



**VEXCEL**  
IMAGING

# ULTRACAM

## Calibration Report

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Camera:  
Serial:

UltraCam Eagle  
UC-E-1-60715585-f100

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

Jan-03-2017  
Apr-13-2018  
Rev07.00  
V01



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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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<b>Camera:</b>	<b>UltraCam Eagle</b>
<b>Serial:</b>	<b>UC-E-1-60715585-f100</b>

<b>Panchromatic Camera:</b>	<b>ck = 100.500 mm</b>
<b>Multispectral Camera:</b>	<b>ck = 100.500 mm</b>

<b>PPA Information:</b>	<b>X: 0.000 mm</b>
	<b>Y: 0.000 mm</b>

<b>Calibration Date:</b>	<b>Jan-03-2017</b>
<b>Date of Report:</b>	<b>Apr-13-2018</b>
<b>Camera Revision:</b>	<b>Rev07.00</b>
<b>Version of Report:</b>	<b>V01</b>



## Panchromatic Camera

### Large Format Panchromatic Output Image

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

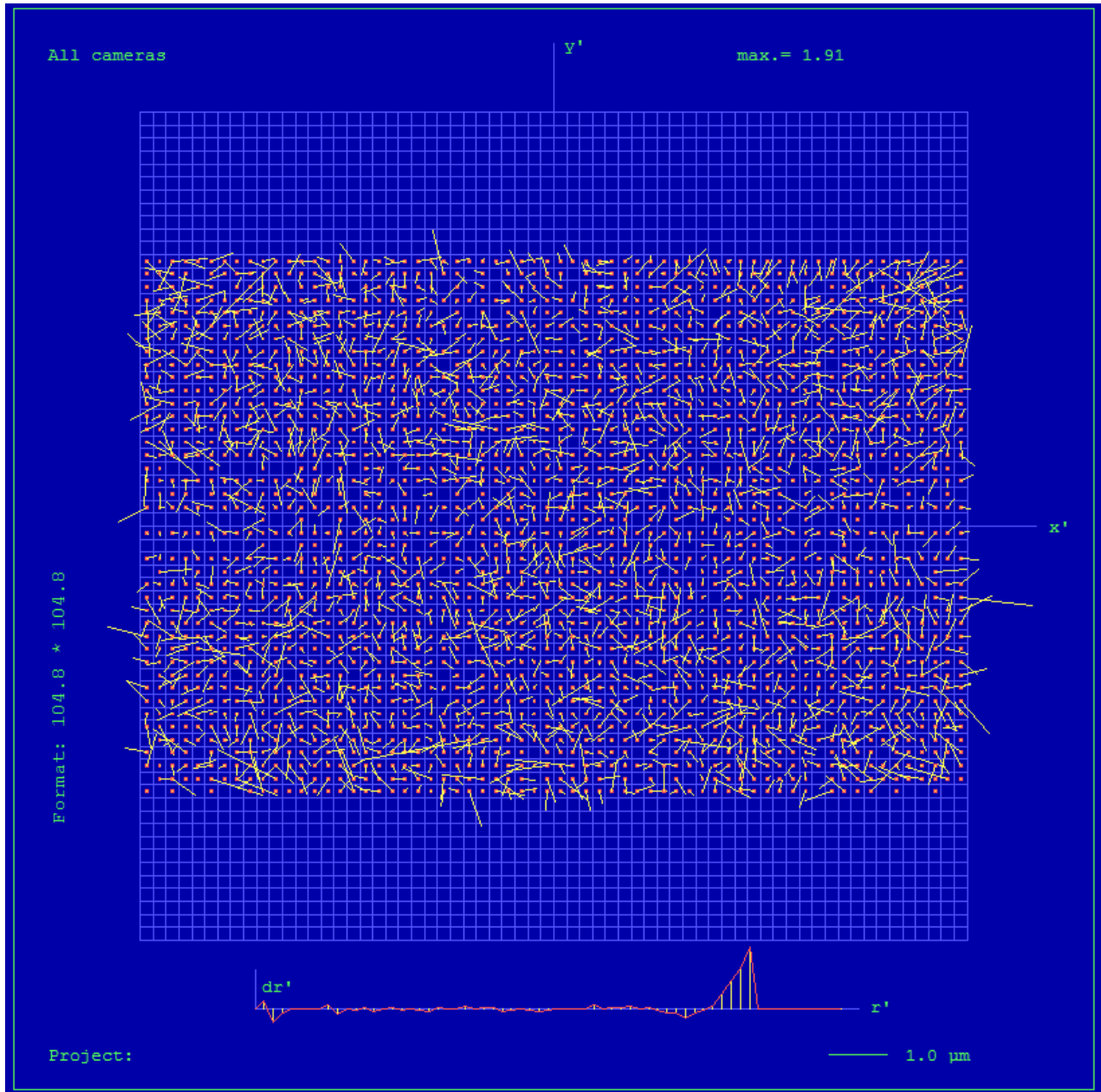
## Multispectral Camera

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

