



# ULTRACAM

## Calibration Report



**Camera:** UltraCam Eagle M3  
**Serial:** 431S52418X711582-f80

**Laboratory Calibration Date:** Nov-15-2021  
**Camera Revision:** Rev01.00

**Date of Report:** May-19-2022  
**Version of Report:** V02

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Venice, Italy

Photo on page 1 courtesy of Vexcel Imaging GmbH



# **ULTRACAM**

## Geometric Calibration

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**Camera:** UltraCam Eagle M3  
**Serial:** 431S52418X711582-f80

**Panchromatic Camera:** ck = 79.800 mm  
**Multispectral Camera:** ck = 79.800 mm

**PPA Information:** X: -0.160 mm  
Y: -0.080 mm



## 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	79.800mm	± 0.002mm
<b>Principal Point (Level 2)</b>	X_ppa	-0.160mm	± 0.002mm
	Y_ppa	-0.080mm	± 0.002mm
<b>Lens Distortion</b>	Remaining Distortion less than 0.002mm		

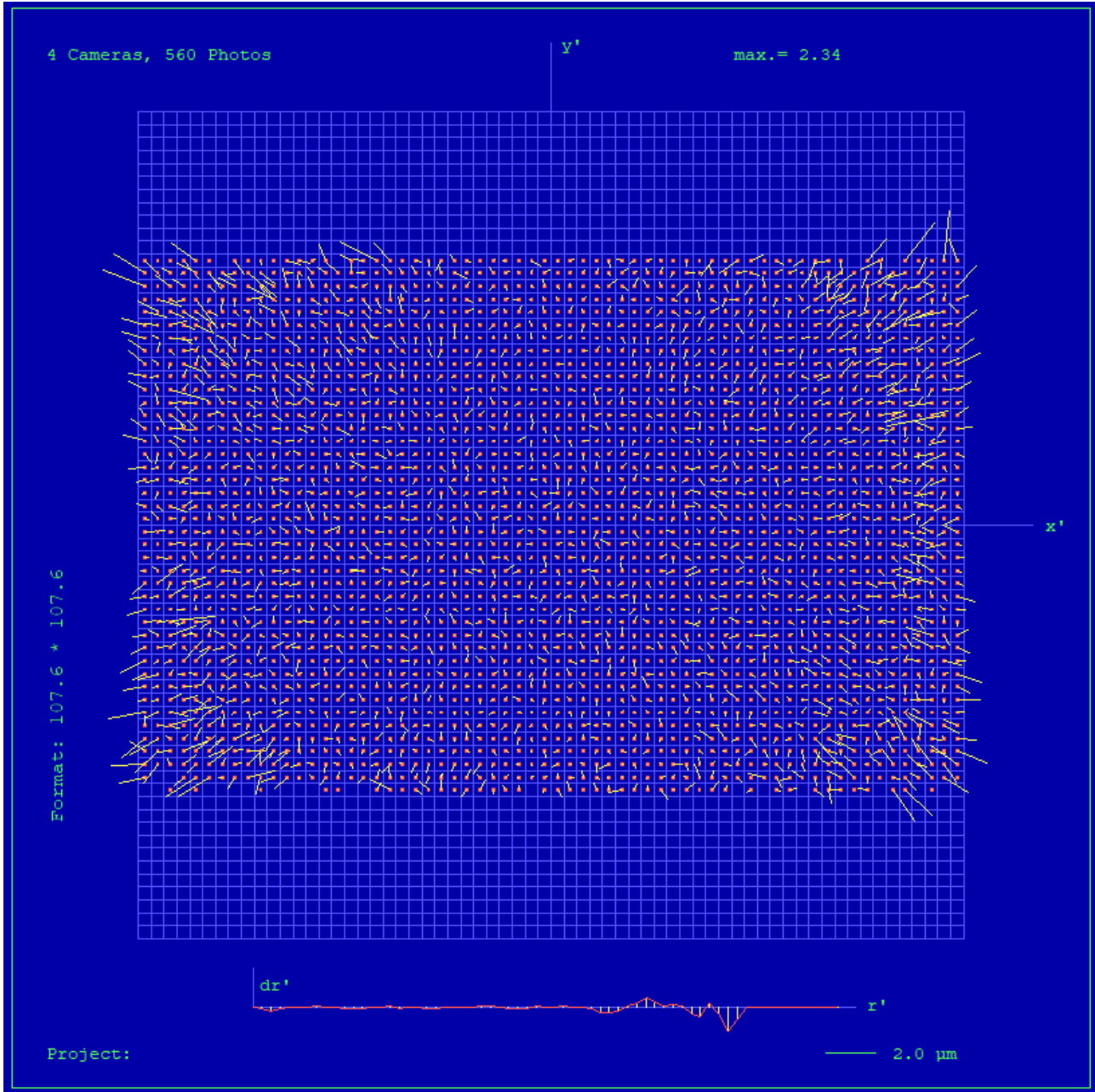
## Multispectral Camera

### 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	79.800mm	± 0.002mm
<b>Principal Point (Level 2)</b>	X_ppa	-0.160mm	± 0.002mm
	Y_ppa	-0.080mm	± 0.002mm
<b>Lens Distortion</b>	Remaining Distortion less than 0.002mm		



