



ULTRACAM

Calibration Report



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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 Falcon Prime
Serial: UC-Fp-1-20519084-f100

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

PPA Information: X: 0.000
Y: 0.000



Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track cross track	67.860mm 103.860mm	11310pixel 17310pixel
Image Extent		(-33.930, -51.930)mm	(33.930, 51.930)mm
Pixel Size		6.000µm*6.000µm	
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		

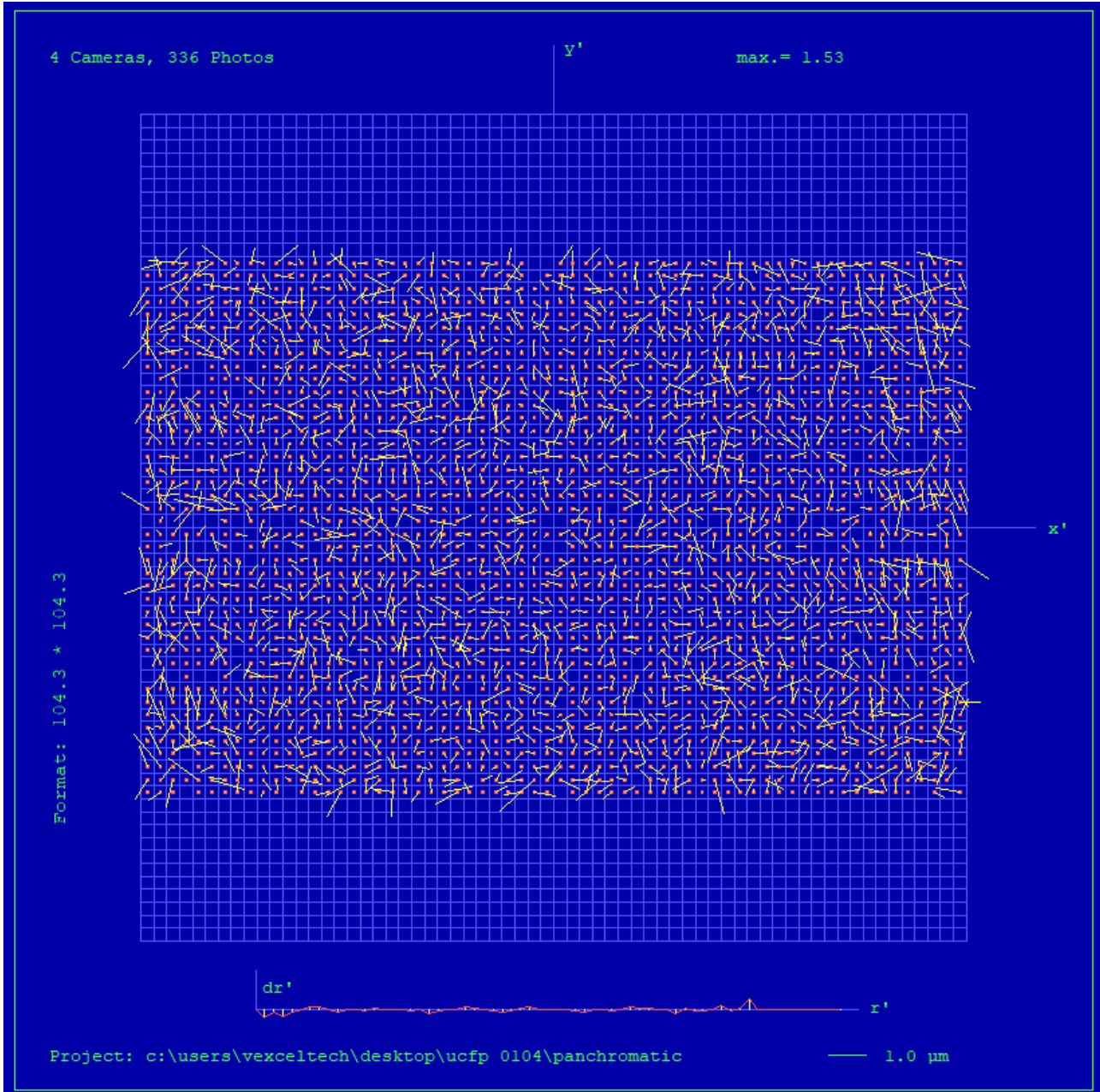
Multispectral Camera

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

Image Format	long track cross track	67.860mm 103.860mm	3770pixel 5770pixel
Image Extent		(-33.930, -51.930)mm	(33.930, 51.930)mm
Pixel Size		18.000µm*18.000µm	
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		



