



# ULTRACAM

## Calibration Report

**Camera:** UltraCam Falcon Prime  
**Serial:** UC-Fp-1-00610270-f100

**Laboratory Calibration Date:** Mar-30-2022  
**Camera Revision:** Rev05.00

**Date of Report:** Apr-05-2022  
**Version of Report:** V01



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Venice, Italy

Photo on page 1 courtesy of Vexcel Imaging GmbH



# **ULTRACAM**

## Geometric Calibration

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**Camera:** UltraCam Falcon Prime  
**Serial:** UC-Fp-1-00610270-f100

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

**PPA Information:** X: -0.120mm  
Y: 0.000mm



## Panchromatic Camera

### Large Format Panchromatic Output Image

<b>Image Format</b>	long track cross track	67.860mm 103.860mm	11310pixel 17310pixel
<b>Image Extent</b>		(-33.930, -51.930)mm	(33.930, 51.930)mm
<b>Pixel Size</b>		6.000µm*6.000µm	
<b>Focal Length</b>	ck	100.500mm	± 0.002mm
<b>Principal Point (Level 2)</b>	X_ppa	-0.120mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
<b>Lens Distortion</b>	Remaining Distortion less than 0.002mm		

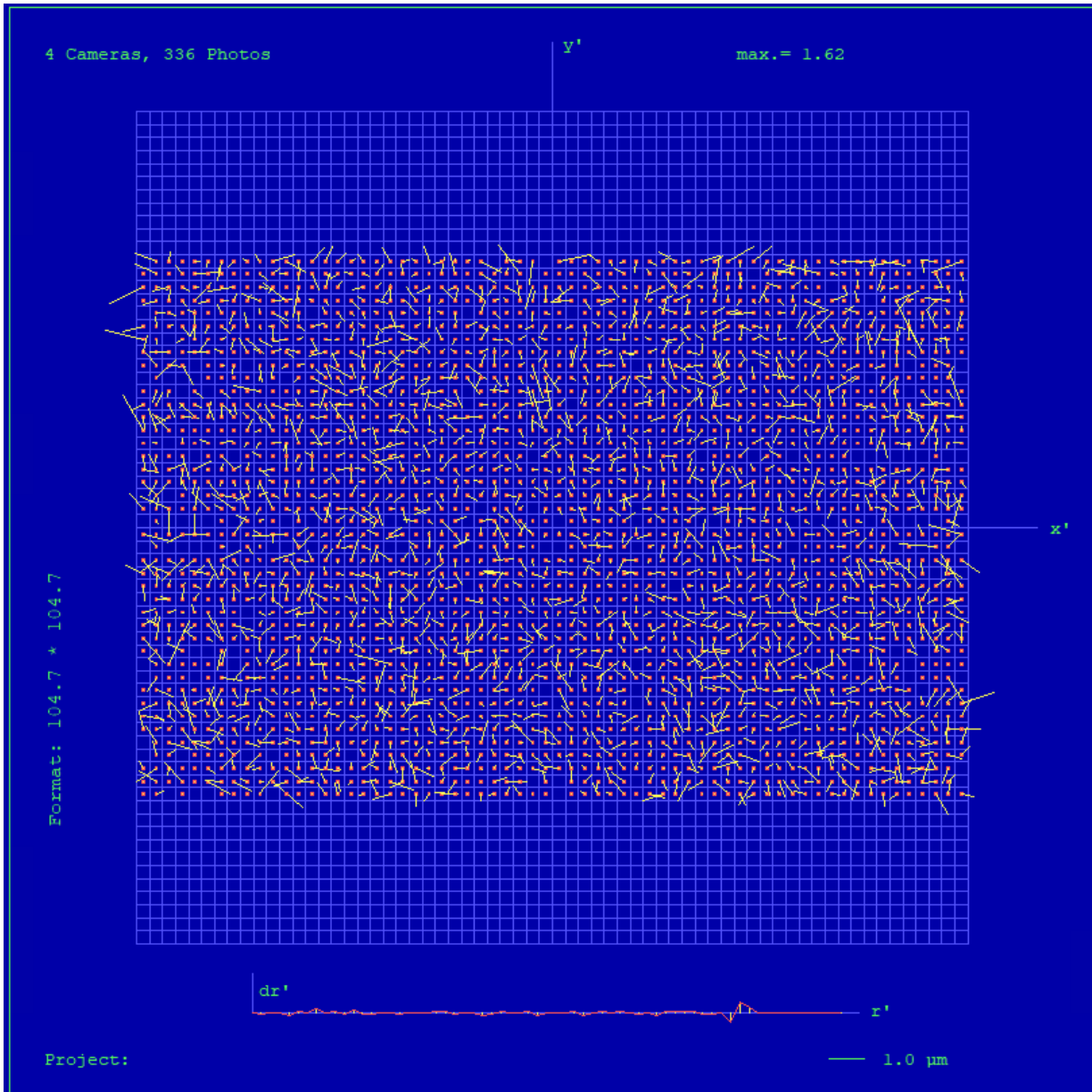
## Multispectral Camera

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

<b>Image Format</b>	long track cross track	67.860mm 103.860mm	3770pixel 5770pixel
<b>Image Extent</b>		(-33.930, -51.930)mm	(33.930, 51.930)mm
<b>Pixel Size</b>		18.000µm*18.000µm	
<b>Focal Length</b>	ck	100.500mm	± 0.002mm
<b>Principal Point (Level 2)</b>	X_ppa	-0.120mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
<b>Lens Distortion</b>	Remaining Distortion less than 0.002mm		



