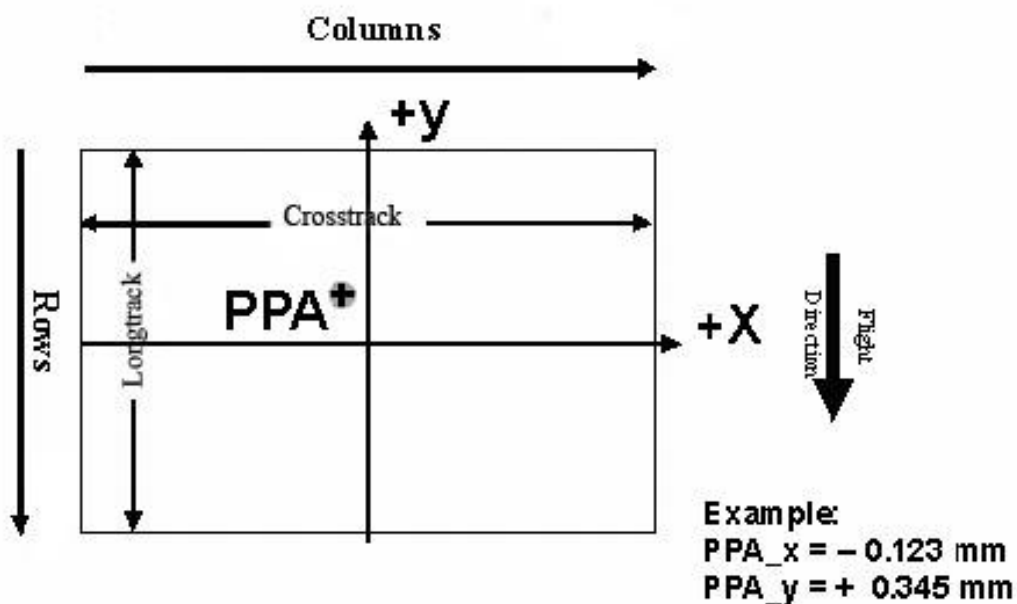
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

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

### Level 2 Image Coordinate System:

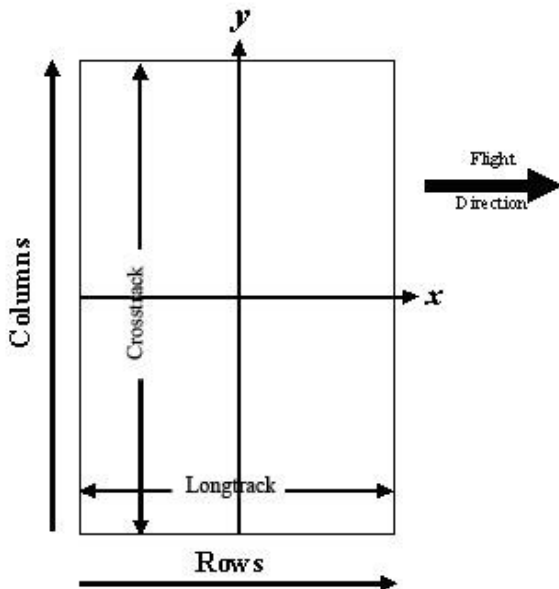
## Lvl2, Camera prop. Orientation



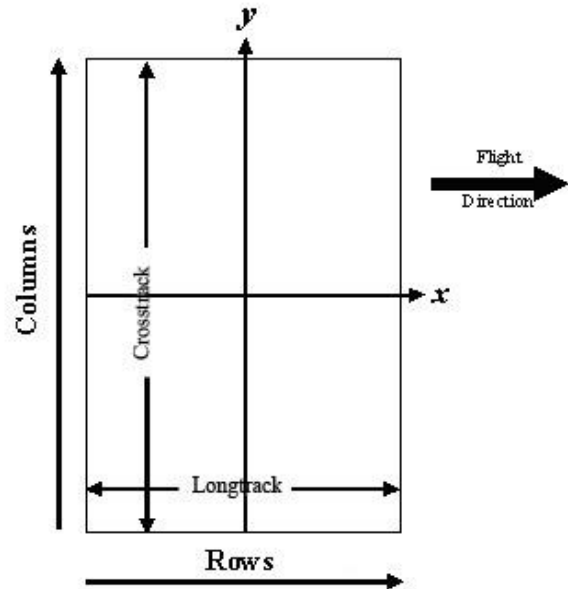
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