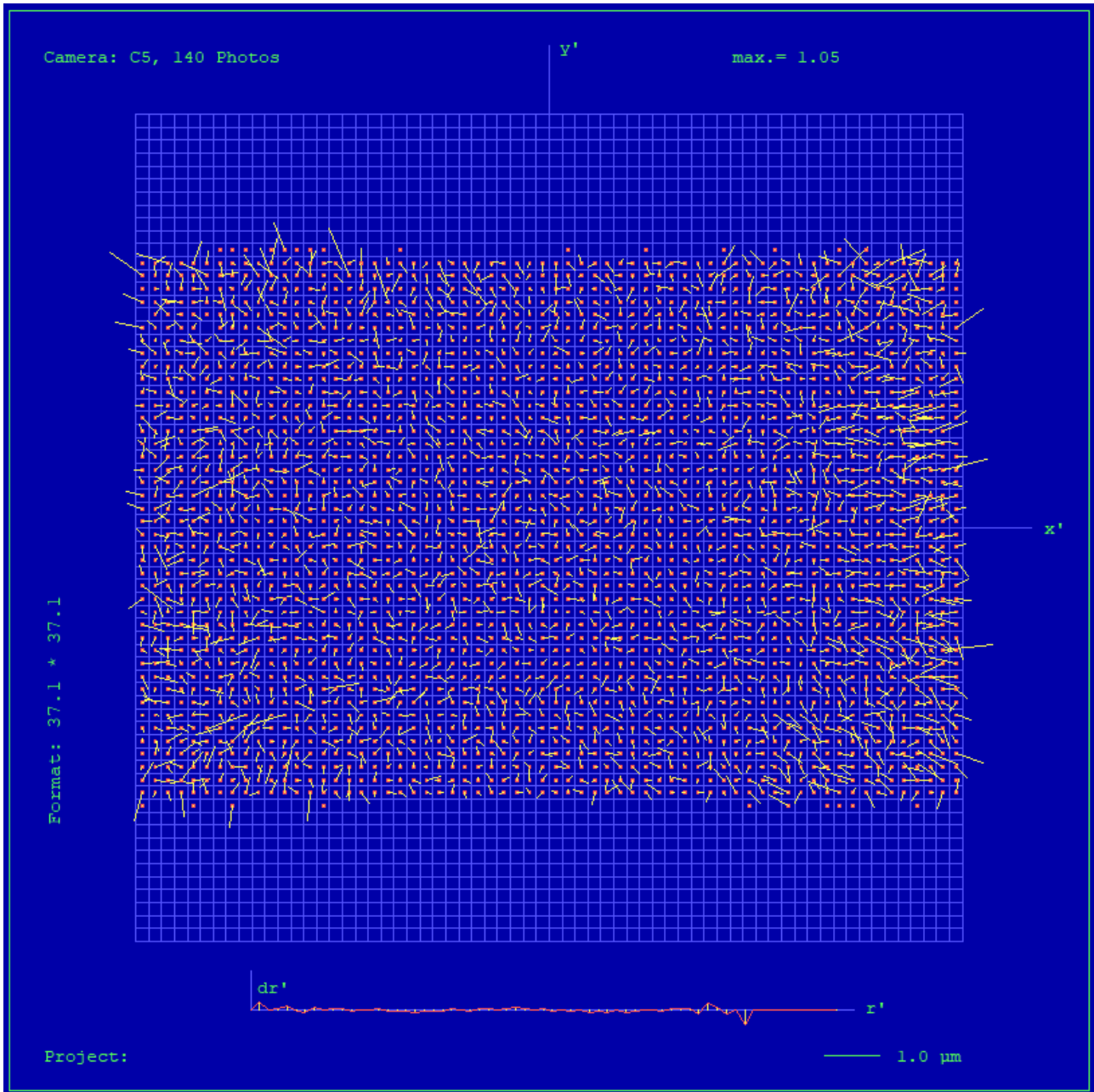
# Full Panchromatic Image, Residual Error Diagram



**Residual Error (RMS):**            **0.68  $\mu\text{m}$**



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



Residual Error (RMS): 0.50  $\mu\text{m}$



## 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

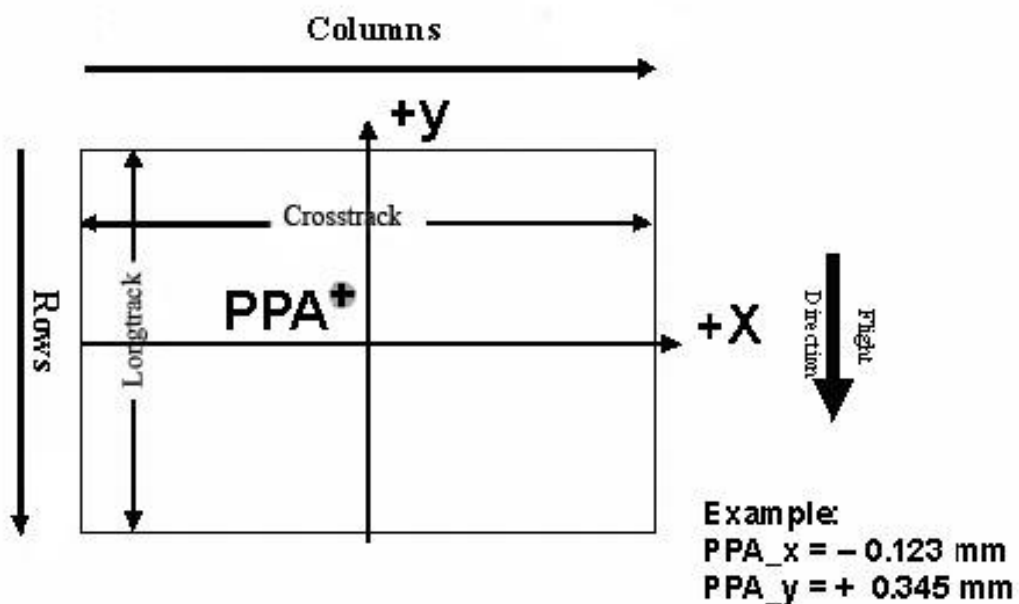
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