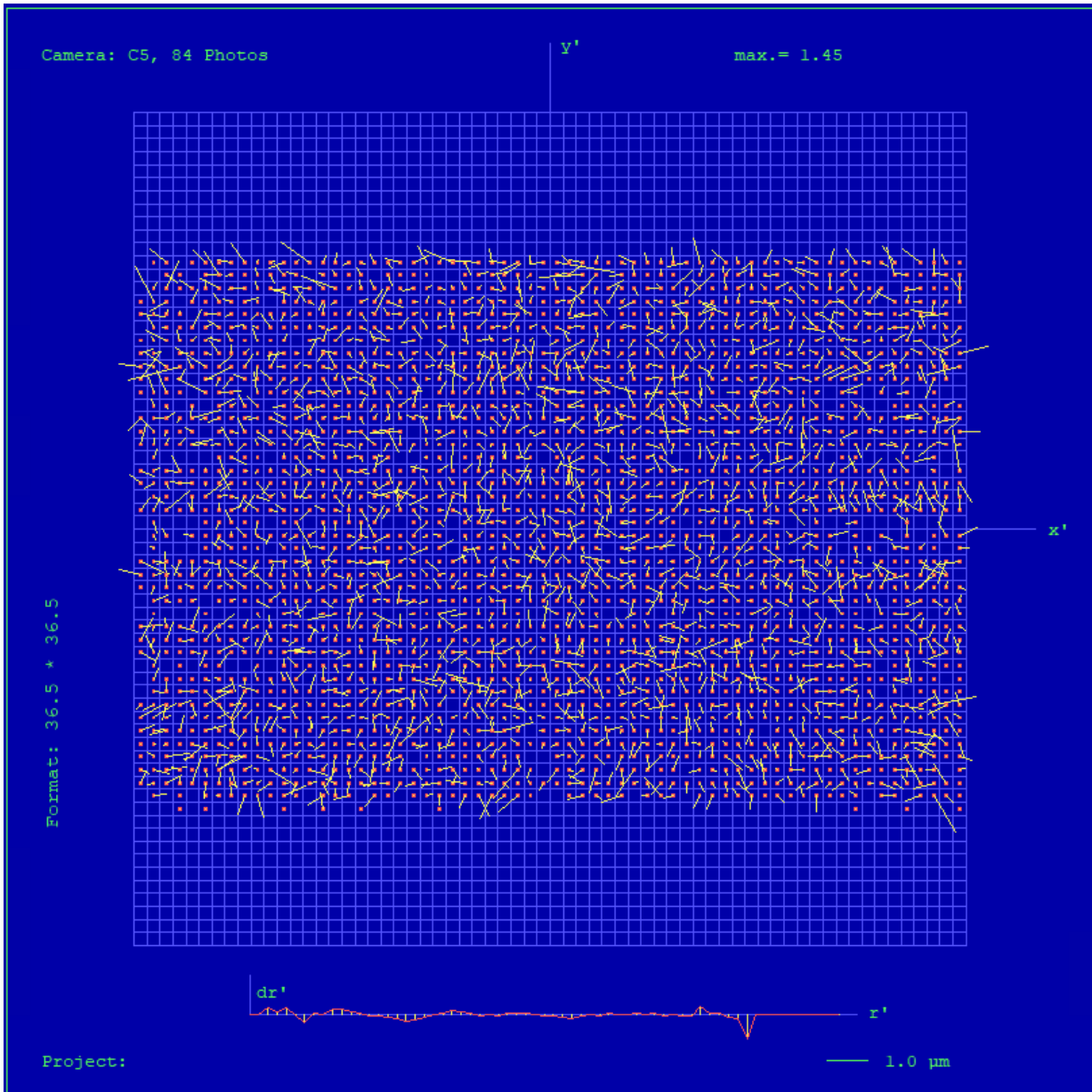
# Full Panchromatic Image, Residual Error Diagram



**Residual Error (RMS):**            **0.71  $\mu\text{m}$**



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



**Residual Error (RMS):            0.58 μm**





## Explanations

### Calibration Method:

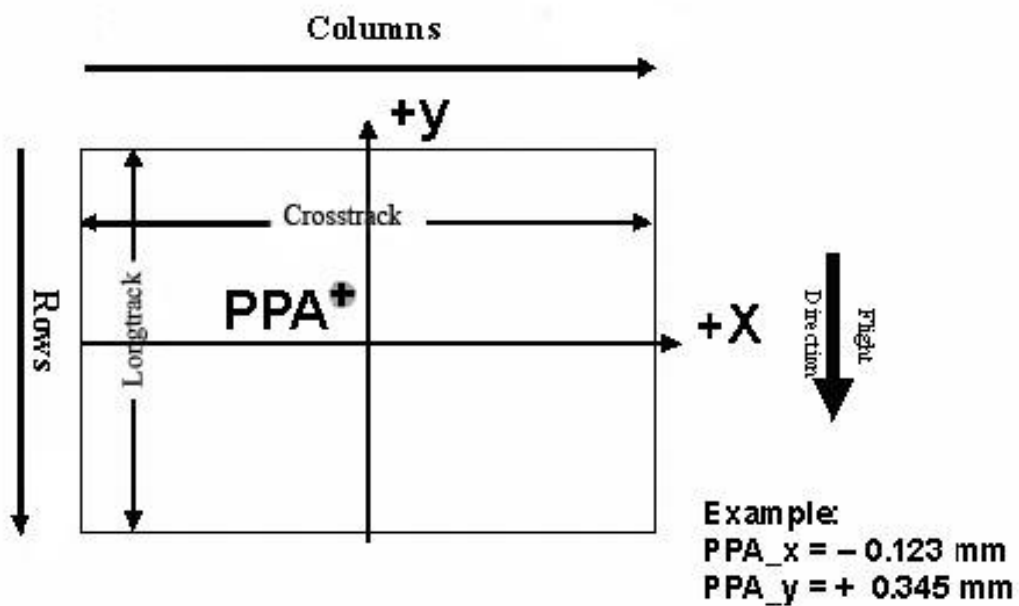
The geometric calibration is based on a set of 84 images of a defined geometry target with 394 GCPs.