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

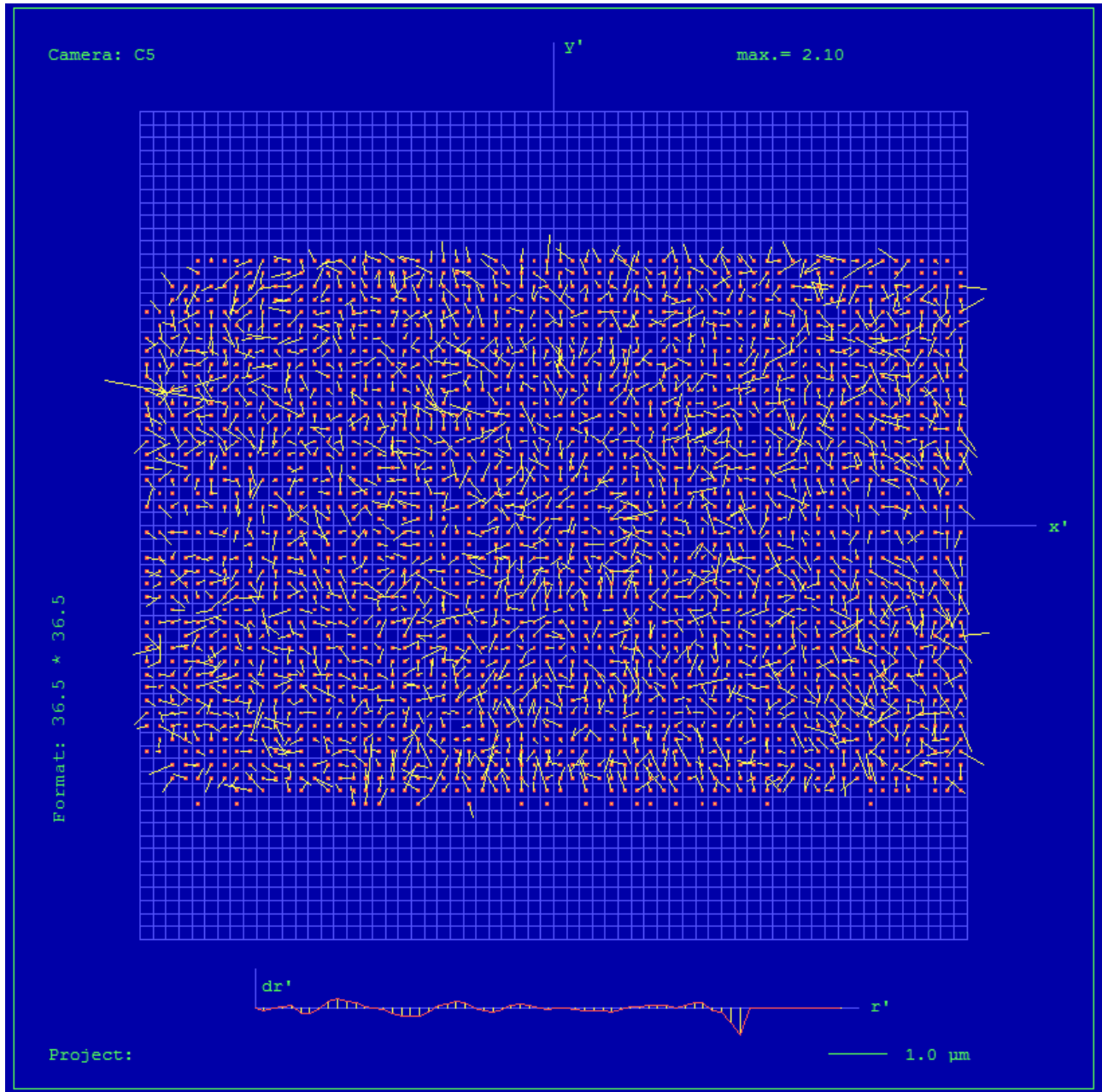


Residual Error (RMS): 0.64  $\mu\text{m}$





## 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

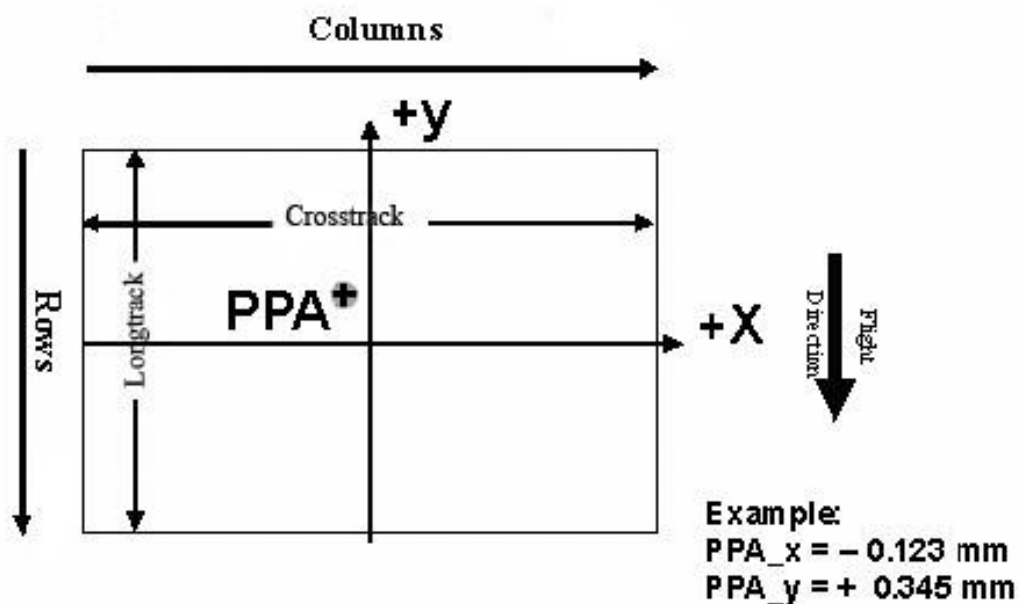
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

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

### Level 2 Image Coordinate System:

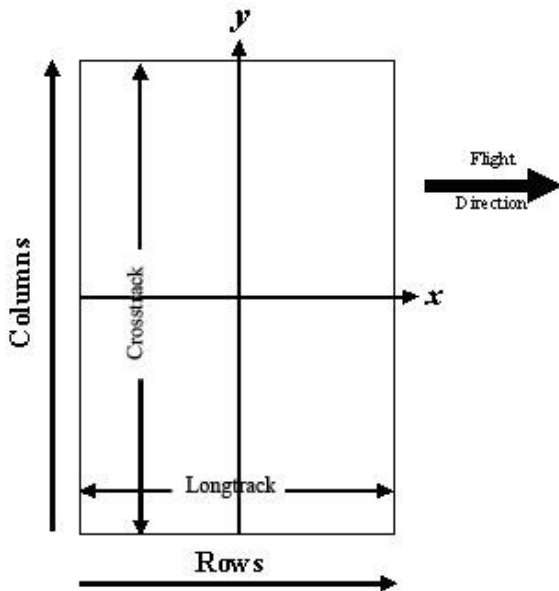
## Lvl2, Camera prop. Orientation



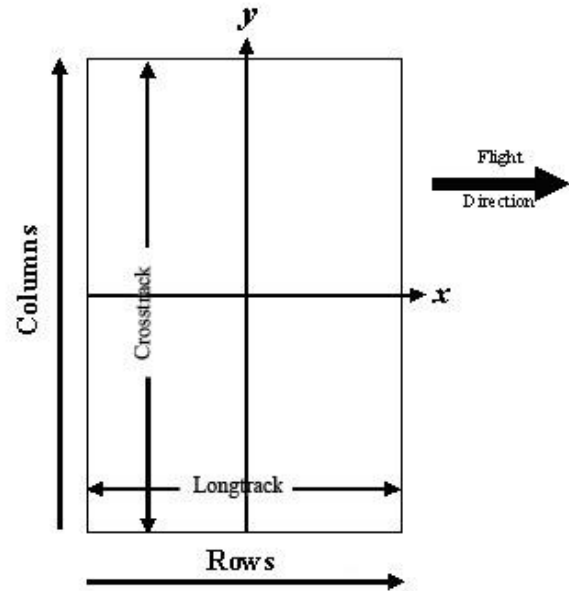
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