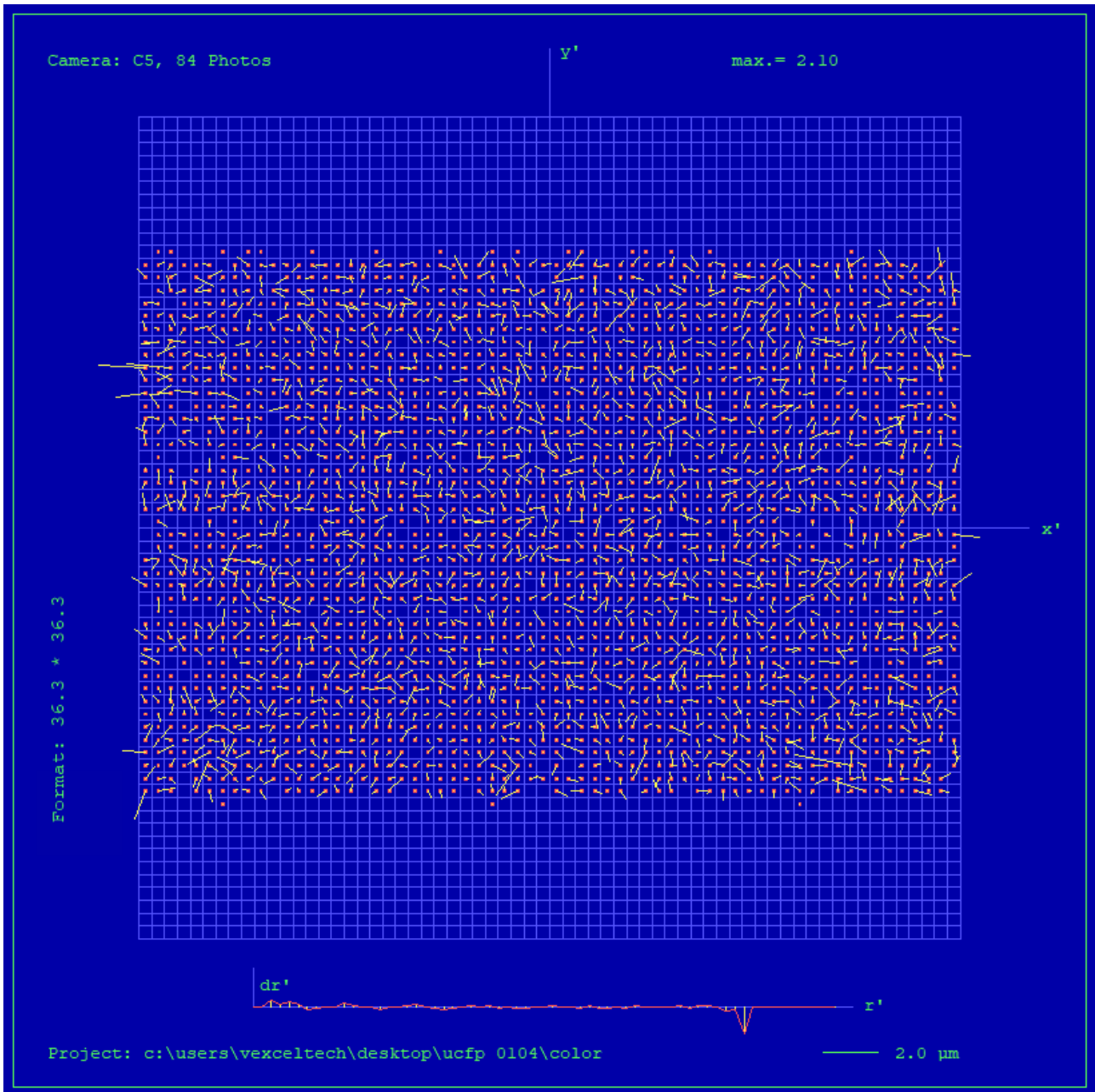
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.81 μm**



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.73 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

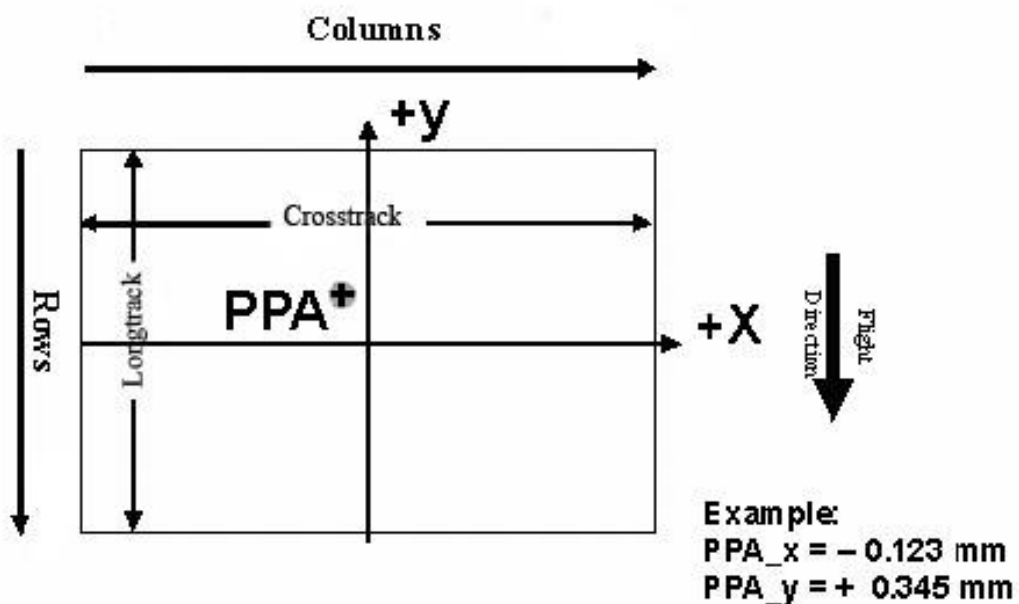
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

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

Level 2 Image Coordinate System:

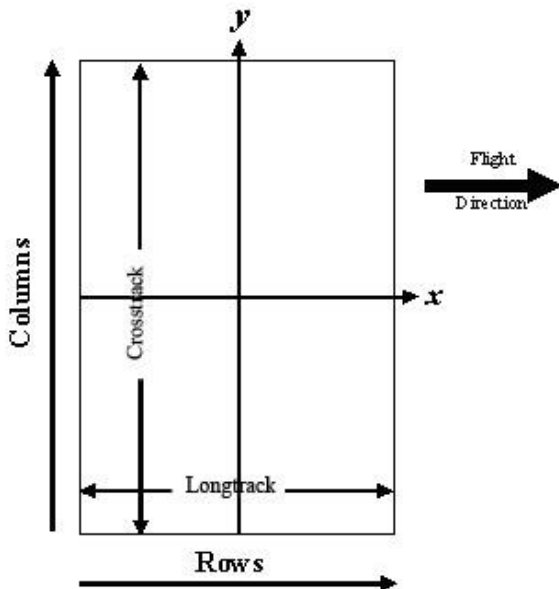
Lvl2, Camera prop. Orientation



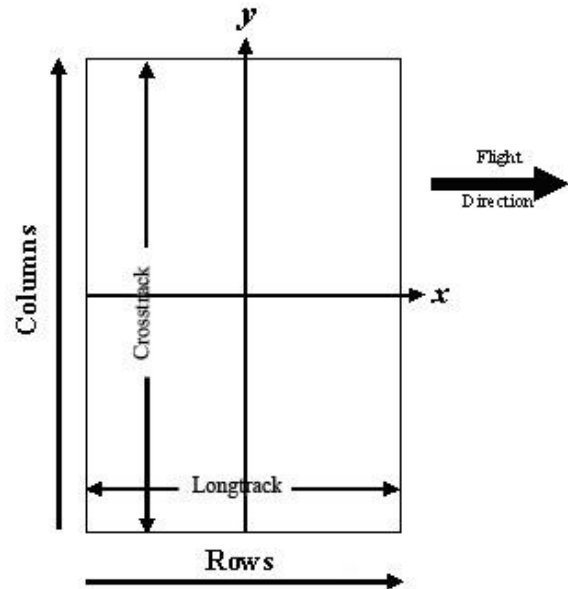
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



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



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

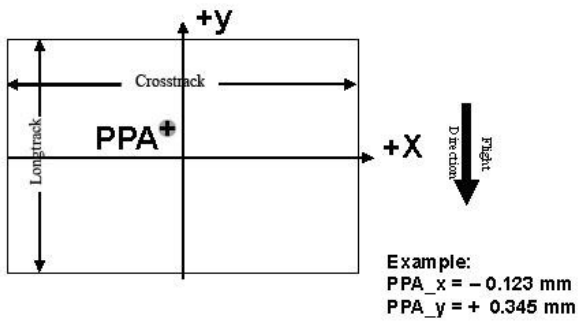
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified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