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:

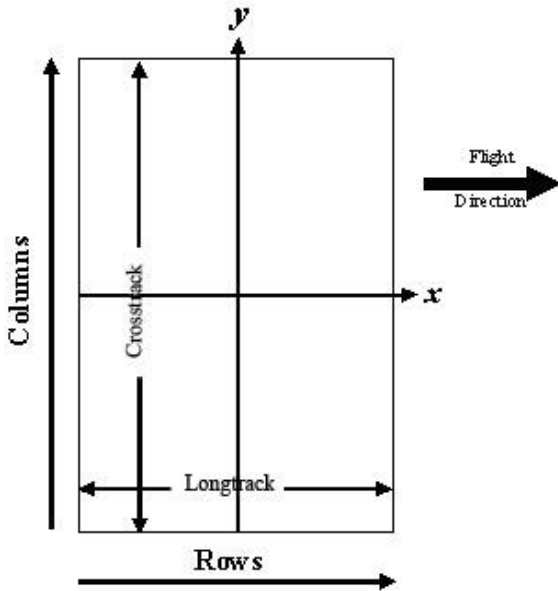
## Lvl2, Camera prop. Orientation



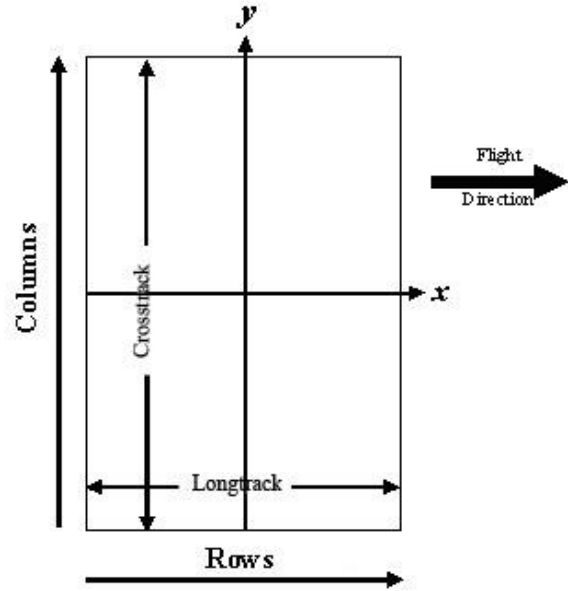
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



**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.

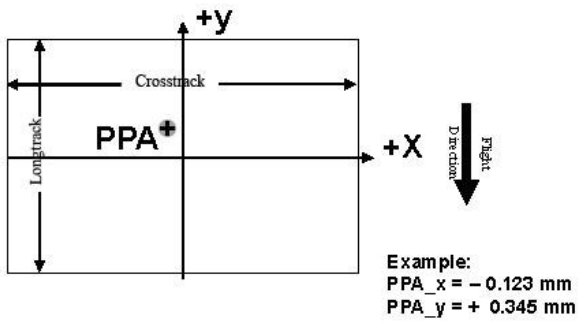
Image Format	Clockwise Rotation (Degree)	PPA	
		X	Y
Level 2	-	-0.120	0.000
Level 3	0	-0.120	0.000
Level 3	90	0.000	0.120
Level 3	180	0.120	0.000
Level 3	270	0.000	-0.120