**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.

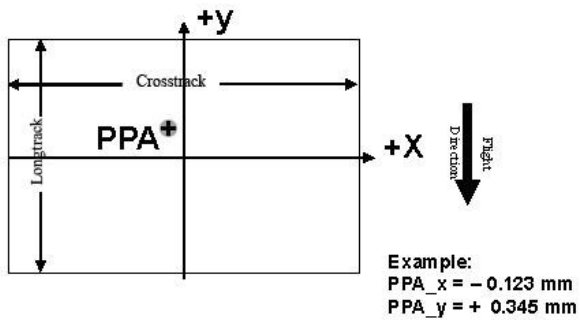
Image Format	Clockwise Rotation (Degree)	PPA	
		X	Y
Level 2	-	0.000	0.000
Level 3	0	0.000	0.000
Level 3	90	0.000	0.000
Level 3	180	0.000	0.000
Level 3	270	0.000	0.000



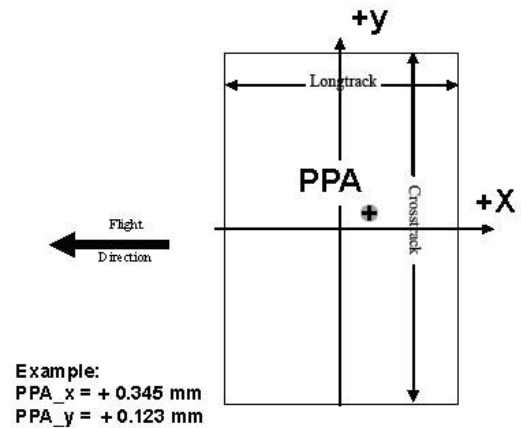


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

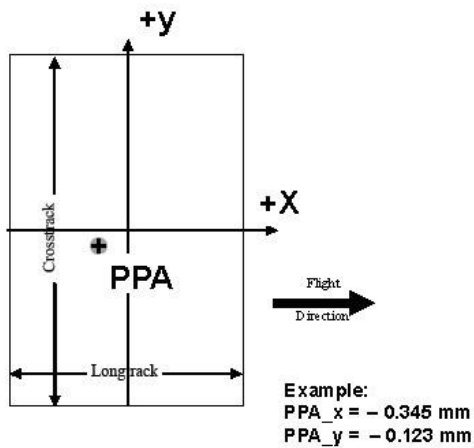
Lvl3, Rotation 0 deg clockwise



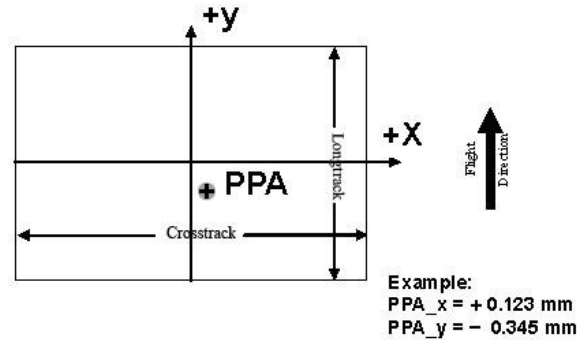
Lvl3, Rotation 90 deg clockwise



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.