**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.

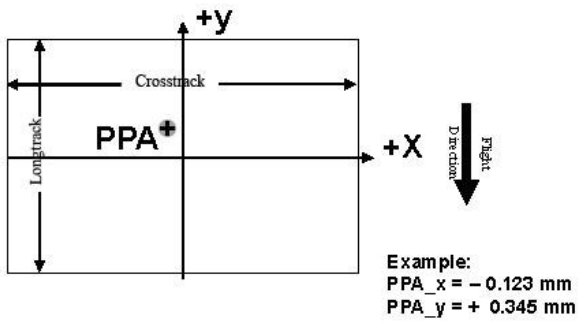
Image Format	Clockwise Rotation (Degree)	PPA	
		X	Y
Level 2	-	0.000	0.000
Level 3	0	0.000	0.000
Level 3	90	0.000	0.000
Level 3	180	0.000	0.000
Level 3	270	0.000	0.000



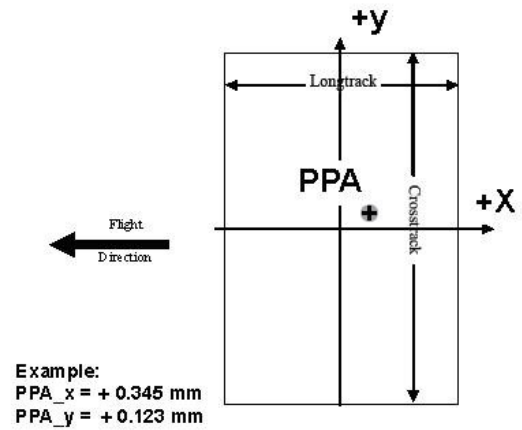


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

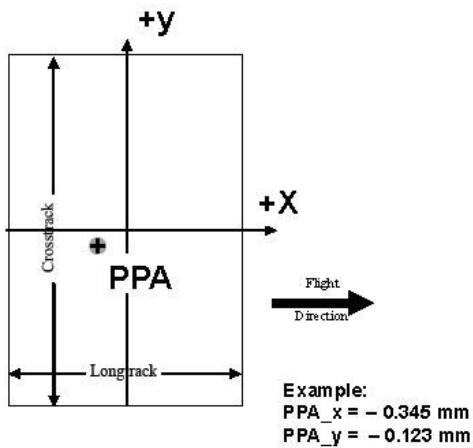
Lvl3, Rotation 0 deg clockwise



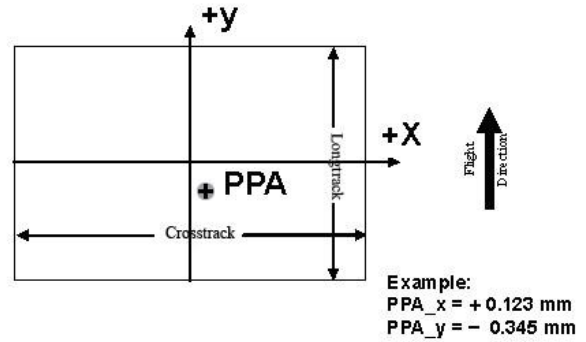
Lvl3, Rotation 90 deg clockwise



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

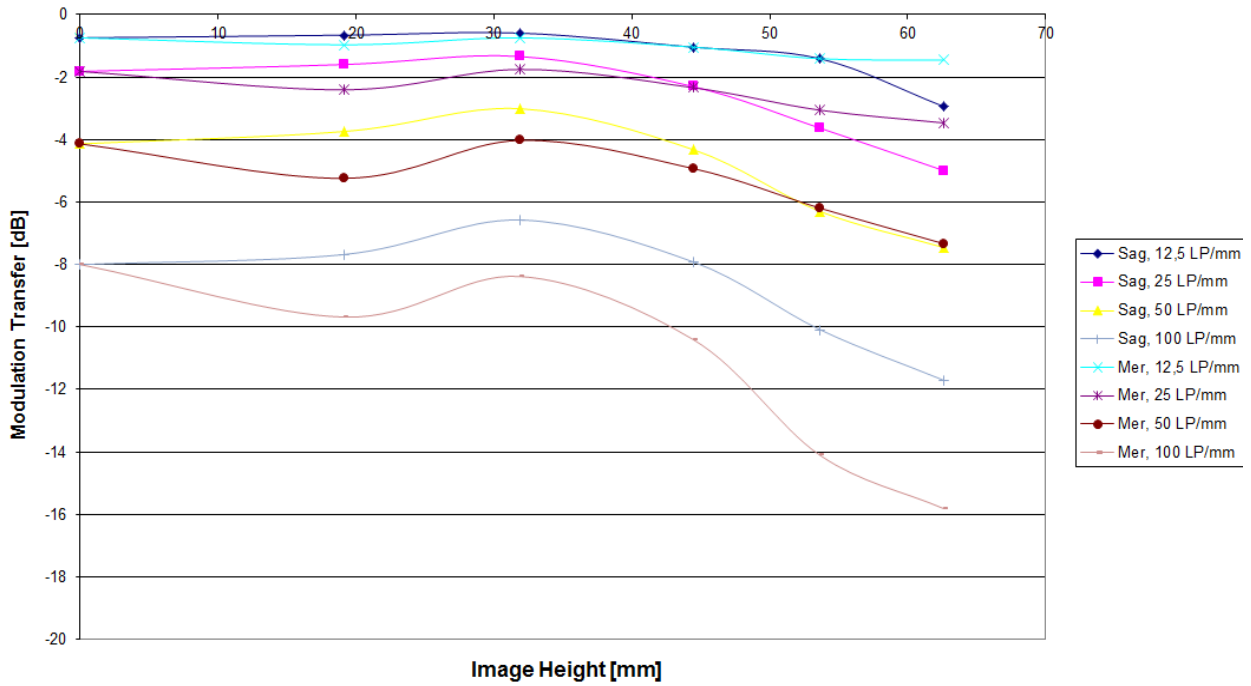
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