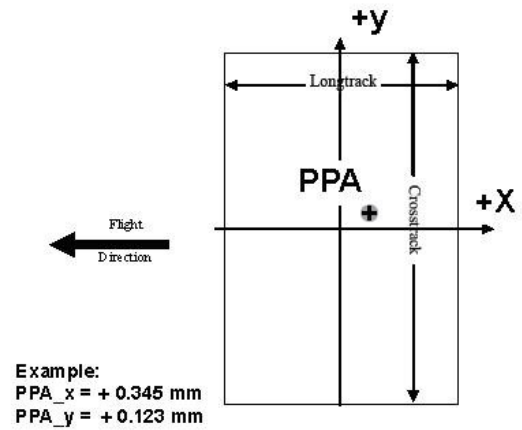


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

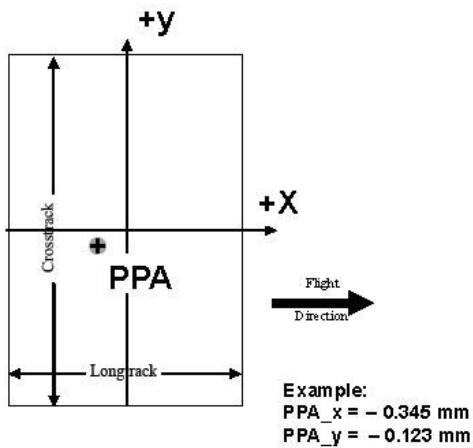
Lvl3, Rotation 0 deg clockwise



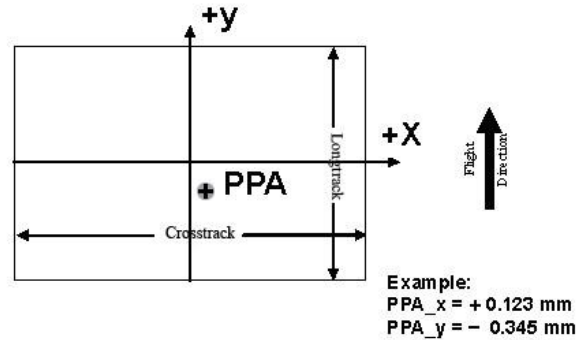
Lvl3, Rotation 90 deg clockwise



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

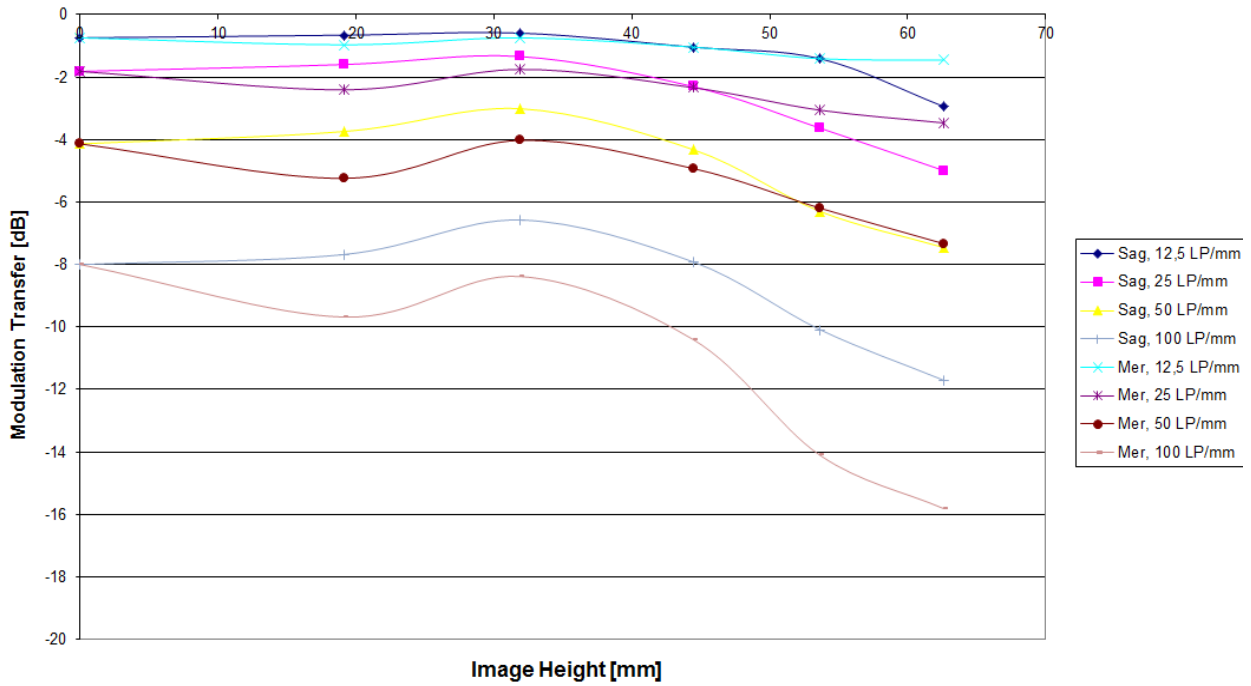
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

### Lens types

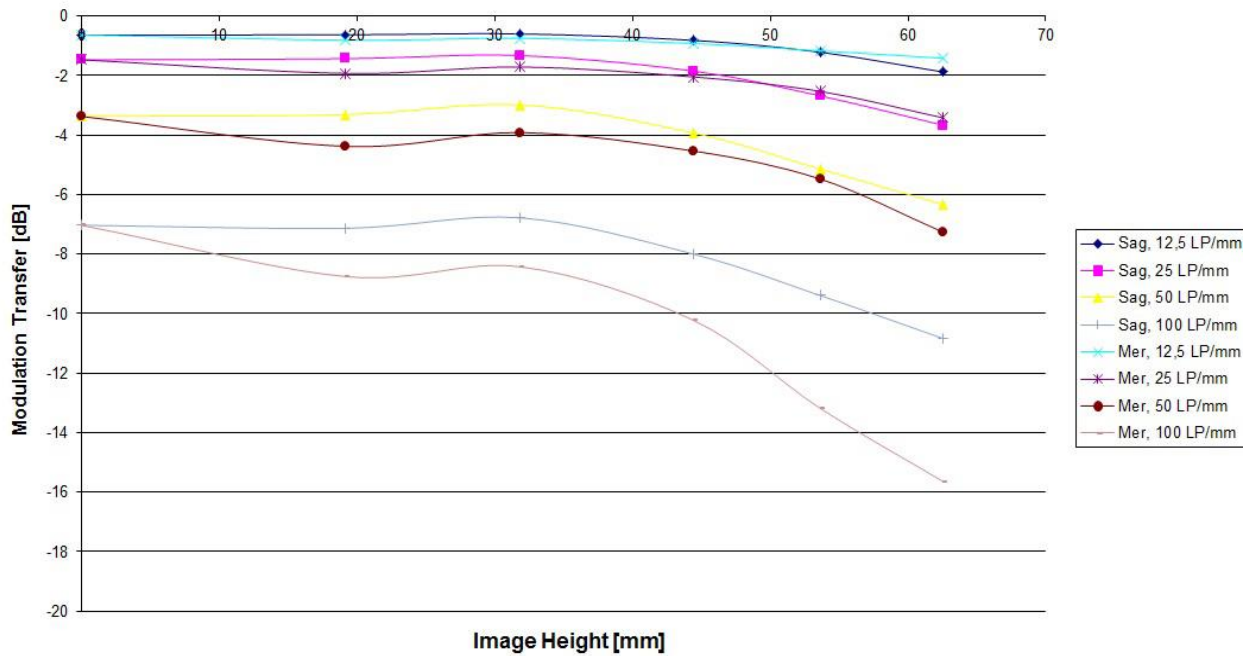
Cone	Lens
C0	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C1	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C2	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C3	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C4 (RED)	Linos Vexcel Apo-Sironar Digital HR 1:4/33mm, Linos GmbH, Germany
C5 (GREEN)	Linos Vexcel Apo-Sironar Digital HR 1:4/33mm, Linos GmbH, Germany
C6 (BLUE)	Linos Vexcel Apo-Sironar Digital HR 1:4/33mm, Linos GmbH, Germany
C7 (NIR)	Linos Vexcel Apo-Sironar Digital HR 1:4/33mm, Linos GmbH, Germany



