



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 Eagle M3
Serial: 431S31385X112156-f80

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

PPA Information: X: 0.000 mm
Y: 0.000 mm

Calibration Date: Jan-21-2019
Date of Report: Mar-15-2019
Camera Revision: Rev01.00
Version of Report: V01



Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track cross track	68.016mm 105.840mm	17004pixel 26460pixel
Image Extent		(-34.008, -52.920)mm	(34.008, 52.920)mm
Pixel Size		4.000μm*4.000μm	
Focal Length	ck	79.800mm	± 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		

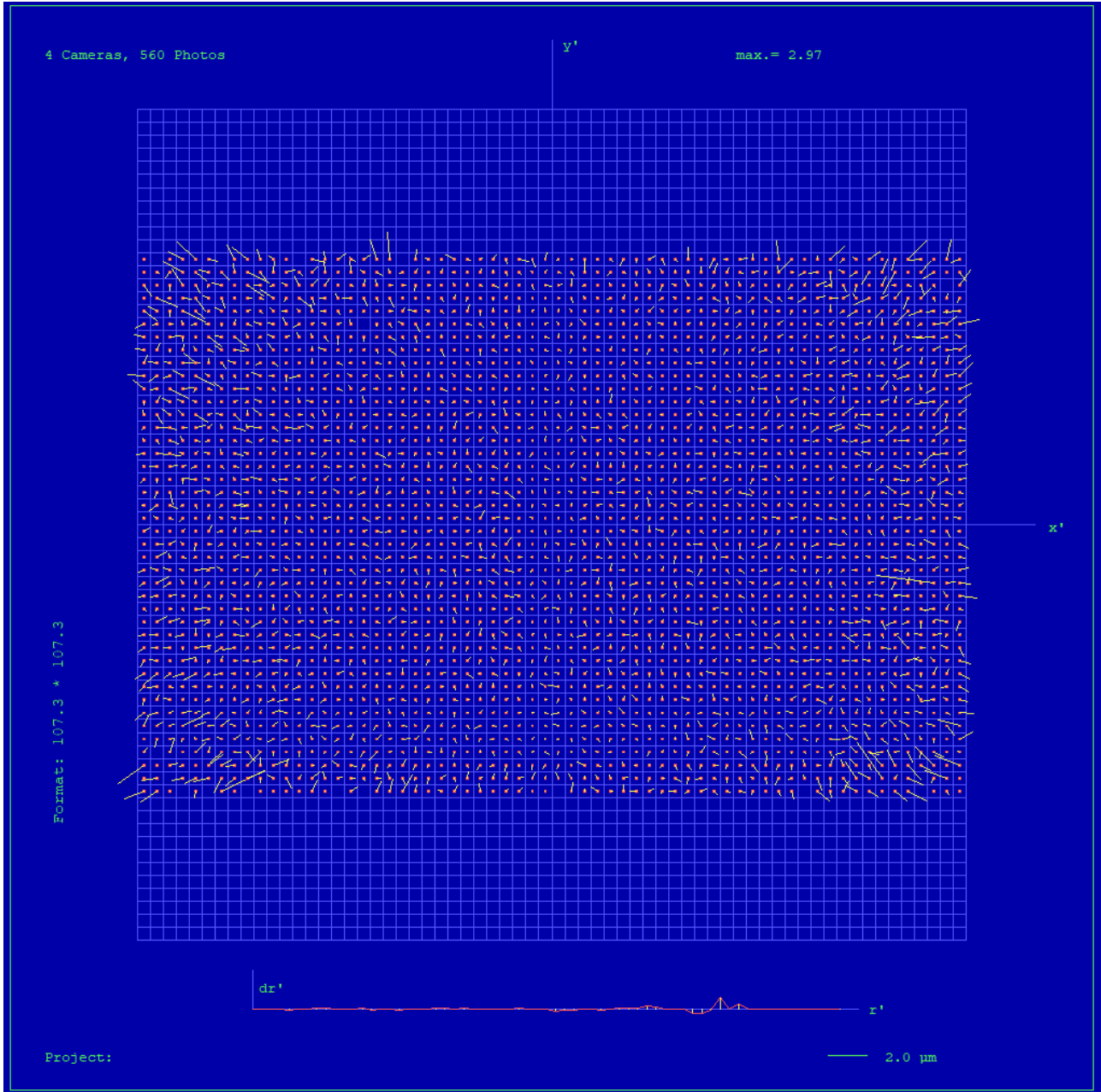
Multispectral Camera

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

Image Format	long track cross track	68.016mm 105.840mm	5668pixel 8820pixel
Image Extent		(-34.008, -52.920)mm	(34.008, 52.920)mm
Pixel Size		12.000μm*12.000μm	
Focal Length	ck	79.800mm	± 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		