### Lens types

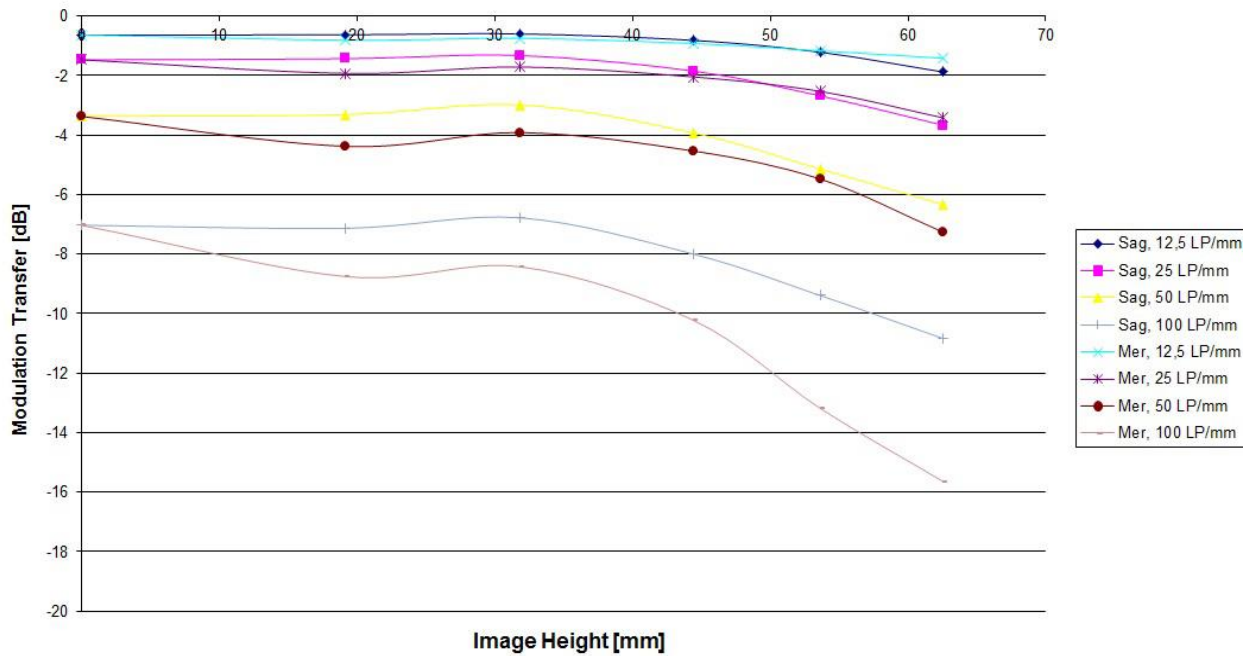
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic 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