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

### Level 2 Image Coordinate System:

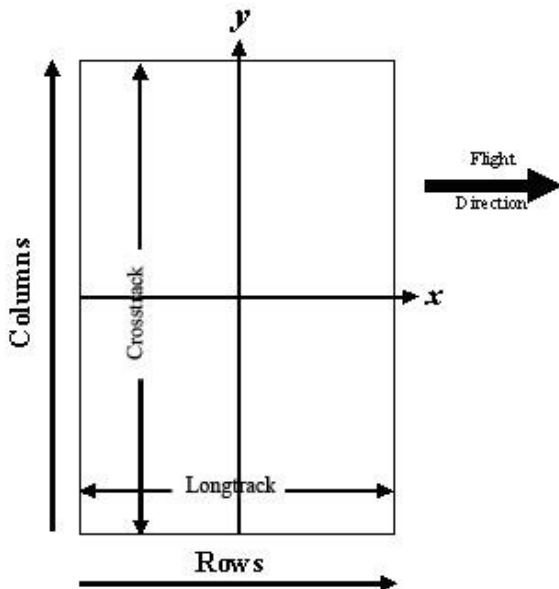
## Lvl2, Camera prop. Orientation



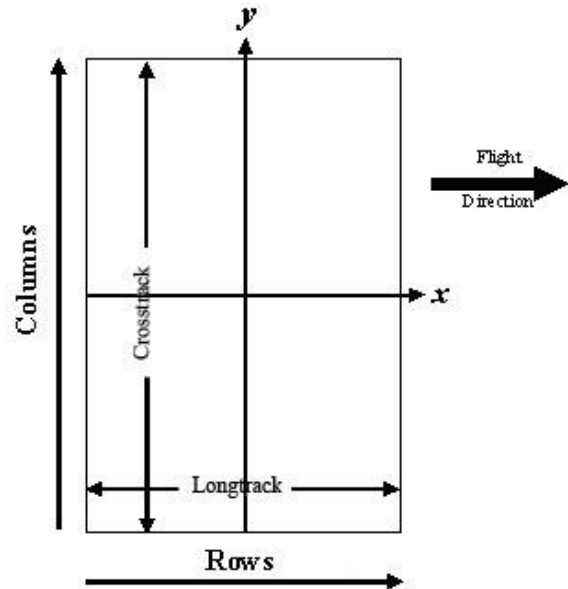
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



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



Panchromatic Image Format



Multispectral Image Format

**Position of Principal Point in Level 3 Image**

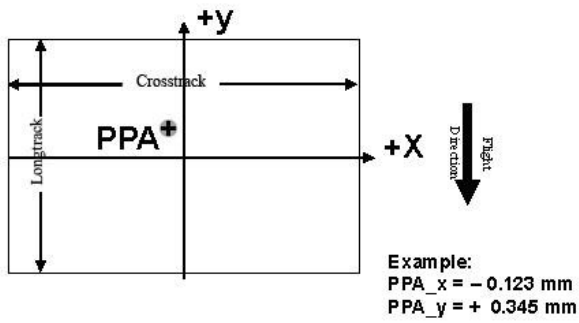
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified 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	-	-0.160	-0.080
Level 3	0	-0.160	-0.080
Level 3	90	-0.080	0.160
Level 3	180	0.160	0.080
Level 3	270	0.080	-0.160

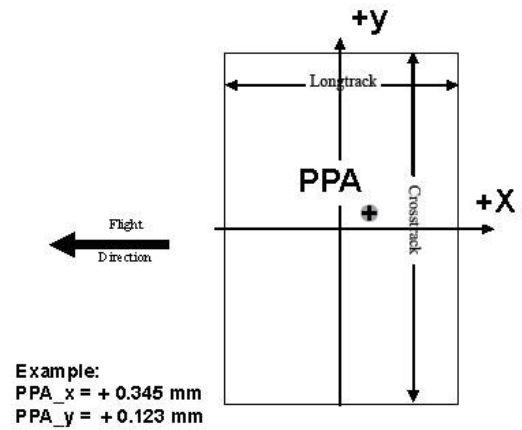


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

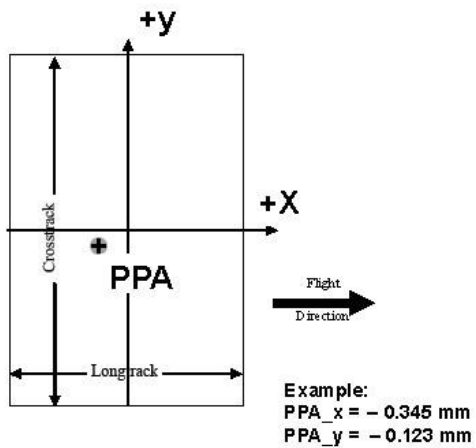
Lvl3, Rotation 0 deg clockwise



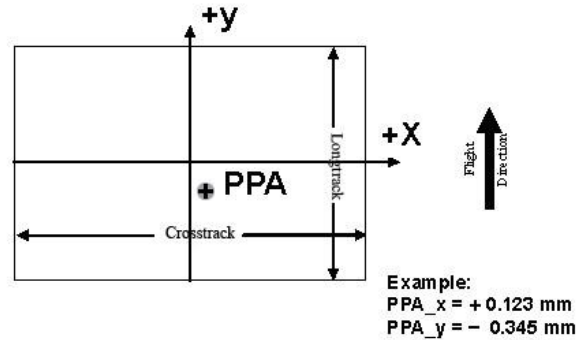
Lvl3, Rotation 90 deg clockwise



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.