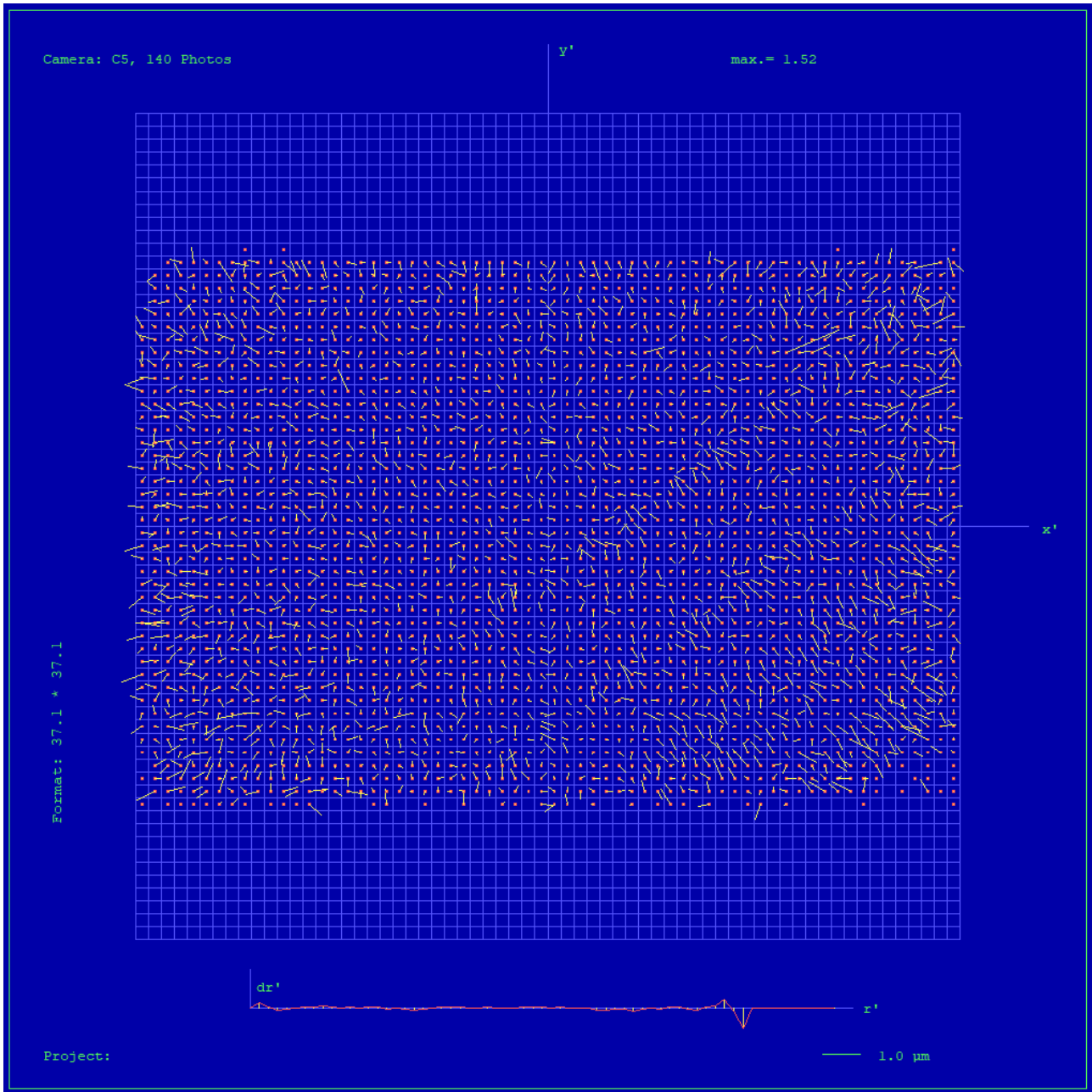
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): 0.61 μm