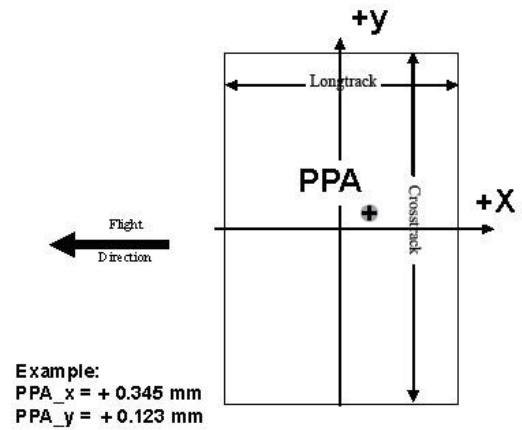


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

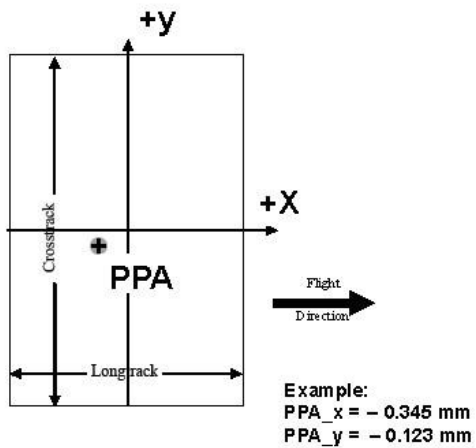
Lvl3, Rotation 0 deg clockwise



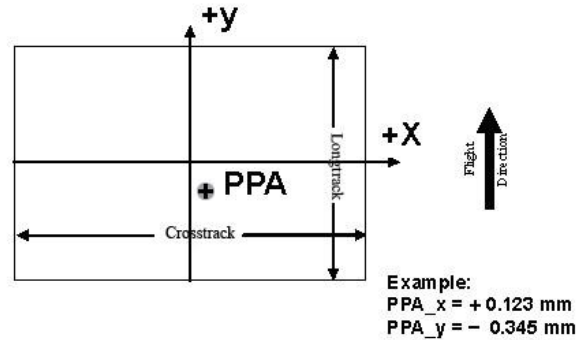
Lvl3, Rotation 90 deg clockwise



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

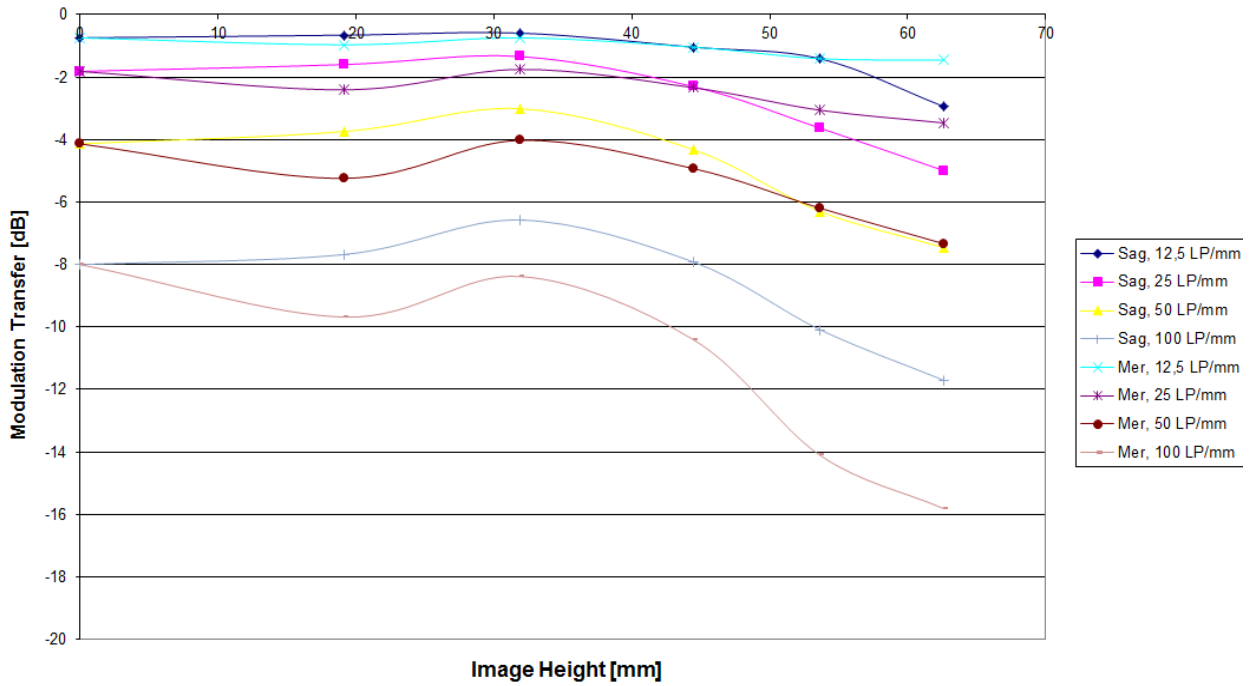
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

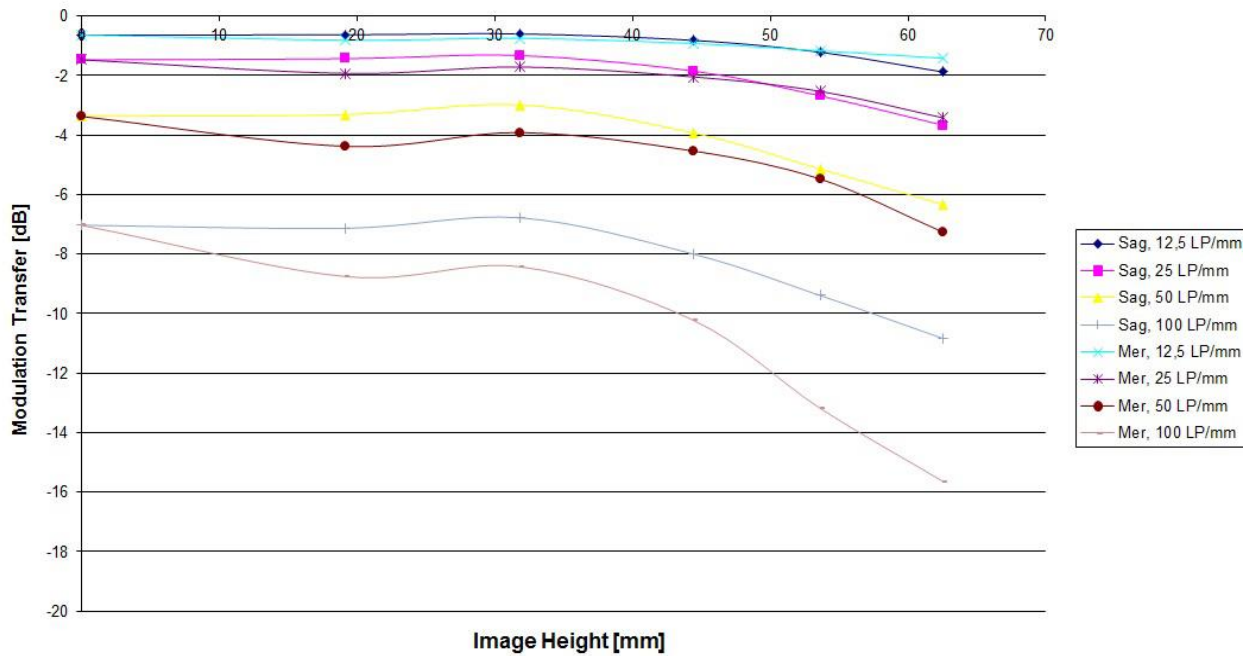
Cone	Lens
C0	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C1	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C2	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C3	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C4 (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