Modulation versus Image Height - Aperture f / 5.6

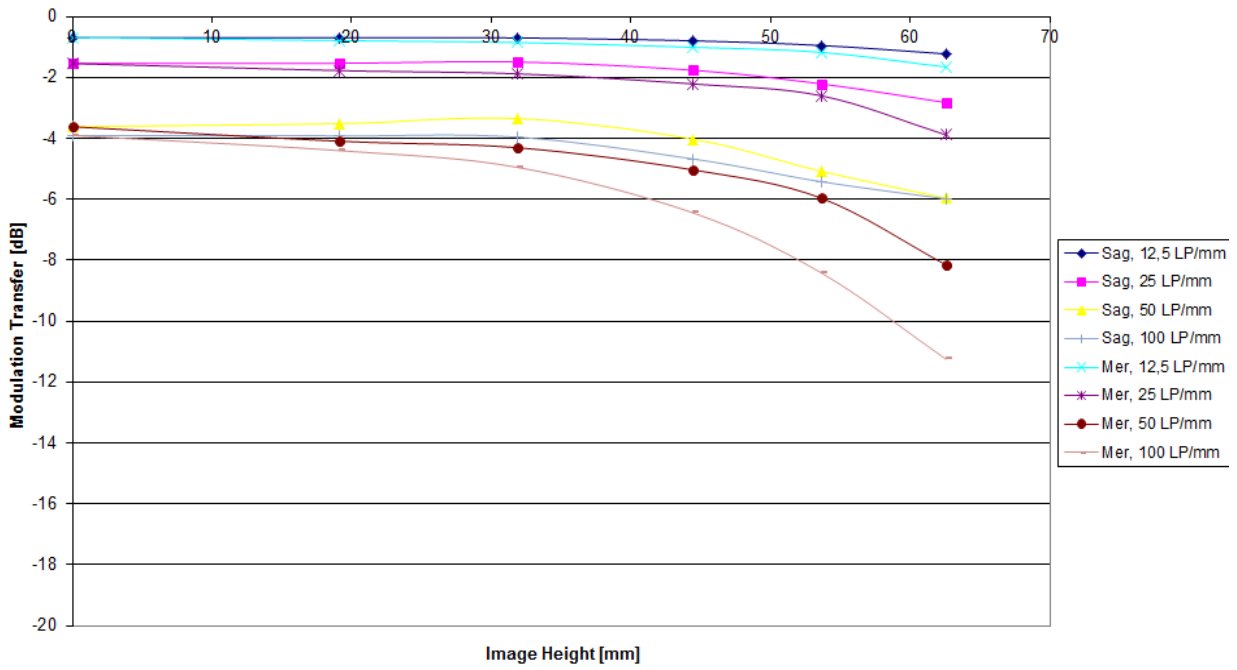


Modulation versus Image Height - Aperture f / 6.7

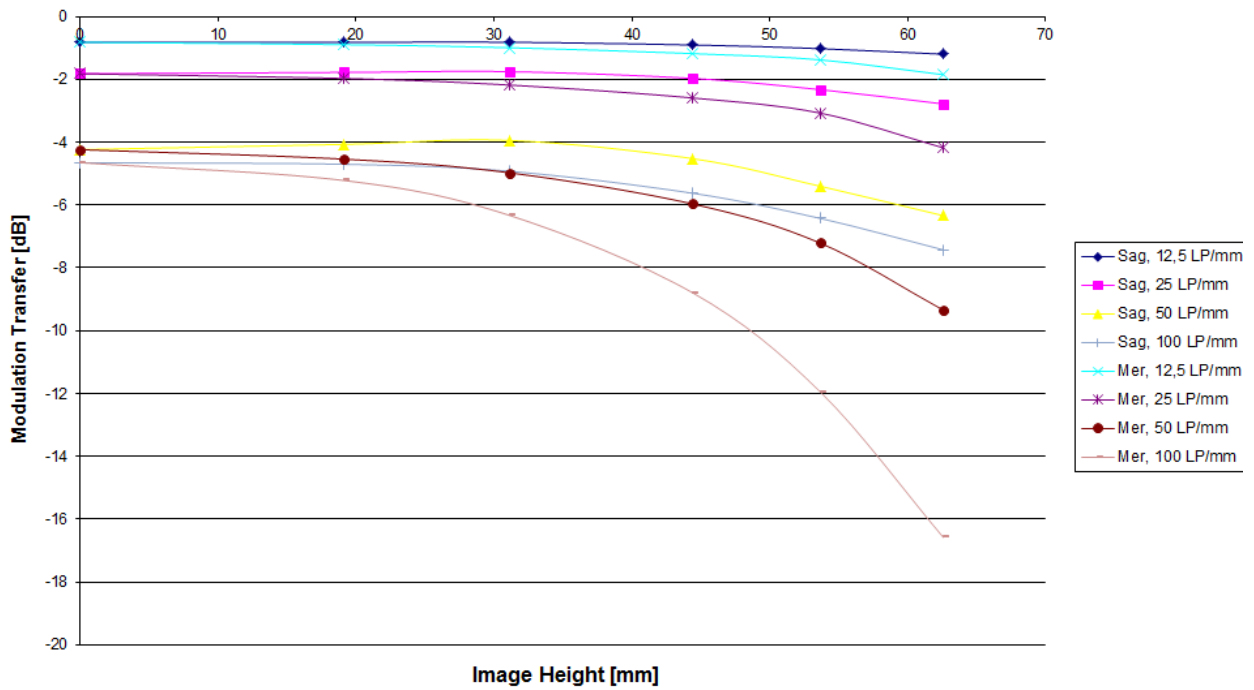




Modulation versus Image Height - Aperture f / 8



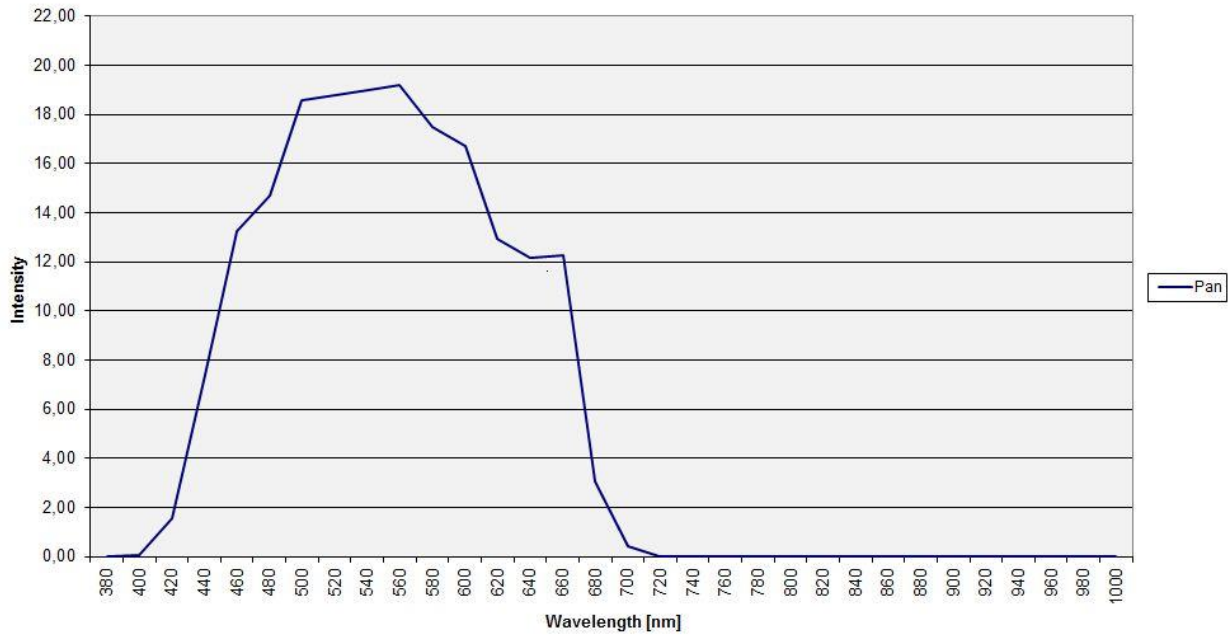
Modulation versus Image Height - Aperture f / 9.5