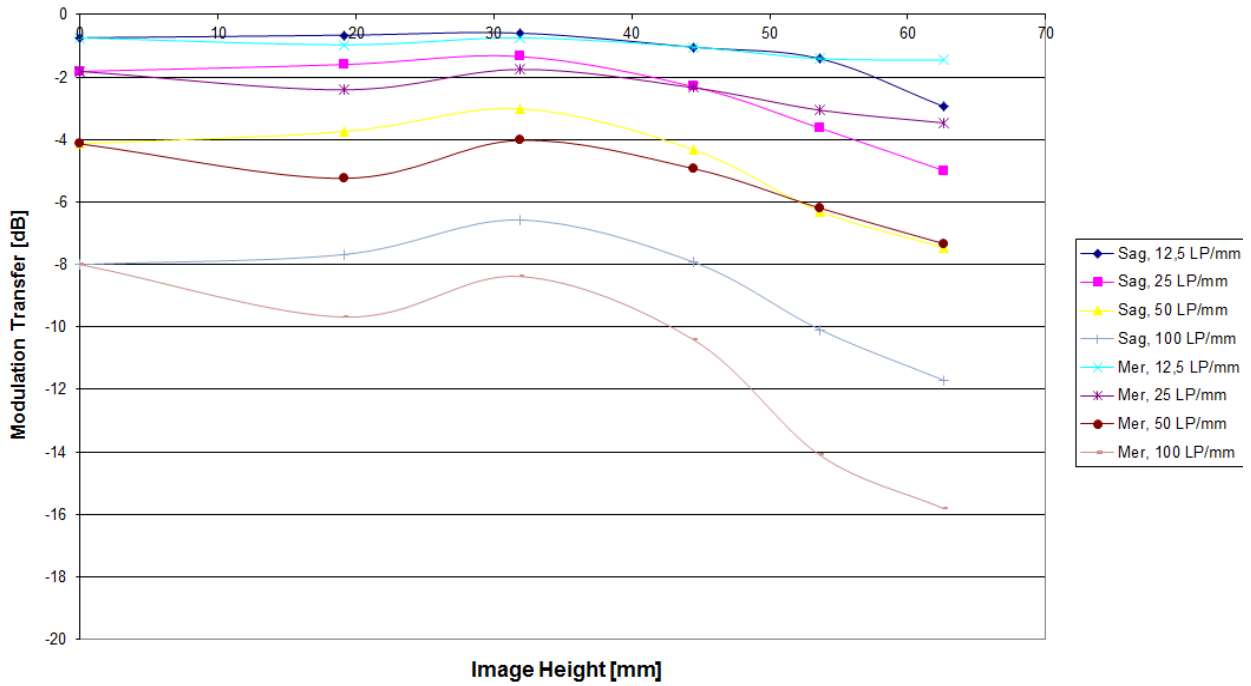
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

### Lens types

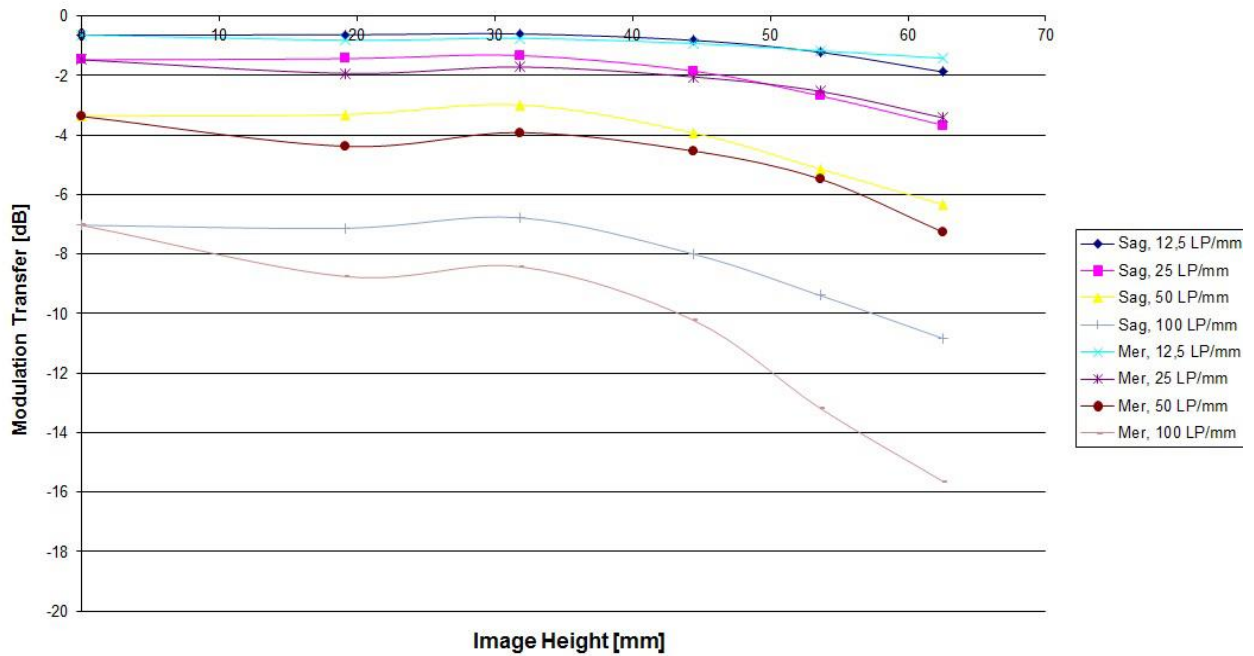
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic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