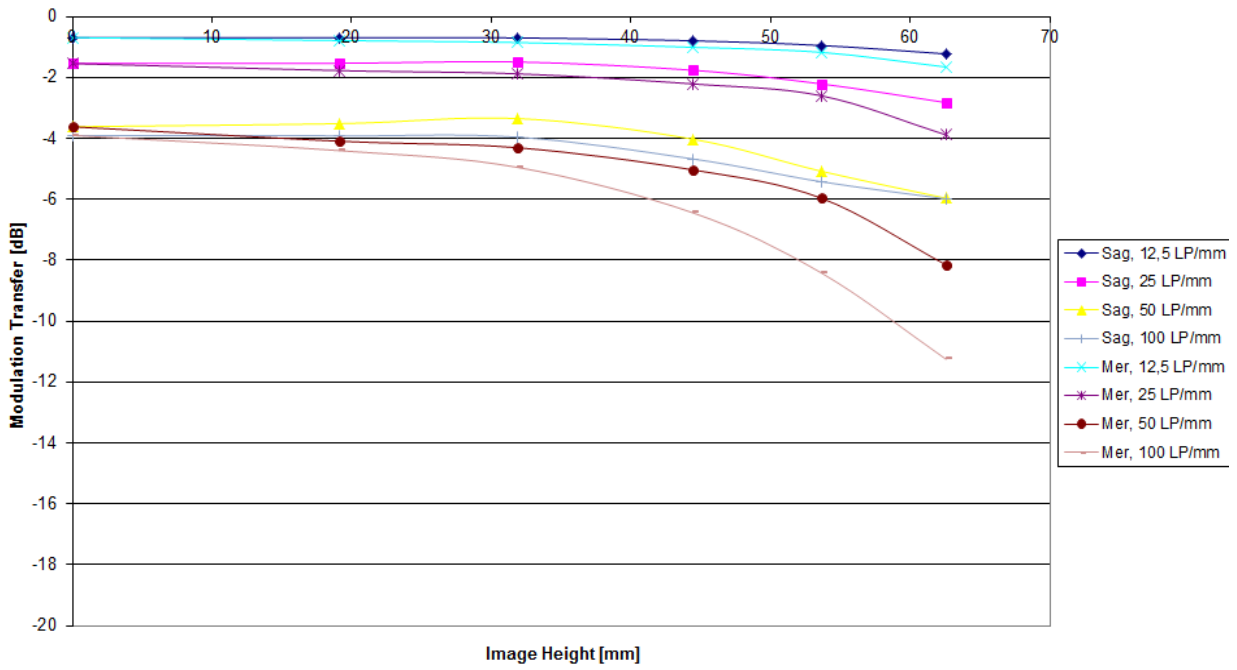


Modulation versus Image Height - Aperture f / 6.7

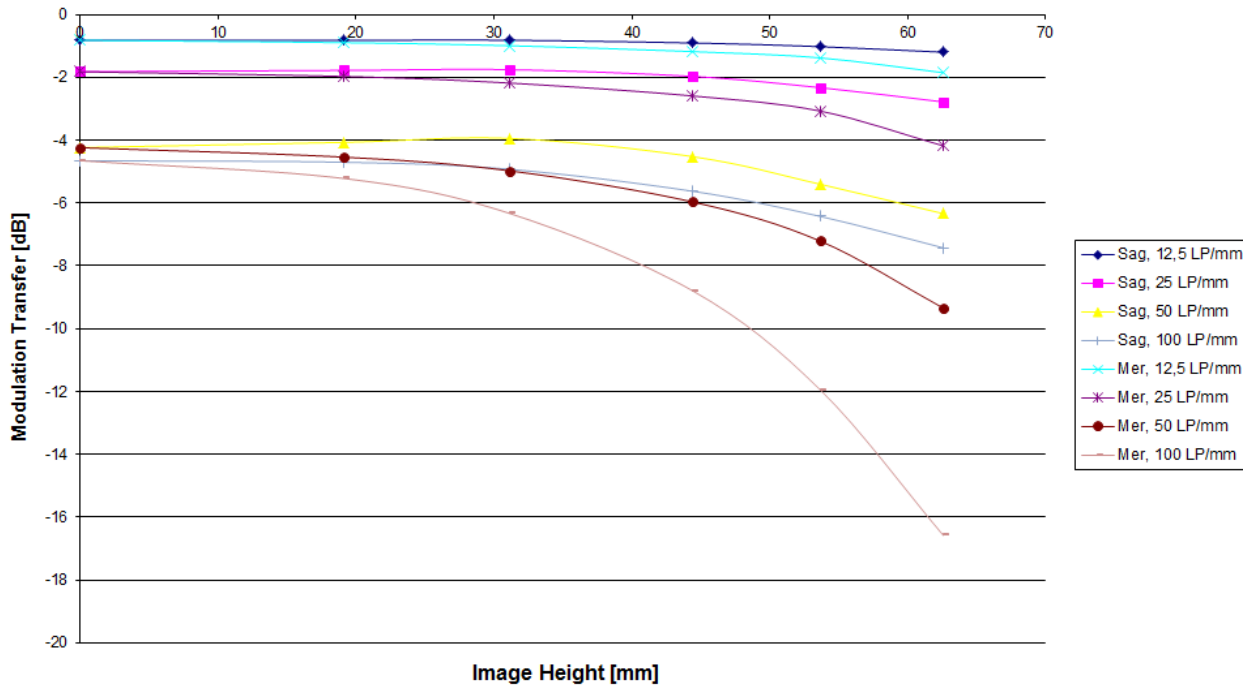




Modulation versus Image Height - Aperture f / 8



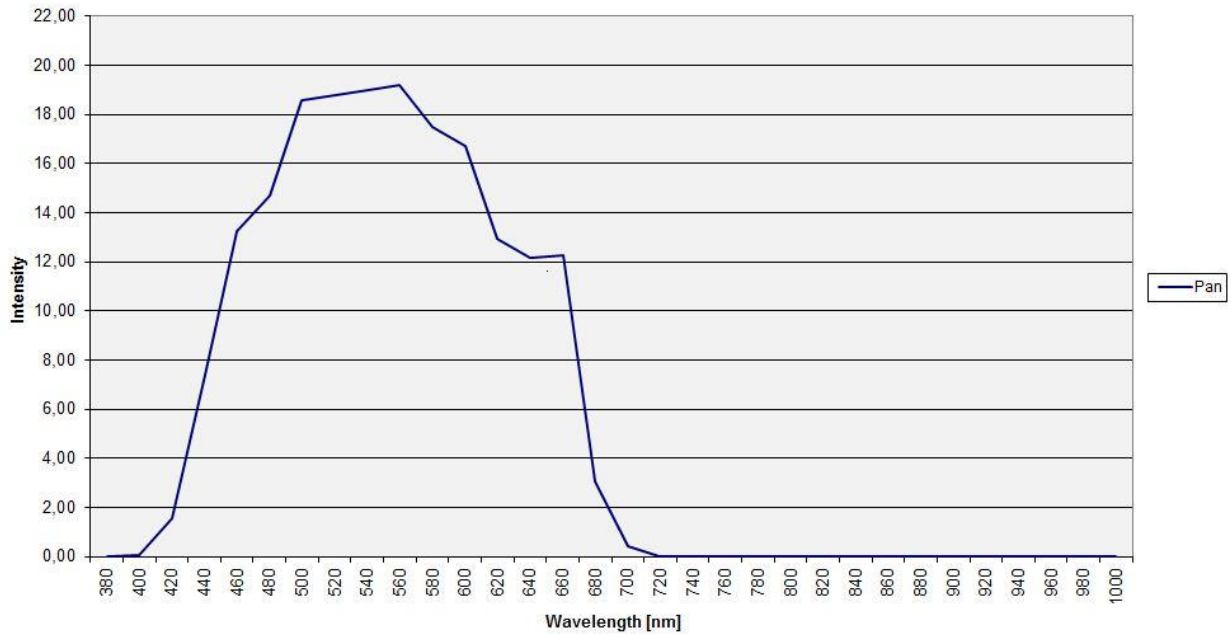