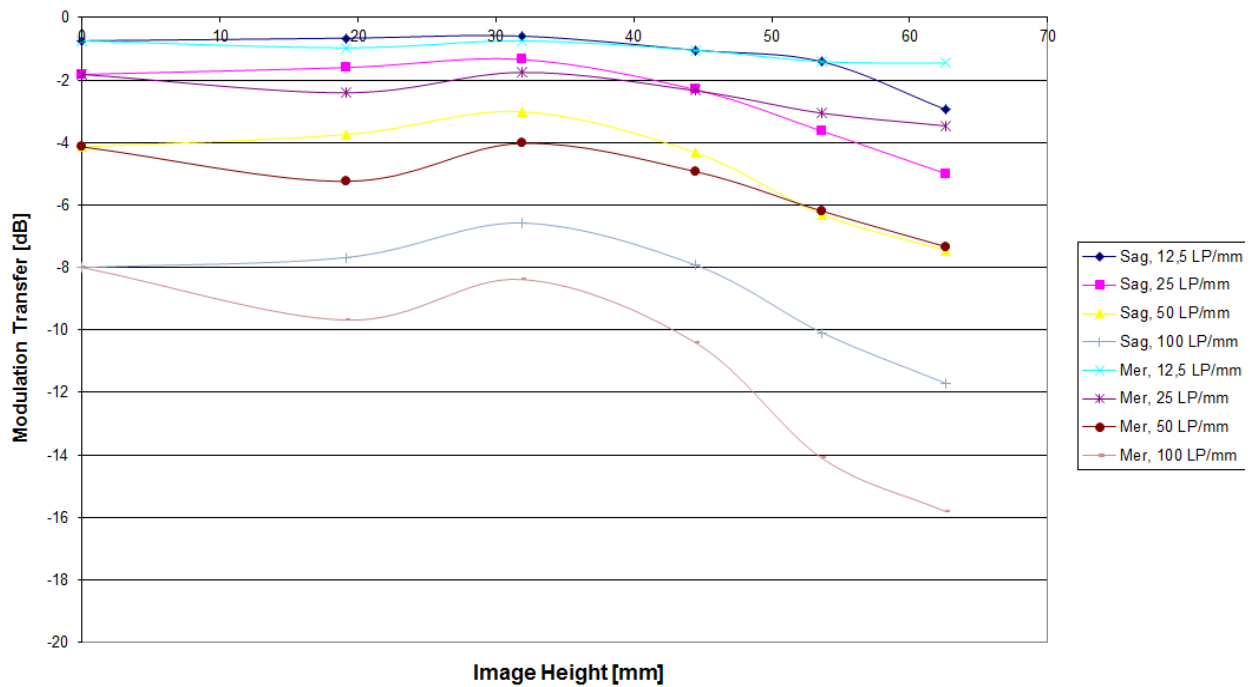
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

### Lens types

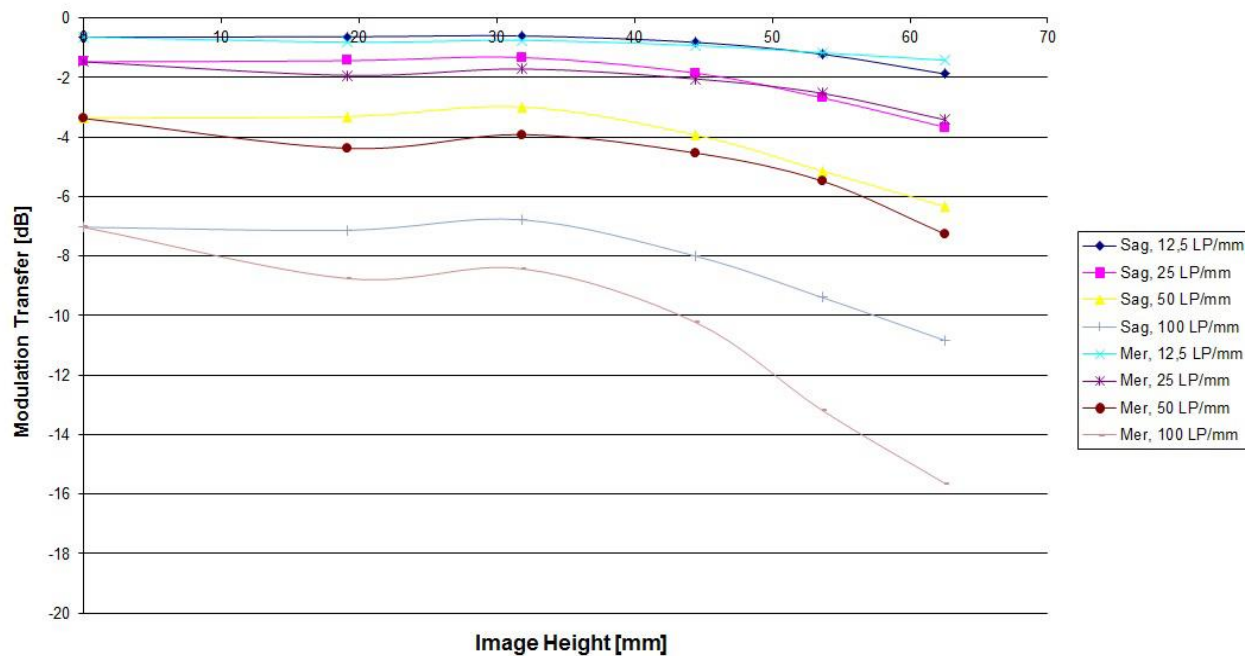
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/100mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic 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/ 5.6