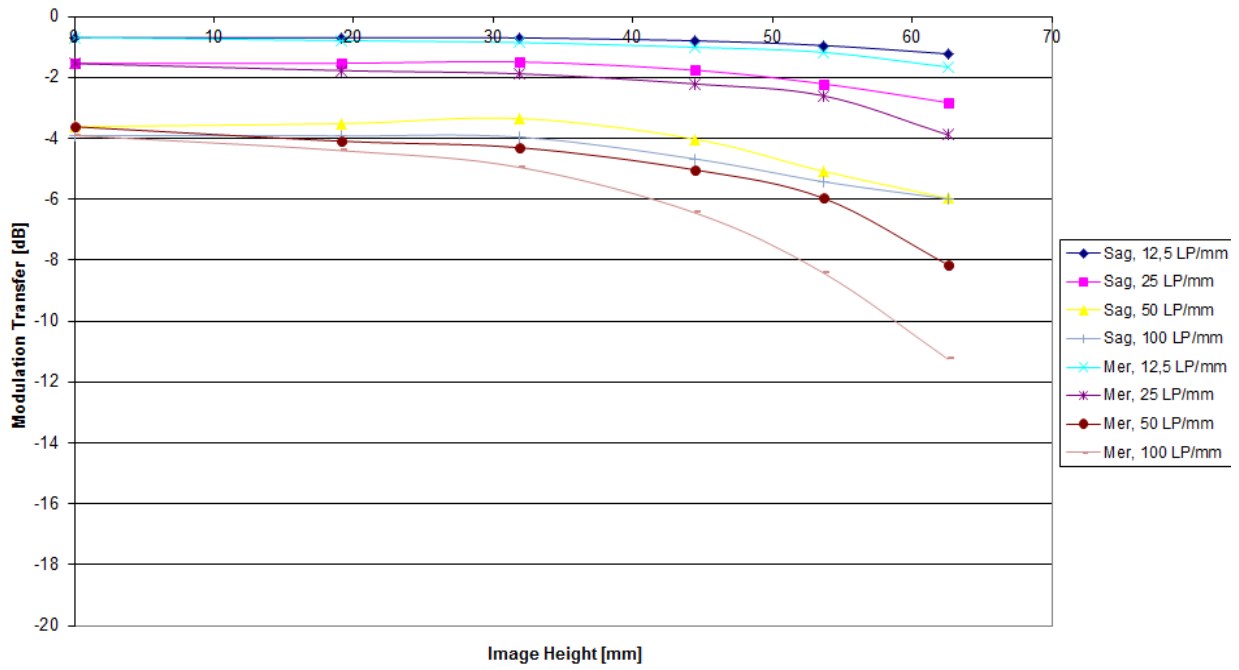


Modulation versus Image Height - Aperture f / 6.7

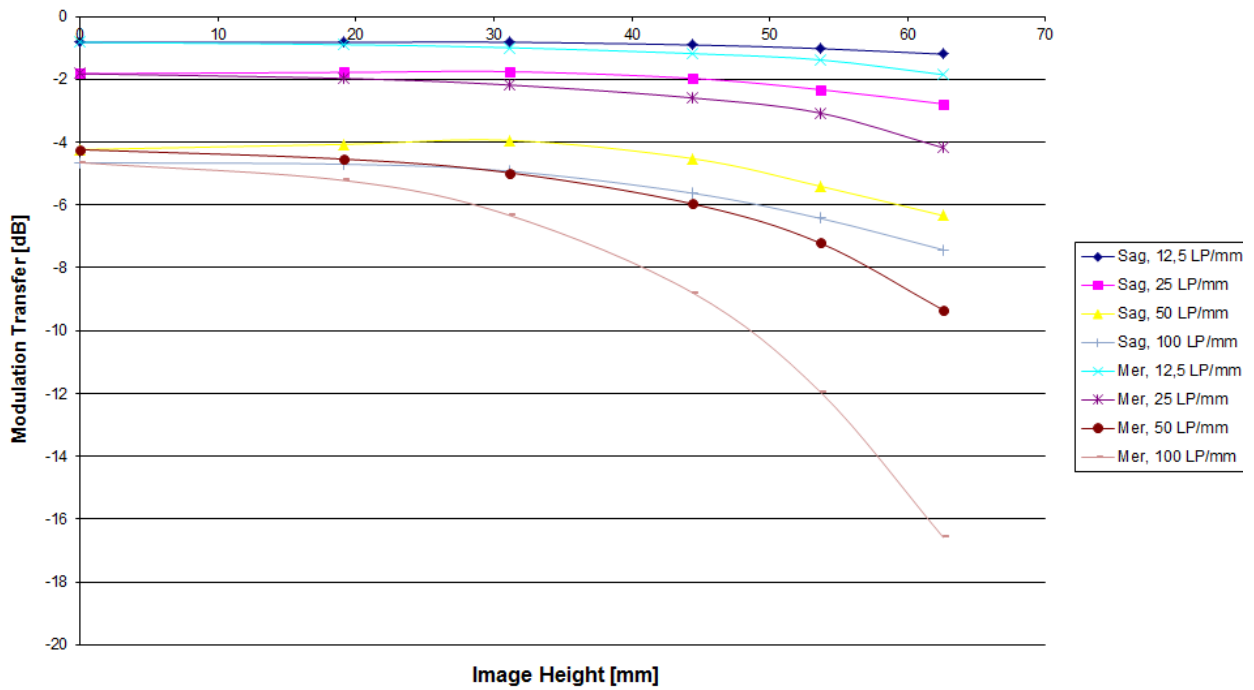