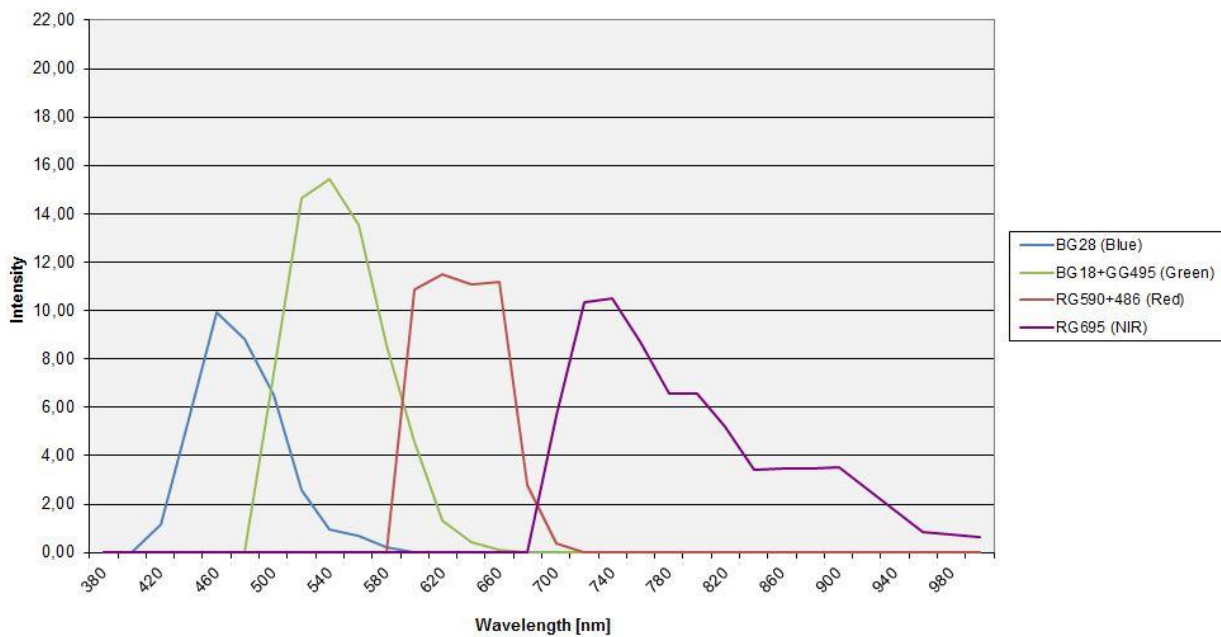


# Spectral Sensitivity

Spectral Sensitivity Vexcel UCX - Panchromatic with AR-106 Coating



Spektral Sensitivity Vexcel UCX - Multispectral with AR-106 Coating





# ULTRACAM

## Radiometric Calibration

Camera: UltraCam Falcon Prime  
Serial: UC-Fp-1-00610270-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