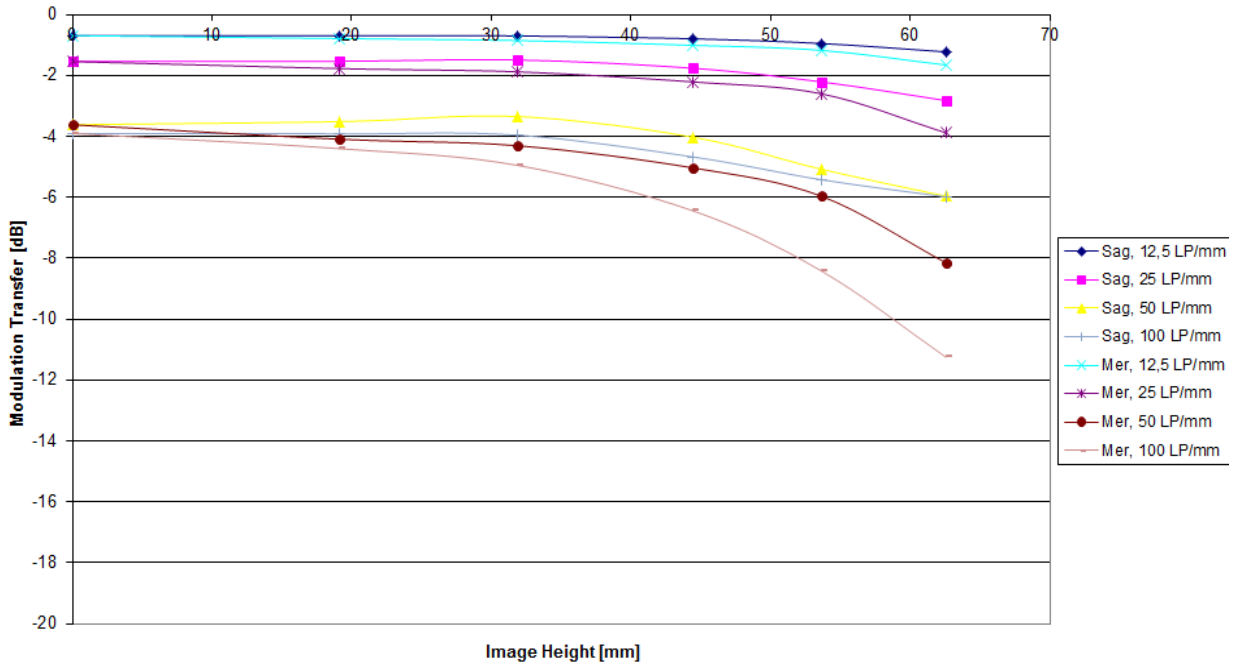


Modulation versus Image Height - Aperture f/ 6.7

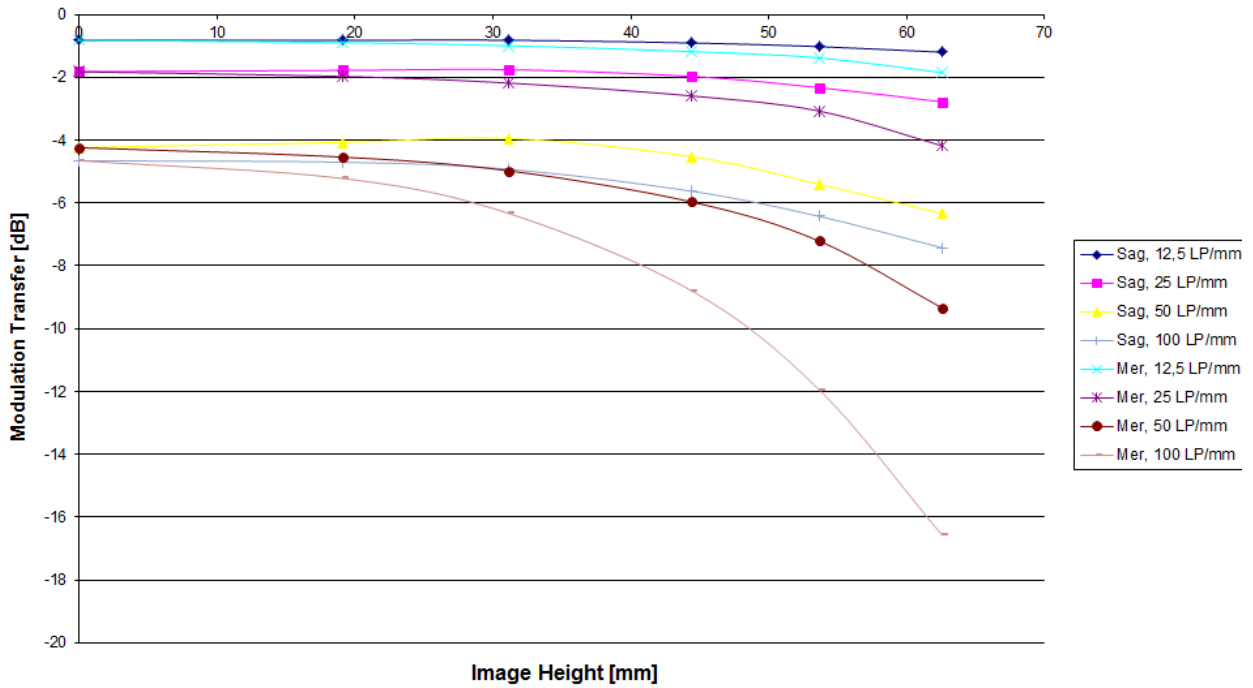