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.45 μm**



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

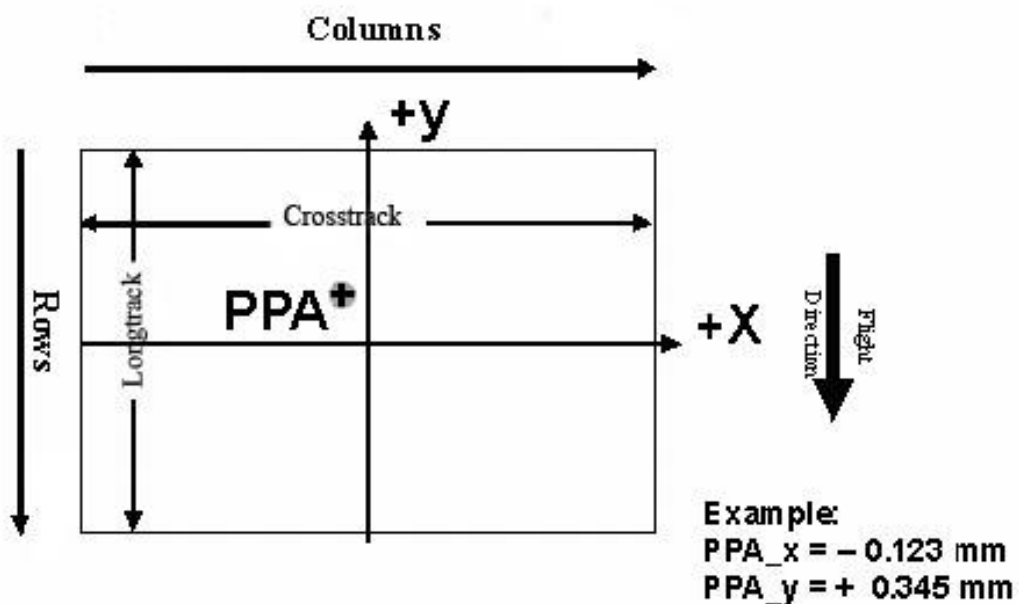
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

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

Level 2 Image Coordinate System:

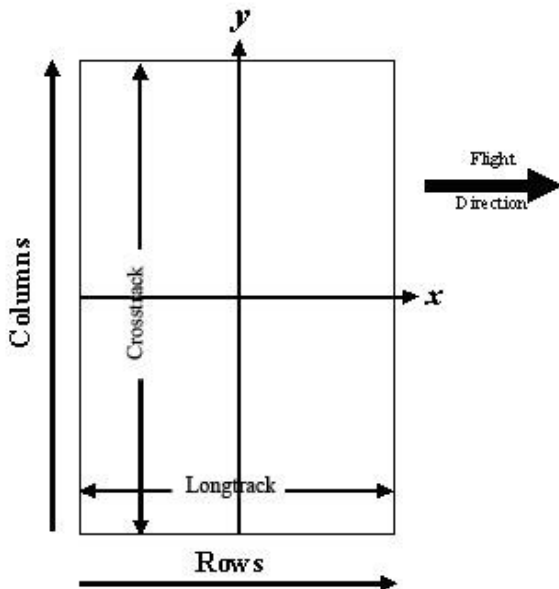
Lvl2, Camera prop. Orientation



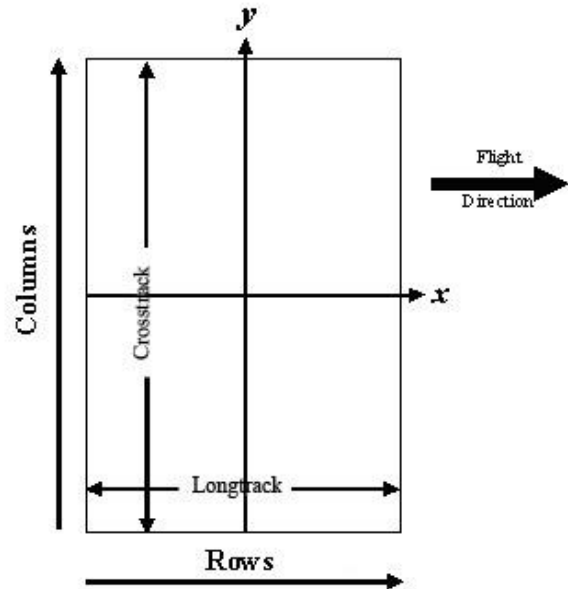
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



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



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

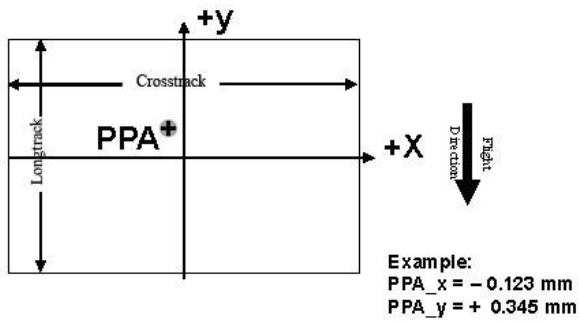
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified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