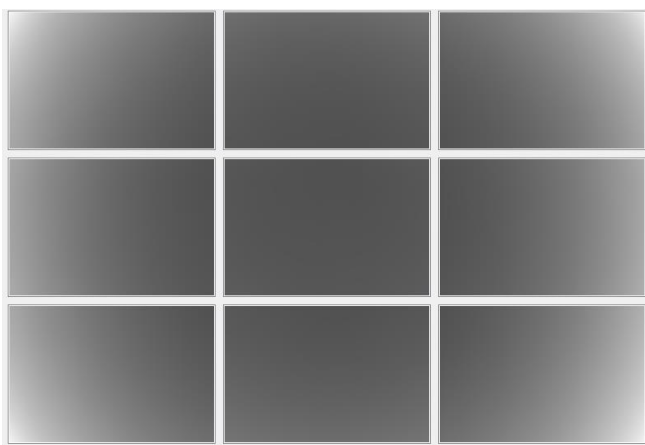
Dead Pixel Report: see Appendix I



## Calibration of Vignetting for working Aperture F6.7

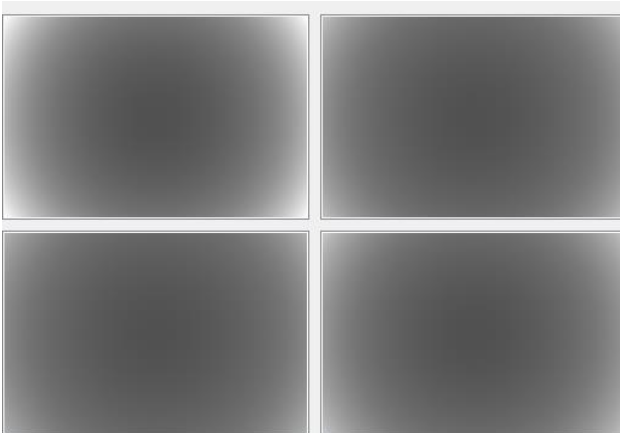
	PAN	R, G, NIR	B
Aperture	F6.7	F5.6	F4.8

### 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)





## 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 Falcon Prime  
**Serial:** UC-Fp-1-00610270-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 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 30 46 34	6.66	6.71	6.71	6.83	7	7.23	7.39	7.41	+/- 0.2
C1 (Pan)	12 30 46 37	6.93	7.09	7.16	7.41	7.74	7.78	8.05	8.08	+/- 0.2
C2 (Pan)	12 27 38 53	6.82	6.92	6.96	7.18	7.34	7.62	7.81	7.99	+/- 0.2
C3 (Pan)	12 30 46 42	6.97	7	7.31	7.62	7.84	8.05	8.19	8.48	+/- 0.2
C4 (Red)	12 28 26 64	6.81	6.94	7.07	7.28	7.46	7.51	7.55	7.65	+/- 0.2
C5 (Green)	12 28 26 57	7.02	7.06	7.29	7.37	7.65	7.65	7.63	7.79	+/- 0.2
C6 (Blue)	12 28 26 60	7.35	7.36	7.36	7.45	7.62	7.78	8.02	8.19	+/- 0.2
C7 (NIR)	12 28 26 65	7.84	7.96	8.04	8.11	8.5	8.61	8.61	8.37	+/- 0.2



# **ULTRACAM**

## Electronics and Sensor Calibration

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**Camera:** UltraCam Falcon Prime  
**Serial:** UC-Fp-1-00610270-f100

**Panchromatic Camera:** 9 \* FTF6040-M Area CCD Sensor by DALSA  
**Multispectral Camera:** 4 \* FTF6040-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]
00_00	FTF6040-M	15 7701/098	20.90
00_01	FTF6040-M	15 7701/034	22.30
00_02	FTF6040-M	15 7701/086	22.60
00_03	FTF6040-M	15 7701/119	22.50
01_00	FTF6040-M	15 7701/101	22.50
01_01	FTF6040-M	15 7701/122	22.60
02_00	FTF6040-M	15 7701/056	22.30
02_01	FTF6040-M	15 7701/093	22.50
03_00	FTF6040-M	15 7701/103	23.10
04_00 (red)	FTF6040-M	15 7701/085	22.60
05_00 (green)	FTF6040-M	15 7701/088	22.50
06_00 (blue)	FTF6040-M	15 7701/039	22.50
07_00 (NIR)	FTF6040-M	15 7701/092	22.50



## 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]
00_00	FTF6040-M	15 7701/098	13490
00_01	FTF6040-M	15 7701/034	14060
00_02	FTF6040-M	15 7701/086	13290
00_03	FTF6040-M	15 7701/119	13440
01_00	FTF6040-M	15 7701/101	13480
01_01	FTF6040-M	15 7701/122	13270
02_00	FTF6040-M	15 7701/056	12670
02_01	FTF6040-M	15 7701/093	13400
03_00	FTF6040-M	15 7701/103	12670
04_00 (red)	FTF6040-M	15 7701/085	13420
05_00 (green)	FTF6040-M	15 7701/088	13650
06_00 (blue)	FTF6040-M	15 7701/039	13520
07_00 (NIR)	FTF6040-M	15 7701/092	13360



# ULTRACAM

## Summary

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<b>Camera:</b>	<b>UltraCam Falcon Prime</b>
<b>Serial:</b>	<b>UC-Fp-1-00610270-f100</b>
<b>Laboratory Calibration Date:</b>	<b>Mar-30-2022</b>
<b>Camera Revision:</b>	<b>Rev05.00</b>
<b>Date of Report:</b>	<b>Apr-05-2022</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.