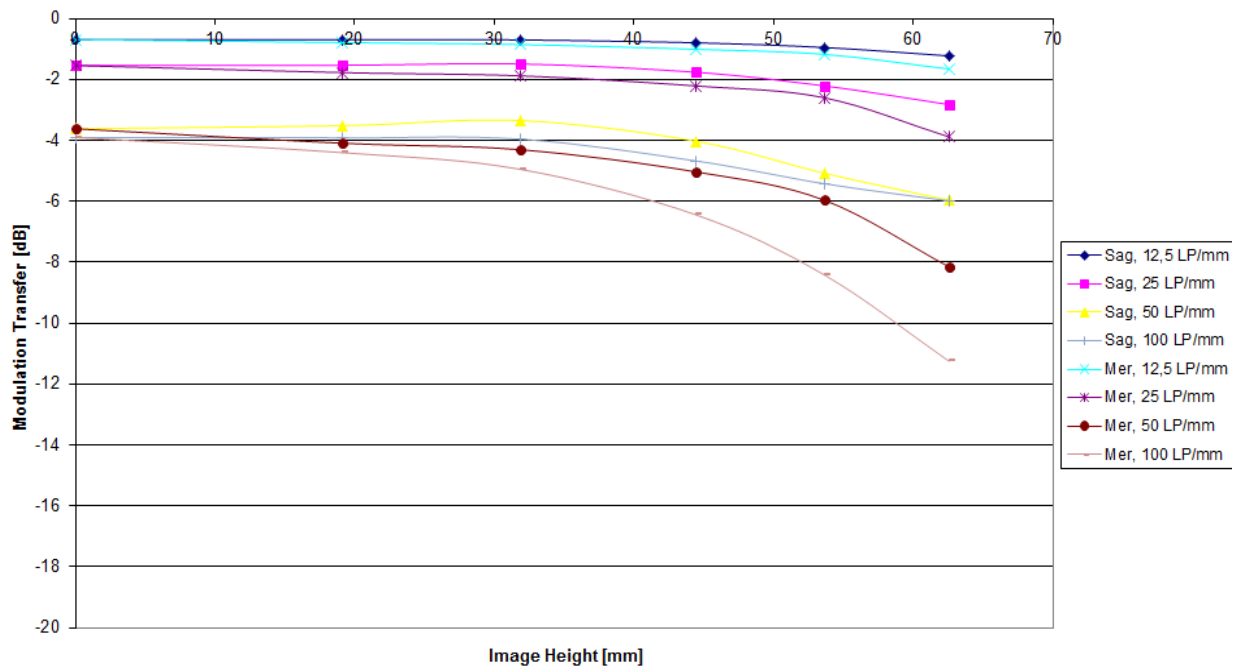


### Modulation versus Image Height - Aperture f/ 6.7

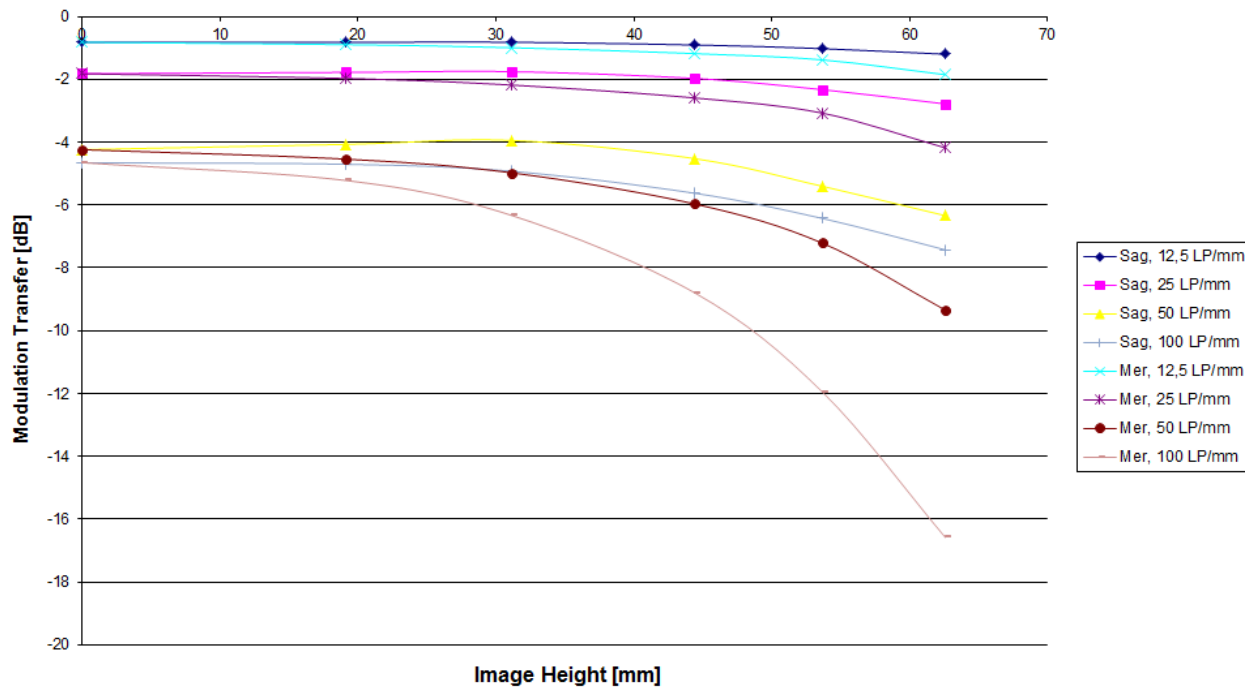