Modulation versus Image Height - Aperture f / 8

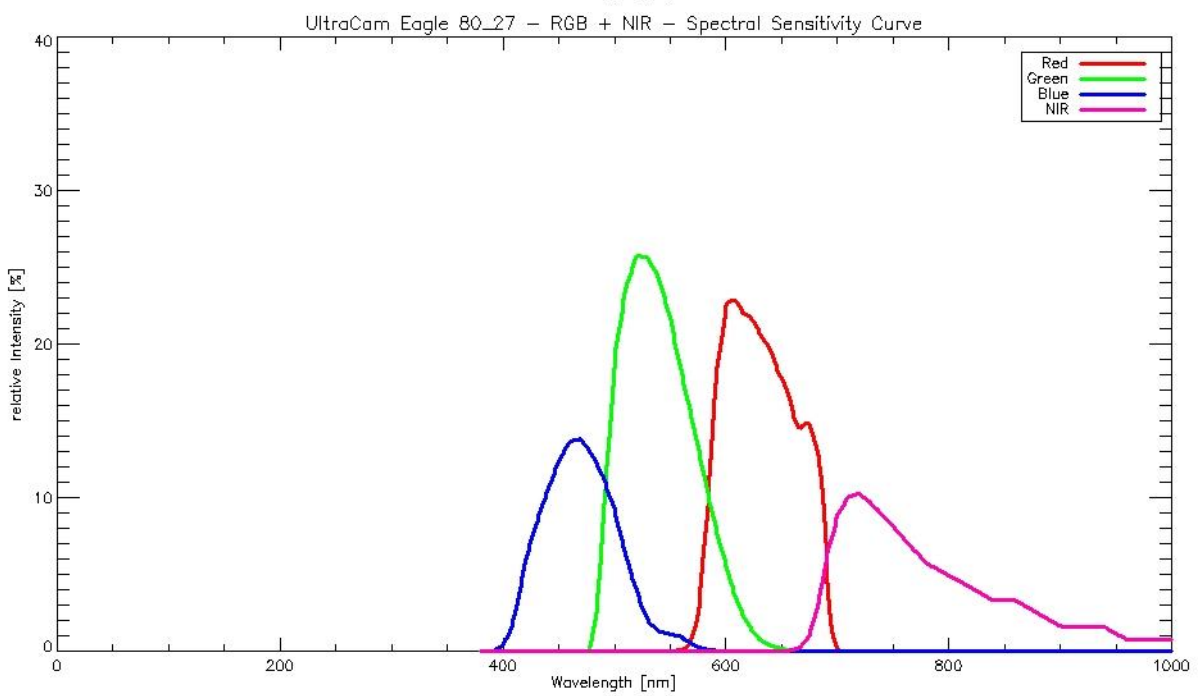
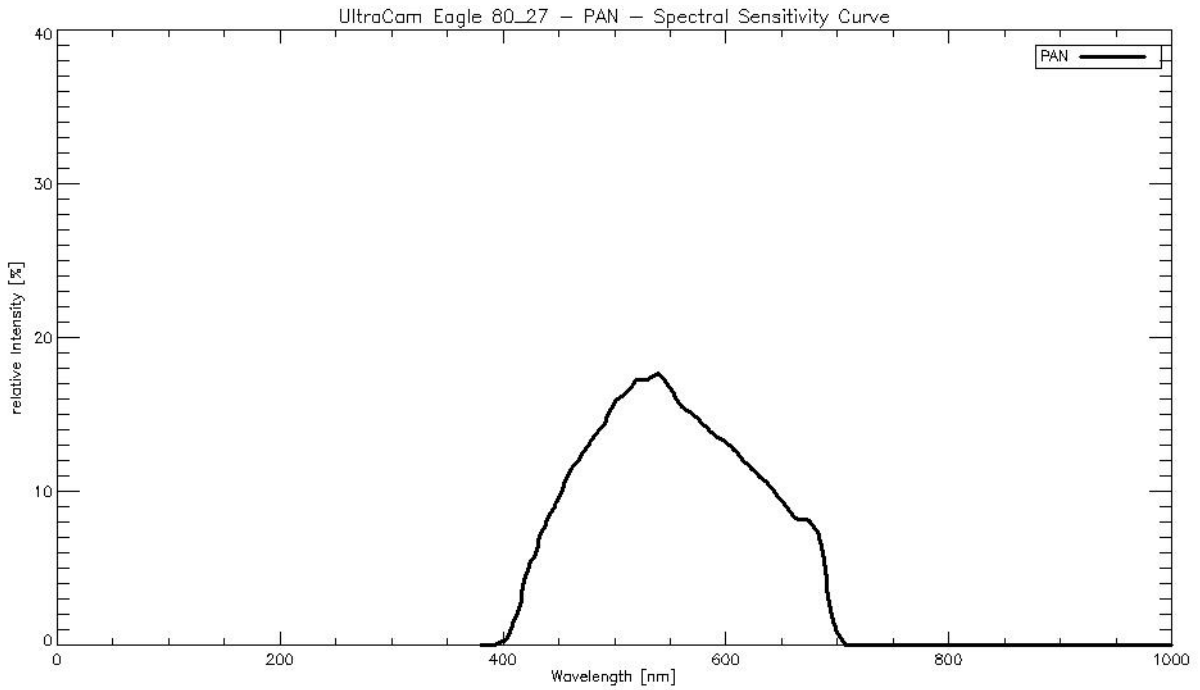