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
C00-00			
	PIXEL: 1796/ 240	PIXEL: 3511/ 685	PIXEL: 3244/ 972
	PIXEL: 4649/1181	PIXEL: 1662/1234	PIXEL: 279/1783
	PIXEL: 2898/2228	PIXEL: 5387/2359	PIXEL: 2498/1049
	PIXEL: 2499/1050	PIXEL: 3384/3209	PIXEL: 3385/3209
C00-01			
	PIXEL: 3396/ 944	PIXEL: 2542/1451	PIXEL: 2197/2059
	PIXEL: 5364/2500	PIXEL: 2317/3562	PIXEL: 2542/3925
	PIXEL: 941/ 54	PIXEL: 986/1615	PIXEL: 855/2291
	PIXEL: 5362/3239		PIXEL: 5332/3257
C00-02			
	PIXEL: 5463/ 62		
	PIXEL: 4621/ 301	PIXEL: 4673/ 352	PIXEL: 3167/ 660
	PIXEL: 3521/ 769	PIXEL: 3892/ 852	PIXEL: 3577/1212
	PIXEL: 482/1793	PIXEL: 2955/1916	PIXEL: 2464/2450
	PIXEL: 4971/2814	PIXEL: 1179/3080	PIXEL: 3034/3625
	PIXEL: 1838/3831	PIXEL: 5018/2497	PIXEL: 5659/3611
C00-03			
	PIXEL: 891/ 849	PIXEL: 1099/3837	PIXEL: 1100/3837
	PIXEL: 240/3835		
C01-00			
	PIXEL: 1892/ 61		
	PIXEL: 5237/ 97	PIXEL: 3369/ 272	PIXEL: 5995/ 621
	PIXEL: 2098/ 916	PIXEL: 5216/ 994	PIXEL: 3547/1096
	PIXEL: 262/1850	PIXEL: 3193/2103	PIXEL: 4236/2420
	PIXEL: 5534/2734	PIXEL: 5230/2815	PIXEL: 1866/3422
	PIXEL: 3876/ 156		PIXEL: 1708/ 709
			PIXEL: 4828/1627
			PIXEL: 3203/2693
			PIXEL: 1118/3583
C01-01			
	PIXEL: 5392/2763		
	PIXEL: 5685/1300	PIXEL: 5745/3259	



C02-00

PIXEL: 4697/ 130	PIXEL: 1657/ 228	PIXEL: 2139/ 331	PIXEL: 3268/ 963
PIXEL: 1814/1163	PIXEL: 4737/1351	PIXEL: 5818/1443	PIXEL: 2843/1869
PIXEL: 1936/1978	PIXEL: 3368/2120	PIXEL: 3368/2180	PIXEL: 963/2328
PIXEL: 2871/2826	PIXEL: 2780/2888	PIXEL: 2063/3094	PIXEL: 5167/3137
PIXEL: 4549/3169	PIXEL: 3368/3638	PIXEL: 4351/2051	PIXEL: 434/3958
PIXEL: 434/3959			

C02-01

PIXEL: 3424/ 123			
PIXEL: 5932/1812	PIXEL: 2326/2293	PIXEL: 1209/2808	PIXEL: 2698/2820
PIXEL: 1126/2905	PIXEL: 5262/2956	PIXEL: 1224/1574	

C03-00

PIXEL: 2665/ 252	PIXEL: 4887/ 915	PIXEL: 915/1332	
PIXEL: 5030/1461	PIXEL: 1101/1674	PIXEL: 4475/2094	PIXEL: 2804/2157
PIXEL: 5117/2257	PIXEL: 3255/2380	PIXEL: 4201/2397	PIXEL: 871/2524
PIXEL: 4976/2546	PIXEL: 250/2610	PIXEL: 4553/2763	PIXEL: 2391/2962
PIXEL: 722/2975	PIXEL: 3321/3209	PIXEL: 2859/3230	PIXEL: 1535/3413
PIXEL: 5267/3609	PIXEL: 2830/3859	PIXEL: 2803/3866	PIXEL: 1737/1777
PIXEL: 4076/2629	PIXEL: 2847/3513		

C04-00

PIXEL: 3108/ 113	PIXEL: 5265/ 773	PIXEL: 5404/ 993	PIXEL: 163/1525
PIXEL: 2781/1760	PIXEL: 812/2667	PIXEL: 1195/3609	PIXEL: 5995/ 537
PIXEL: 675/1842	PIXEL: 675/1843	PIXEL: 248/2286	PIXEL: 5109/2877
PIXEL: 5110/2877	PIXEL: 5110/2878		

C05-00

PIXEL: 5283/ 430	PIXEL: 5153/ 716	PIXEL: 5154/ 716	PIXEL: 807/ 929
PIXEL: 5986/1417	PIXEL: 772/1713	PIXEL: 4856/1879	PIXEL: 5790/2592

C06-00

PIXEL: 5561/ 230	PIXEL: 3318/ 678		
PIXEL: 3031/2697	PIXEL: 4384/2890	PIXEL: 931/3527	PIXEL: 708/ 227
PIXEL: 709/ 227	PIXEL: 5629/3965		

C07-00

PIXEL: 1368/ 179	PIXEL: 272/ 289	PIXEL: 5164/1928	PIXEL: 4178/2325
PIXEL: 5014/2419	PIXEL: 2740/2595	PIXEL: 196/2630	PIXEL: 197/2630
PIXEL: 197/2631	PIXEL: 1165/2902	PIXEL: 4297/3141	PIXEL: 1939/3763

**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	30.Mar.2022		
Radiometric Calibration	30.Mar.2022		
Shutter Calibration	30.Mar.2022		
Electronics and Sensor Calibration	30.Mar.2022		

**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.