### Modulation versus Image Height - Aperture f / 8

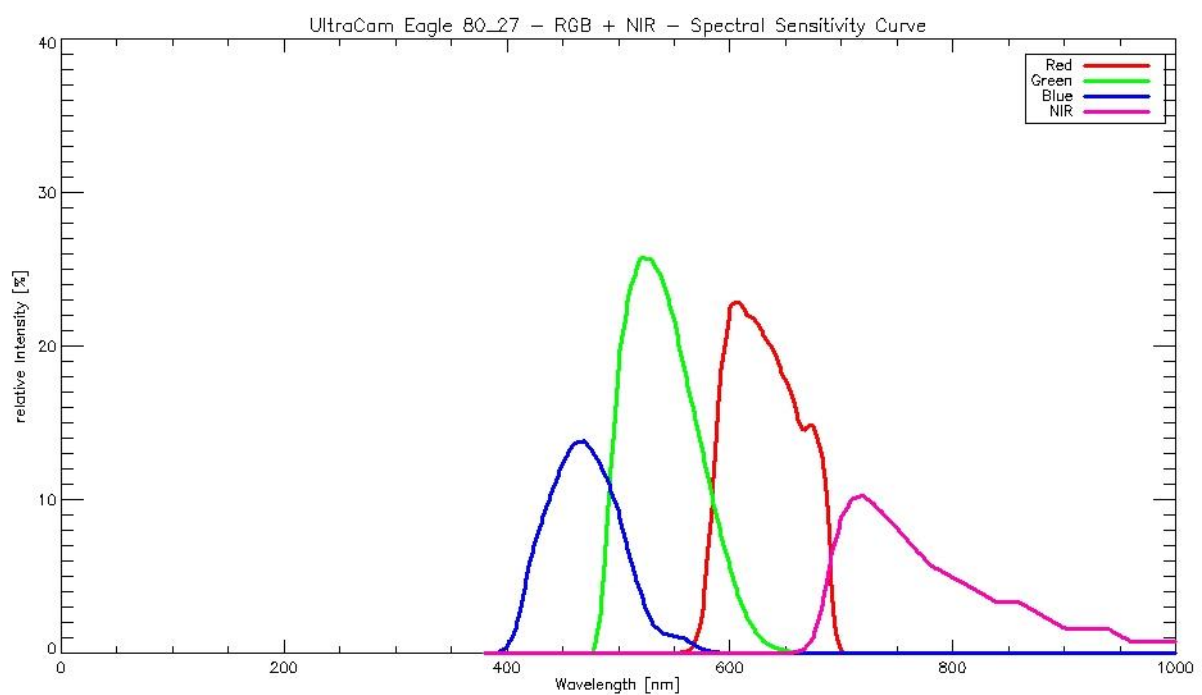
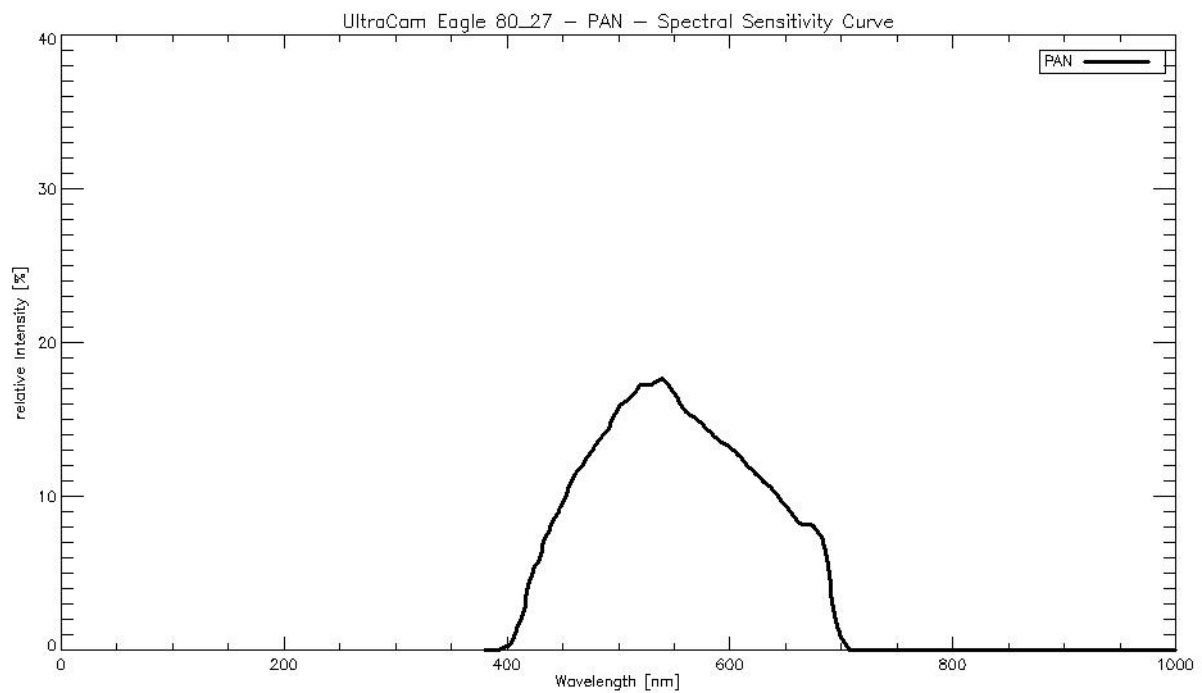