Modulation versus Image Height - Aperture f / 8

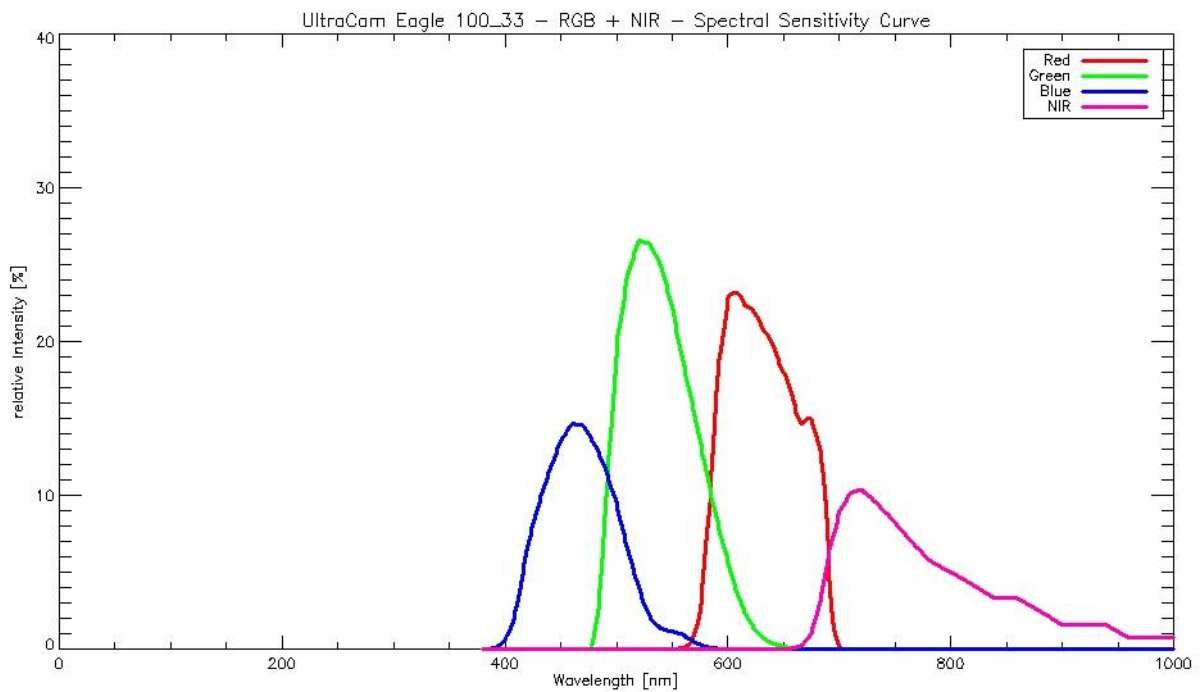
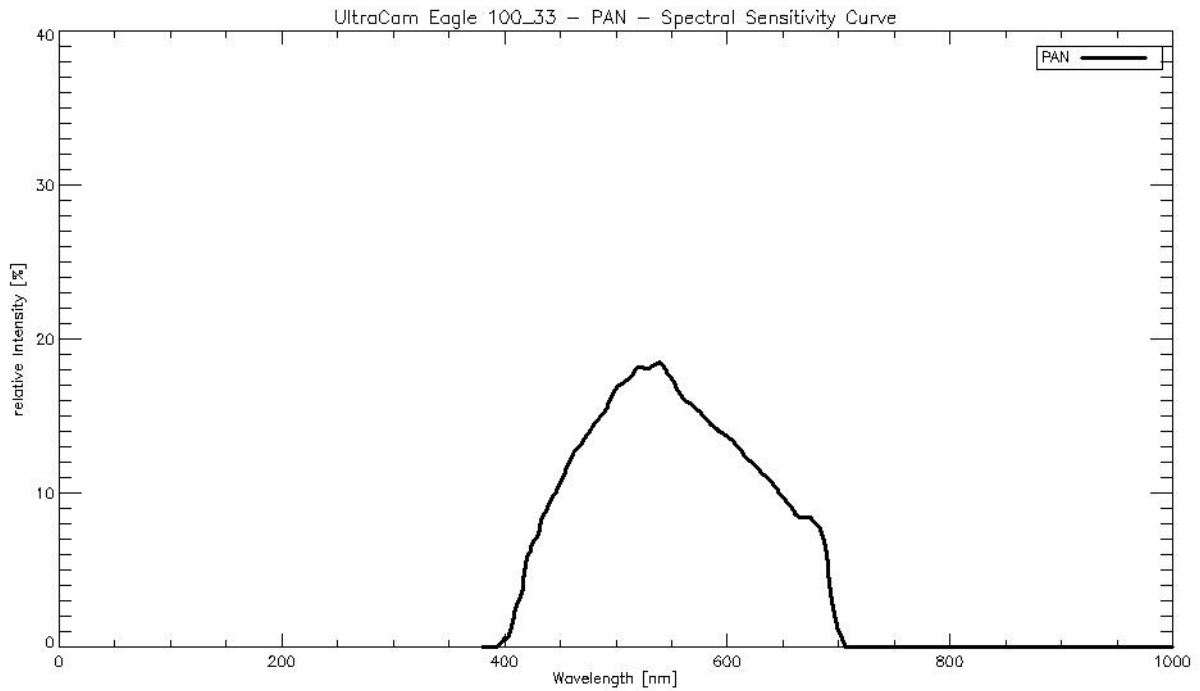