Modulation versus Image Height - Aperture f / 9.5



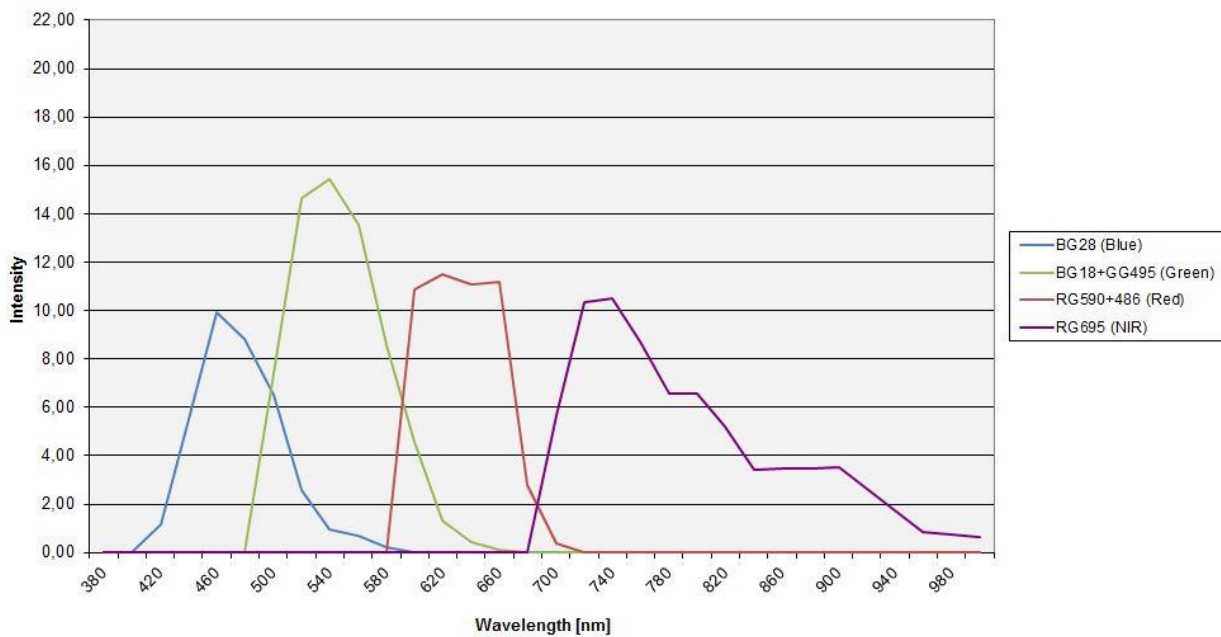


Spectral Sensitivity

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-1-20519084-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