Modulation versus Image Height - Aperture f / 9.5





# Spectral Sensitivity





# ULTRACAM

## Radiometric Calibration

Camera: UltraCam Eagle M3  
Serial: 431S52418X711582-f80

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

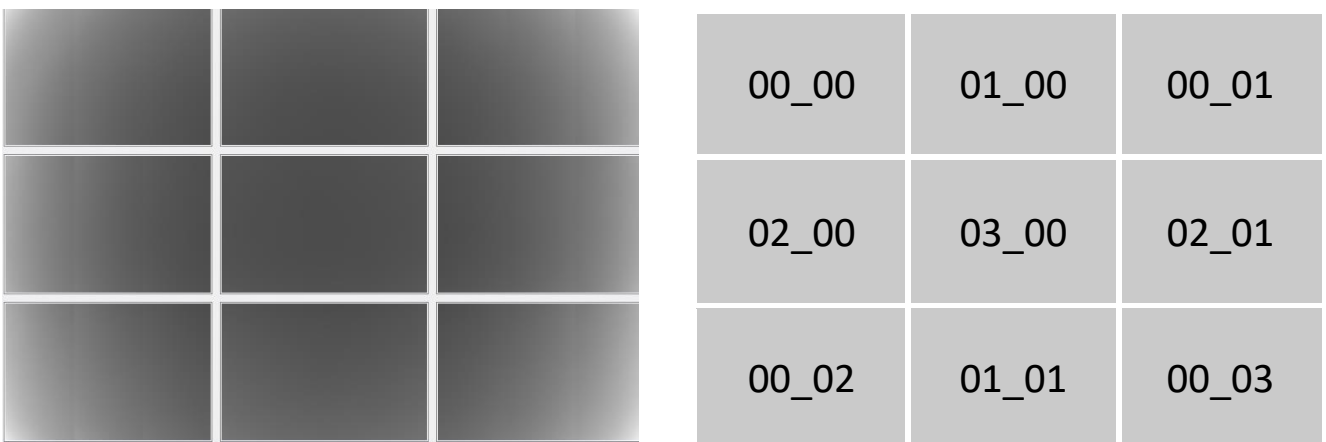
Dead Pixel Report: see Appendix I



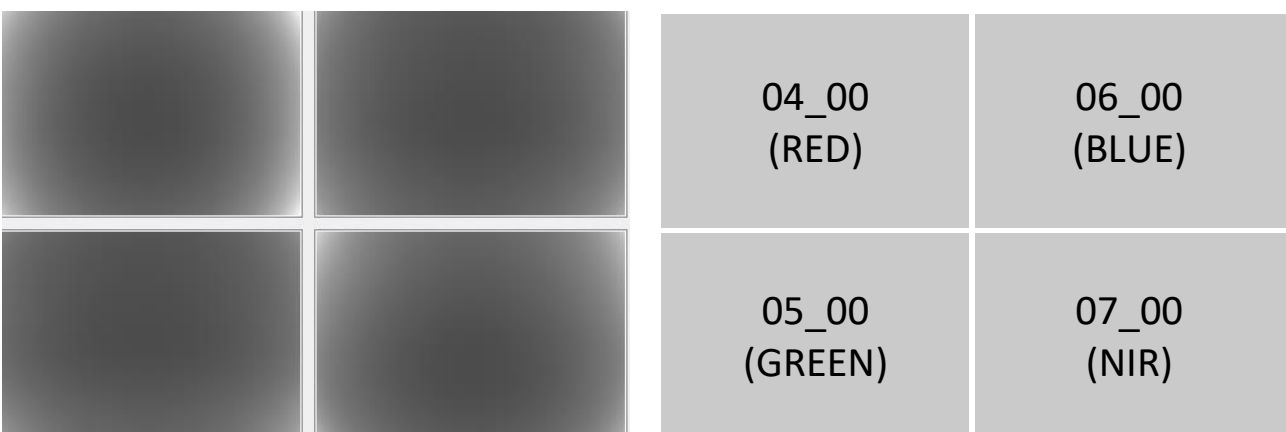
## Calibration of Vignetting for working Aperture F6.7

	PAN	R, G, NIR	B
Aperture	F6.7	F5.4	F4.8

### Graphical Overview of Pan Sensors:



### Graphical Overview of Multispectral Sensors:





## 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:** 431S52418X711582-f80

**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 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.

Currently used SRT values (operation values):

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 16 06 28	5.96	6.13	6.45	6.67	6.83	6.94	7.04	7.36	+/- 0.2
C1 (Pan)	12 12 20 35	6.34	6.55	6.85	7.05	7.23	7.36	7.45	7.71	+/- 0.2
C2 (Pan)	12 16 06 00	6.43	6.59	6.91	7.11	7.30	7.47	7.55	7.83	+/- 0.2
C3 (Pan)	12 10 09 82	6.42	6.57	6.92	7.14	7.32	7.39	7.48	7.66	+/- 0.2
C4 (Red)	12 10 16 28	7.49	7.50	7.84	7.84	7.89	8.02	8.16	8.42	+/- 0.2
C5 (Green)	12 10 16 16	7.17	7.22	7.35	7.57	7.57	7.62	7.76	8.01	+/- 0.2
C6 (Blue)	DSN12283	7.13	7.15	7.15	7.25	7.45	7.55	7.61	7.92	+/- 0.2
C7 (NIR)	12 16 03 90	7.27	7.38	7.49	7.69	7.92	7.92	7.98	8.35	+/- 0.2



# **ULTRACAM**

## Electronics and Sensor Calibration

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**Camera:** UltraCam Eagle M3  
**Serial:** 431S52418X711582-f80

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



## 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.

Currently used VNS and VOG values (operation values):

Cone_Sensor	Sensor Type	Sensor Serial Number	VNS Voltage [V]	VOG Voltage [V]
00_00	FTF9060-M	20 5221/002	21.80	6.57
00_01	FTF9060-M	20 5221/001	21.80	6.63
00_02	FTF9060-M	20 5221/020	21.80	6.71
00_03	FTF9060-M	21 3059/008	20.00	6.42
01_00	FTF9060-M	21 3059/039	21.20	6.28
01_01	FTF9060-M	21 3059/007	20.00	6.03
02_00	FTF9060-M	20 5221/014	21.40	6.70
02_01	FTF9060-M	20 5221/015	21.40	6.52
03_00	FTF9060-M	21 3059/027	20.00	6.38
04_00 (red)	FTF9060-M	20 5221/034	21.60	6.71
05_00 (green)	FTF9060-M	20 5221/031	21.60	6.76
06_00 (blue)	FTF9060-M	20 5220/051	21.60	6.26
07_00 (NIR)	FTF9060-M	20 5220/047	21.20	6.18



## 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.

Currently used Threshold values (operation values):