Modulation versus Image Height - Aperture f / 9.5





# Spectral Sensitivity





# ULTRACAM

## Radiometric Calibration

Camera: UltraCam Eagle M3  
Serial: 431S61680X916102-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

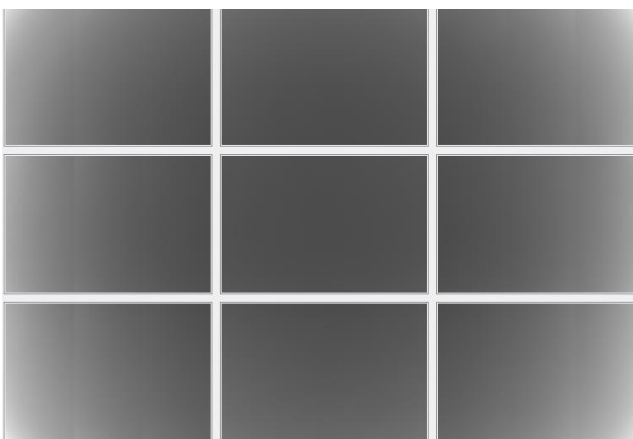
Calibration Date: May-11-2018  
Date of Report: Nov-08-2018  
Camera Revision: Rev01.01  
Version of Report: V01



## Calibration of Vignetting for working Aperture F6.7

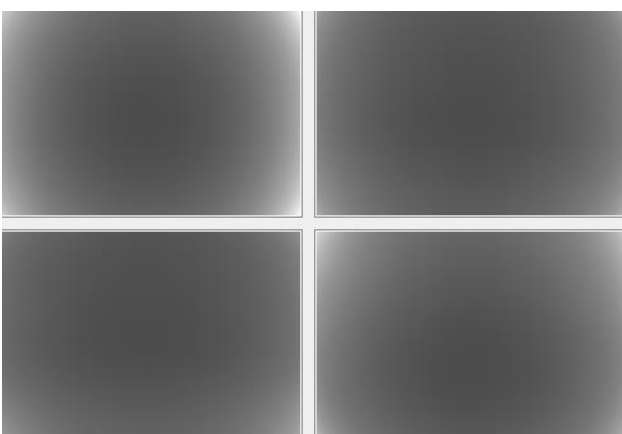
	PAN	R, G, NIR	B
Aperture	F6.7	F5.6	F4.8

### 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
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### C00-00

- PIXEL: 1816/4077
- PIXEL: 2400/1907
- PIXEL: 2964/5745
- PIXEL: 3039/3052
- PIXEL: 3446/3703
- PIXEL: 3852/5387
- PIXEL: 3861/5643
- PIXEL: 4741/ 763
- PIXEL: 5422/ 808
- PIXEL: 5453/4727
- PIXEL: 5595/3886
- PIXEL: 5642/1531
- PIXEL: 6384/5575
- PIXEL: 6531/4791
- PIXEL: 6647/3979
- PIXEL: 6729/5248
- PIXEL: 7262/3910
- PIXEL: 7833/5829
- PIXEL: 7969/5661
- PIXEL: 9041/5988
- PIXEL: 177/3840
- PIXEL: 237/4311
- PIXEL: 237/4312
- PIXEL: 576/5203
- PIXEL: 579/5563
- PIXEL: 714/5350
- PIXEL: 739/5341
- PIXEL: 1328/4809
- PIXEL: 1328/4810
- PIXEL: 1655/5495
- PIXEL: 5852/5728
- PIXEL: 5852/5729

### C00-01

- PIXEL: 339/3770
- PIXEL: 1107/ 650
- PIXEL: 1986/4926
- PIXEL: 2888/5440
- PIXEL: 2912/4139
- PIXEL: 3769/2632
- PIXEL: 3797/4640
- PIXEL: 6170/4493
- PIXEL: 7041/1229
- PIXEL: 7264/1881





PIXEL: 878/5256  
PIXEL: 1628/4996  
PIXEL: 2075/4551  
PIXEL: 2788/4246  
PIXEL: 4509/1034  
PIXEL: 7194/ 716  
PIXEL: 7948/2763  
PIXEL: 8937/5803  
PIXEL: 7949/2762  
PIXEL: 7949/2763