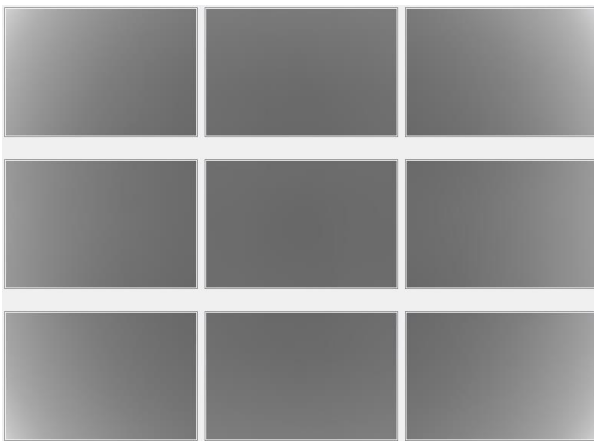
Dead Pixel Report: see Appendix I



Calibration of Vignetting for working Aperture F6.7

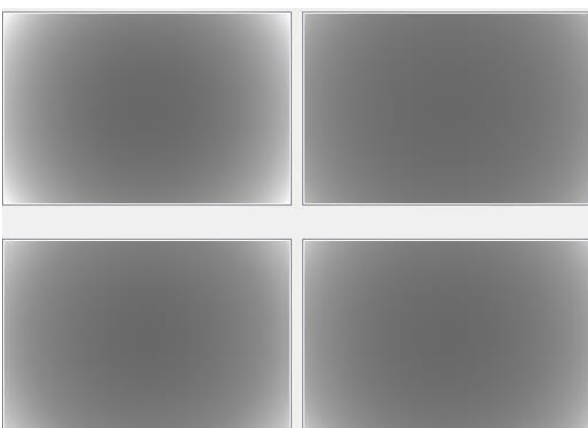
	PAN	R, G, NIR	B
Aperture	F6.7	F5.6	F4.8

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

Camera: UltraCam Falcon Prime
Serial: UC-Fp-1-20519084-f100

Panchromatic Camera: 4 * Prontor Magnetic 0
Prontor-Werk Alfred Gauthier GmbH, Germany

Multispectral Camera: 4 * Prontor Magnetic 0
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 13 49 35	11.13	11.21	11.77	12.11	12.47	12.80	13.18	13.49	+/- 0.2
C1 (Pan)	12 13 00 84	10.87	11.22	11.68	12.09	12.55	12.76	13.01	13.29	+/- 0.2
C2 (Pan)	12 13 00 79	11.79	12.17	12.34	12.80	13.18	13.34	13.81	14.13	+/- 0.2
C3 (Pan)	12 13 00 86	9.98	10.21	10.78	11.25	11.75	12.01	12.27	12.43	+/- 0.2
C4 (Red)	12 13 00 96	12.32	12.41	12.82	13.12	13.34	13.55	13.63	13.83	+/- 0.2
C5 (Green)	12 13 00 91	11.15	11.34	11.65	11.90	12.15	12.32	12.46	12.59	+/- 0.2
C6 (Blue)	12 13 00 94	11.06	11.09	11.11	11.59	11.88	12.25	12.46	12.71	+/- 0.2
C7 (NIR)	12 13 00 93	11.32	11.56	11.83	11.95	12.08	12.30	12.54	12.54	+/- 0.2



ULTRACAM

Electronics and Sensor Calibration

Camera: UltraCam Falcon Prime
Serial: UC-Fp-1-20519084-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	14 3859/056	22.50
00_01	FTF6040-M	14 3859/053	22.80
00_02	FTF6040-M	14 3859/046	22.60
00_03	FTF6040-M	14 3859/051	22.60
01_00	FTF6040-M	14 3859/043	22.60
01_01	FTF6040-M	14 3859/042	22.60
02_00	FTF6040-M	14 3859/006	22.60
02_01	FTF6040-M	14 3859/014	22.50
03_00	FTF6040-M	14 4982/023	22.50
04_00 (red)	FTF6040-M	14 3859/058	22.50
05_00 (green)	FTF6040-M	14 892/058	22.30
06_00 (blue)	FTF6040-M	14 2892/061	22.30
07_00 (NIR)	FTF6040-M	14 2892/057	22.10



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	14 3859/056	13930
00_01	FTF6040-M	14 3859/053	13500
00_02	FTF6040-M	14 3859/046	13600
00_03	FTF6040-M	14 3859/051	13030
01_00	FTF6040-M	14 3859/043	13830
01_01	FTF6040-M	14 3859/042	13680
02_00	FTF6040-M	14 3859/006	13610
02_01	FTF6040-M	14 3859/014	13280
03_00	FTF6040-M	14 4982/023	13090
04_00 (red)	FTF6040-M	14 3859/058	13630
05_00 (green)	FTF6040-M	14 892/058	13460
06_00 (blue)	FTF6040-M	14 2892/061	13460
07_00 (NIR)	FTF6040-M	14 2892/057	13710



ULTRACAM

Summary

Camera: UltraCam Falcon Prime
Serial: UC-Fp-1-20519084-f100

Laboratory Calibration Date: SEP-18-2023
Camera Revision: Rev09.00

Date of Report: SEP-25-2023
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.