### Modulation versus Image Height - Aperture f / 9.5





## Spectral Sensitivity





# ULTRACAM

## Radiometric Calibration

**Camera:** UltraCam Eagle  
**Serial:** UC-E-1-60715585-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:** Apr-13-2018  
**Camera Revision:** Rev07.00  
**Version of Report:** V01








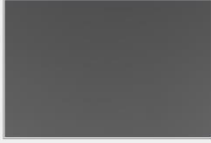
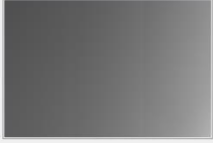




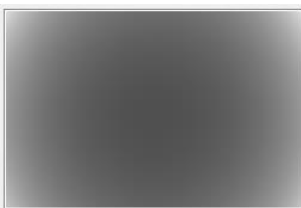
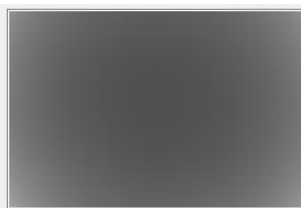
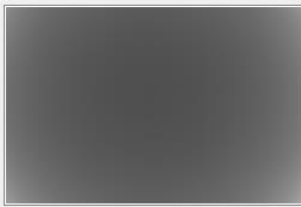
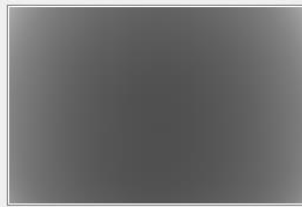
## Calibration of Vignetting for working Aperture F6.7

	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

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**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:** Dec-03-2017  
**Shutter Calibration Date:** Dec-03-2017  
**Date of Report:** Apr-13-2018  
**Camera Revision:** Rev07.00  
**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 27 38 31	5.83	6.13	6.38	6.59	6.77	6.92	7.04	7.24	+/- 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

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**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

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<b>Camera:</b>	<b>UltraCam Eagle</b>
<b>Serial:</b>	<b>UC-E-1-60715585-f100</b>
<b>Calibration Date:</b>	<b>Jan-03-2017</b>
<b>Date of Report:</b>	<b>Apr-13-2018</b>
<b>Camera Revision:</b>	<b>Rev07.00</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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Vexcel Imaging GmbH

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