Cone_Sensor	Sensor Type	Sensor Serial Number	Intensity Threshold [DN]	
			Tap 1	Tap2
00_00	FTF9060-M	20 5221/002	13780	12910
00_01	FTF9060-M	20 5221/001	13750	12380
00_02	FTF9060-M	20 5221/020	13180	12180
00_03	FTF9060-M	21 3059/008	15010	13810
01_00	FTF9060-M	21 3059/039	14400	13390
01_01	FTF9060-M	21 3059/007	14880	13770
02_00	FTF9060-M	20 5221/014	13980	12580
02_01	FTF9060-M	20 5221/015	14090	12560
03_00	FTF9060-M	21 3059/027	15330	14290
04_00 (red)	FTF9060-M	20 5221/034	13730	12700
05_00 (green)	FTF9060-M	20 5221/031	13820	13270
06_00 (blue)	FTF9060-M	20 5220/051	13860	12890
07_00 (NIR)	FTF9060-M	20 5220/047	13790	12840



# ULTRACAM

## Summary

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<b>Camera:</b>	<b>UltraCam Eagle M3</b>
<b>Serial:</b>	<b>431S52418X711582-f80</b>
<b>Laboratory Calibration Date:</b>	<b>Nov-15-2021</b>
<b>Camera Revision:</b>	<b>Rev01.00</b>
<b>Date of Report:</b>	<b>May-19-2022</b>
<b>Version of Report:</b>	<b>V02</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.

Dr. Michael Gruber  
Chief Scientist, Photogrammetry  
Vexcel Imaging GmbH

Dipl. Ing. (FH) Helmut Jauk  
Senior Project Engineer R&D  
Vexcel Imaging GmbH



## Appendix I

### Dead Pixel Report:

Sensor number	Anomaly type	X-Coordinate	Y-Coordinate
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#### C00-00

PIXEL: 5671/1380  
PIXEL: 5648/1816  
PIXEL: 3016/3172  
PIXEL: 1628/3468  
PIXEL: 136/ 53  
PIXEL: 404/ 57  
PIXEL: 1780/ 125  
PIXEL: 1463/3375

#### C00-01

PIXEL: 6566/2022  
PIXEL: 386/3085  
PIXEL: 5597/5703  
PIXEL: 112/ 149  
PIXEL: 8767/ 190  
PIXEL: 8377/ 770  
PIXEL: 602/4870  
PIXEL: 603/4870  
PIXEL: 7057/5894

#### C00-02

PIXEL: 144/2714  
PIXEL: 7224/1153  
PIXEL: 2747/4456  
PIXEL: 8462/1000  
PIXEL: 391/5164

#### C00-03

PIXEL: 5971/1501  
PIXEL: 1129/2138  
PIXEL: 7855/2731  
PIXEL: 8956/4133  
PIXEL: 717/4868  
PIXEL: 8675/5033  
COLUMN: 3405/4843



**C01-00**

PIXEL: 588/ 813  
PIXEL: 938/1947  
PIXEL: 3524/2440  
PIXEL: 3524/3639  
PIXEL: 7199/4142  
PIXEL: 3811/ 401  
PIXEL: 3360/5517  
PIXEL: 3361/5517  
PIXEL: 3360/5518  
PIXEL: 3361/5518  
PIXEL: 450/5895  
PIXEL: 179/6014

**C01-01**

PIXEL: 637/4161  
PIXEL: 3385/4905  
PIXEL: 5373/5034  
PIXEL: 1853/3806  
PIXEL: 1854/3806  
PIXEL: 7604/4082  
PIXEL: 7605/4082  
PIXEL: 1753/4573  
PIXEL: 5751/4920

**C02-00**

PIXEL: 4837/ 796  
PIXEL: 4837/ 797  
PIXEL: 2227/3289  
PIXEL: 4000/6013

**C02-01**

PIXEL: 4860/2571  
PIXEL: 2329/3191  
PIXEL: 2606/2978  
PIXEL: 290/4865

**C03-00**

PIXEL: 4027/4048  
PIXEL: 1777/4173  
PIXEL: 9037/ 109  
PIXEL: 1709/ 261  
PIXEL: 8743/ 490  
PIXEL: 5933/1582  
PIXEL: 8975/2788  
PIXEL: 1281/4890  
PIXEL: 9038/5191  
PIXEL: 8485/5271  
PIXEL: 8486/5271  
PIXEL: 3778/5953



**C04-00**

PIXEL: 2166/ 24

PIXEL: 76/5803

**C05-00**

PIXEL: 5121/1477

PIXEL: 7589/2632

PIXEL: 7049/3207

PIXEL: 528/ 564

PIXEL: 445/ 571

PIXEL: 446/ 571

PIXEL: 8171/1172

PIXEL: 3398/3890

PIXEL: 5971/3982

PIXEL: 5971/3983

PIXEL: 226/5160

PIXEL: 226/5161

PIXEL: 341/5950

**C06-00**

PIXEL: 6433/ 400

PIXEL: 8856/2083

PIXEL: 57/1399

PIXEL: 7989/1772

PIXEL: 1006/2728

PIXEL: 1303/4276

PIXEL: 264/5345

**C07-00**

PIXEL: 3971/3950

PIXEL: 7722/ 339

PIXEL: 5345/1414

PIXEL: 2348/2196

PIXEL: 2181/4842

PIXEL: 398/5621

PIXEL: 398/5622

**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).



## Appendix II

### Calibration and Modification Dates

Type of Calibration	Laboratory Calibration Date	Modification Date	Modification Reason
Geometric Calibration	Nov-15-2021		
Radiometric Calibration	Nov-15-2021		
Shutter Calibration	Nov-15-2021		
Electronics and Sensor Calibration	Nov-15-2021		

**Note:** The above-mentioned Laboratory Calibration Dates represent the dates the camera was calibrated in one of our calibration labs for a full Laboratory Calibration. The Modification date represents a date on which the calibration has been modified due to a calibration enhancement or part exchange. It is an additional information and does not replace the Laboratory Calibration date in any way. With the Modification Reason, always the last modification to the calibration is highlighted