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: 1698/3165	PIXEL: 811/3399	PIXEL: 5937/2474
C00-01	PIXEL: 416/2185 PIXEL: 5547/2251 PIXEL: 5288/3642	PIXEL: 4320/2211 PIXEL: 2012/2433 PIXEL: 728/3995	PIXEL: 1157/3102 PIXEL: 5939/3603
C00-02	PIXEL: 1939/ 138 PIXEL: 5124/2252 PIXEL: 3202/3782	PIXEL: 294/ 544 PIXEL: 358/2540 PIXEL: 1768/3945	PIXEL: 5475/1122 PIXEL: 4939/2752 PIXEL: 1769/3945 PIXEL: 1116/2159 PIXEL: 1635/2829 PIXEL: 1768/3944
C00-03	PIXEL: 2726/ 657 PIXEL: 2740/1101 PIXEL: 3925/2602 PIXEL: 4747/3717 PIXEL: 604/3700 PIXEL: 1309/3919	PIXEL: 2274/ 839 PIXEL: 2333/1308 PIXEL: 3061/3045 PIXEL: 440/ 288 PIXEL: 4264/3703 PIXEL: 443/3956	PIXEL: 5808/1693 PIXEL: 4072/3283 PIXEL: 5460/1324 PIXEL: 559/3745 PIXEL: 2572/2346 PIXEL: 2496/3680 PIXEL: 846/3639 PIXEL: 254/3798
C01-00	PIXEL: 3184/ 35 PIXEL: 2056/1428 PIXEL: 5448/2546 PIXEL: 670/3851	PIXEL: 1062/ 104 PIXEL: 1552/1539 PIXEL: 4592/3064 PIXEL: 345/3992	PIXEL: 2084/ 647 PIXEL: 3620/1672 PIXEL: 2501/3638 PIXEL: 182/3938 PIXEL: 5225/ 895 PIXEL: 2524/2364 PIXEL: 3000/3731
C01-01	PIXEL: 5363/ 663	PIXEL: 3993/ 834	PIXEL: 101/3987
C02-00	PIXEL: 4080/ 26 PIXEL: 3494/ 681 PIXEL: 5354/1830 PIXEL: 241/2686 PIXEL: 4002/ 369	PIXEL: 2479/ 549 PIXEL: 447/ 809 PIXEL: 4862/1926 PIXEL: 5089/3330	PIXEL: 4827/1032 PIXEL: 2818/2421 PIXEL: 3003/3707 PIXEL: 5509/1097 PIXEL: 1335/2548 PIXEL: 2587/3970



C02-01

PIXEL: 3151/1045			
PIXEL: 591/1310	PIXEL: 189/1735	PIXEL: 1517/1742	PIXEL: 1116/1760
PIXEL: 4220/2186	PIXEL: 1435/2750	PIXEL: 1420/3336	PIXEL: 3208/3467
PIXEL: 3652/ 410	PIXEL: 2294/1125	PIXEL: 4872/2840	PIXEL: 3092/2944

C03-00

PIXEL: 2099/ 217	PIXEL: 3588/ 533		
PIXEL: 3594/ 967	PIXEL: 820/1257	PIXEL: 113/2465	PIXEL: 1665/2735
PIXEL: 1300/2851	PIXEL: 5541/3662	PIXEL: 5208/3748	PIXEL: 2272/3842
PIXEL: 2272/3843	PIXEL: 2271/3845	PIXEL: 2270/3847	PIXEL: 2269/3849
PIXEL: 2269/3850	PIXEL: 752/3972	PIXEL: 894/ 207	PIXEL: 895/ 207
PIXEL: 3166/1259	PIXEL: 542/1798	PIXEL: 542/1799	

C04-00

PIXEL: 2301/ 662	PIXEL: 2497/2984	PIXEL: 4335/3522	
PIXEL: 853/ 33	PIXEL: 4856/1050	PIXEL: 4857/1050	PIXEL: 4858/1050
PIXEL: 4856/1051	PIXEL: 4857/1051	PIXEL: 5115/2157	PIXEL: 5043/2852
PIXEL: 5044/2852	PIXEL: 5044/2853		

C05-00

PIXEL: 2106/ 330	PIXEL: 5568/1884	PIXEL: 3249/1907	PIXEL: 1075/3316
PIXEL: 258/3636	PIXEL: 826/3943	PIXEL: 5669/2751	

C06-00

PIXEL: 569/ 69	PIXEL: 2587/ 162	PIXEL: 322/ 182	
PIXEL: 2035/1681	PIXEL: 2203/3522	PIXEL: 453/3715	PIXEL: 4941/2523

C07-00

PIXEL: 5224/2009	PIXEL: 5012/2093		
PIXEL: 3083/2569	PIXEL: 1613/2873	PIXEL: 2664/3089	PIXEL: 5161/3396
PIXEL: 2667/3749			

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	Sep.18.2023	N/A	
Radiometric Calibration	Sep.18.2023	N/A	
Shutter Calibration	Sep.18.2023	N/A	
Electronics and Sensor Calibration	Sep.18.2023	N/A	

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.