**C00-02**

PIXEL: 893/3255  
PIXEL: 1345/3498  
PIXEL: 3316/2762  
PIXEL: 4585/4984  
PIXEL: 5350/2287  
PIXEL: 1104/ 429  
PIXEL: 1968/5636  
PIXEL: 2395/1429  
PIXEL: 2396/1429  
PIXEL: 2751/2737  
PIXEL: 2751/2738  
PIXEL: 2752/2737  
PIXEL: 6346/4522  
PIXEL: 6346/4523  
PIXEL: 6938/5257  
PIXEL: 1968/5637  
PIXEL: 1104/ 430  
PIXEL: 6345/4522

**C00-03**

PIXEL: 2059/5847  
PIXEL: 2068/1496  
PIXEL: 3783/4665  
PIXEL: 4647/4113  
PIXEL: 4733/3503  
PIXEL: 5419/2152  
PIXEL: 5848/1399  
PIXEL: 5881/4477  
PIXEL: 5908/1496  
PIXEL: 6217/1878  
PIXEL: 8185/1764  
PIXEL: 617/ 261  
PIXEL: 619/ 693  
PIXEL: 7867/5103

**C01-00**

PIXEL: 254/5965  
PIXEL: 525/3654  
PIXEL: 574/2785  
PIXEL: 2159/1105  
PIXEL: 3027/3853  
PIXEL: 3514/3311



PIXEL: 5277/4134  
PIXEL: 6202/4997  
PIXEL: 8774/5203  
PIXEL: 202/4466  
PIXEL: 906/ 629  
PIXEL: 949/ 982  
PIXEL: 3910/3005  
PIXEL: 4112/ 305  
PIXEL: 7109/3268  
PIXEL: 7873/4500  
PIXEL: 4111/ 305

**C01-01**

PIXEL: 672/5981  
PIXEL: 1255/1269  
PIXEL: 3152/1734  
PIXEL: 3269/5613  
PIXEL: 3364/4504  
PIXEL: 4193/4579  
PIXEL: 6355/1373  
PIXEL: 6600/1208  
PIXEL: 7566/5101  
PIXEL: 7915/5470  
PIXEL: 1024/ 352  
PIXEL: 1711/5517  
PIXEL: 2194/3389  
PIXEL: 3637/5703  
PIXEL: 3637/5704

**C02-00**

PIXEL: 980/5331  
PIXEL: 1190/2133  
PIXEL: 1741/1575  
PIXEL: 1814/ 479  
PIXEL: 4305/ 327  
PIXEL: 5944/5725  
PIXEL: 6049/2408  
PIXEL: 7210/4706  
PIXEL: 7444/ 510  
PIXEL: 7787/2013  
PIXEL: 8186/3678  
PIXEL: 961/4795  
PIXEL: 5550/1204  
PIXEL: 5550/1205  
PIXEL: 5550/1206  
PIXEL: 5551/1204  
PIXEL: 5551/1206  
PIXEL: 5551/1206  
PIXEL: 5552/1205  
PIXEL: 5552/1206  
PIXEL: 2657/5996  
PIXEL: 2611/5943  
COLUMN: 7862/2177



**C02-01**

PIXEL: 2067/2467  
PIXEL: 2654/2193  
PIXEL: 3756/ 92  
PIXEL: 5424/4054  
PIXEL: 6134/5090  
PIXEL: 6920/ 432  
PIXEL: 255/4515  
PIXEL: 255/4516  
PIXEL: 347/3753  
PIXEL: 2470/3936  
PIXEL: 3304/4899  
PIXEL: 3305/4899  
PIXEL: 7923/5019  
PIXEL: 7923/5018

**C03-00**

PIXEL: 388/1555  
PIXEL: 766/5141  
PIXEL: 1985/5802  
PIXEL: 2015/1388  
PIXEL: 3288/1278  
PIXEL: 8107/ 133

**C04-00**

PIXEL: 3234/3517  
PIXEL: 4046/5887  
PIXEL: 38/ 253  
PIXEL: 448/5190  
PIXEL: 3097/ 473  
PIXEL: 3097/ 474  
PIXEL: 3607/ 25  
PIXEL: 7024/3013  
PIXEL: 7024/3014

**C05-00**

PIXEL: 2010/2864  
PIXEL: 4965/5365  
PIXEL: 4985/5366  
PIXEL: 6559/1342  
PIXEL: 280/5792  
PIXEL: 1235/2683  
PIXEL: 1236/2682  
PIXEL: 3461/ 171  
PIXEL: 3462/ 171  
PIXEL: 4032/3440  
PIXEL: 7685/1212  
PIXEL: 1236/2683  
PIXEL: 3462/ 170



**C06-00**

PIXEL: 7613/ 69  
PIXEL: 6050/ 827  
PIXEL: 7612/ 69  
PIXEL: 7612/ 70  
PIXEL: 7613/ 70

**C07-00**

PIXEL: 7084/5470  
PIXEL: 3922/ 95  
PIXEL: 3922/ 96  
PIXEL: 3923/ 95  
PIXEL: 4823/1966  
PIXEL: 8869/5793  
PIXEL: 8869/5794  
PIXEL: 3922/ 94  
PIXEL: 3923/ 96  
PIXEL: 8870/5793

**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

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**Camera:** UltraCam Eagle M3  
**Serial:** 431S61680X916102-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:** May-11-2018  
**Date of Report:** Nov-08-2018  
**Camera Revision:** Rev01.01  
**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 36 14 15	6.32	6.58	6.87	7.14	7.32	7.46	7.53	7.91	+/- 0.2
C1 (Pan)	12 36 14 05	6.05	6.31	6.59	6.82	7.06	7.13	7.23	7.64	+/- 0.2
C2 (Pan)	12 36 14 17	6.03	6.26	6.53	6.78	6.94	7.13	7.19	7.59	+/- 0.2
C3 (Pan)	12 36 14 14	6.29	6.50	6.81	7.04	7.18	7.35	7.46	7.84	+/- 0.2
C4 (Red)	12 36 53 26	7.39	7.57	7.68	7.85	7.85	7.98	8.15	8.41	+/- 0.2
C5 (Green)	12 31 46 00	6.92	7.04	7.21	7.37	7.43	7.47	7.70	7.90	+/- 0.2
C6 (Blue)	12 33 15 29	6.87	6.94	6.94	7.00	7.18	7.35	7.48	7.60	+/- 0.2
C7 (NIR)	12 31 45 86	6.93	7.01	7.18	7.47	7.59	7.72	7.79	8.36	+/- 0.2



# **ULTRACAM**

## Electronics and Sensor Calibration

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**Camera:** UltraCam Eagle M3  
**Serial:** 431S61680X916102-f100

**Panchromatic Camera:** 9 \* FTF9060-M Area CCD Sensor by DALSA  
**Multispectral Camera:** 4 \* FTF9060-M Area CCD Sensor by DALSA

**Calibration Date:** May-11-2018  
**Date of Report:** Nov-08-2018  
**Camera Revision:** Rev01.01  
**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	18 7966/022	23.20	6.25
00_01	FTF9060-M	18 7966/030	22.60	6.33
00_02	FTF9060-M	18 7966/002	22.60	6.86
00_03	FTF9060-M	18 7966/019	23.00	6.33
01_00	FTF9060-M	18 7966/013	22.80	6.12
01_01	FTF9060-M	18 7966/021	23.00	6.43
02_00	FTF9060-M	18 7966/049	22.60	6.29
02_01	FTF9060-M	18 7966/045	23.00	6.41
03_00	FTF9060-M	18 7966/018	23.00	6.35
04_00 (red)	FTF9060-M	18 7966/031	22.20	6.04
05_00 (green)	FTF9060-M	18 7966/035	22.20	6.42
06_00 (blue)	FTF9060-M	18 7966/004	22.40	6.29
07_00 (NIR)	FTF9060-M	18 7966/036	22.80	6.07



## 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	18 7966/022	13780	12810
00_01	FTF9060-M	18 7966/030	13840	13030
00_02	FTF9060-M	18 7966/002	13810	12940
00_03	FTF9060-M	18 7966/019	13860	12900
01_00	FTF9060-M	18 7966/013	13600	12790
01_01	FTF9060-M	18 7966/021	13370	12930
02_00	FTF9060-M	18 7966/049	14220	12930
02_01	FTF9060-M	18 7966/045	13660	12610
03_00	FTF9060-M	18 7966/018	13900	13060
04_00 (red)	FTF9060-M	18 7966/031	13910	12950
05_00 (green)	FTF9060-M	18 7966/035	13930	13020
06_00 (blue)	FTF9060-M	18 7966/004	14060	13010
07_00 (NIR)	FTF9060-M	18 7966/036	13530	12920



# ULTRACAM

## Summary

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<b>Camera:</b>	<b>UltraCam Eagle M3</b>
<b>Serial:</b>	<b>431S61680X916102-f100</b>
<b>Calibration Date:</b>	<b>May-11-2018</b>
<b>Date of Report:</b>	<b>Nov-08-2018</b>
<b>Camera Revision:</b>	<b>Rev01.01</b>
<b>Version of Report:</b>	<b>V01</b>

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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