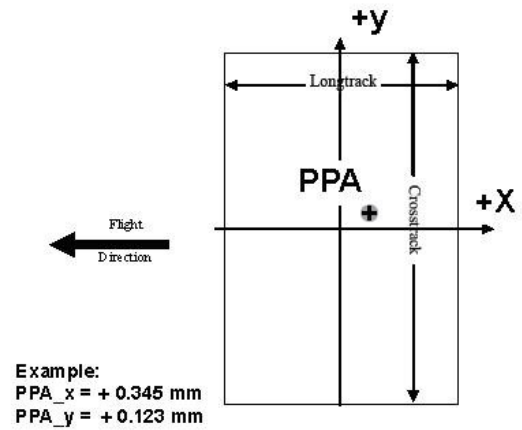


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

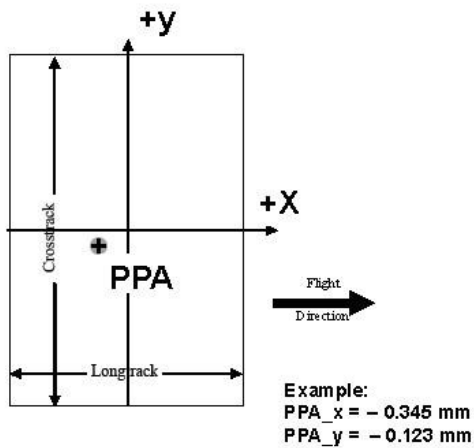
Lvl3, Rotation 0 deg clockwise



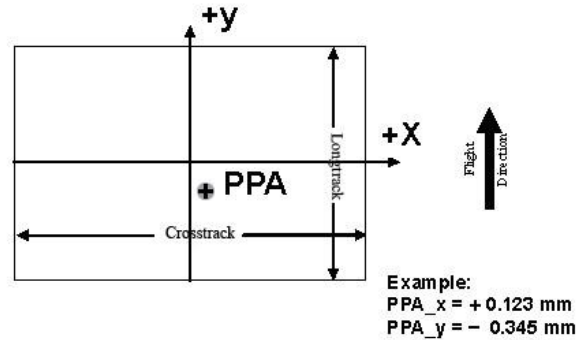
Lvl3, Rotation 90 deg clockwise



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

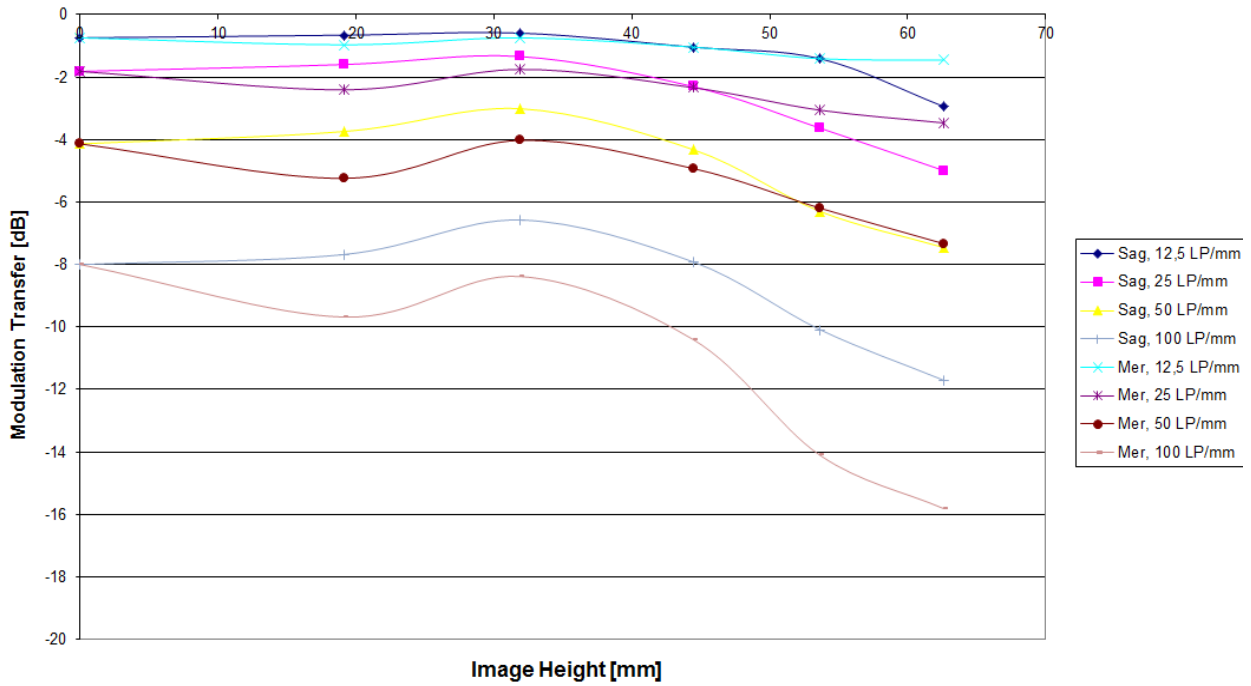
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

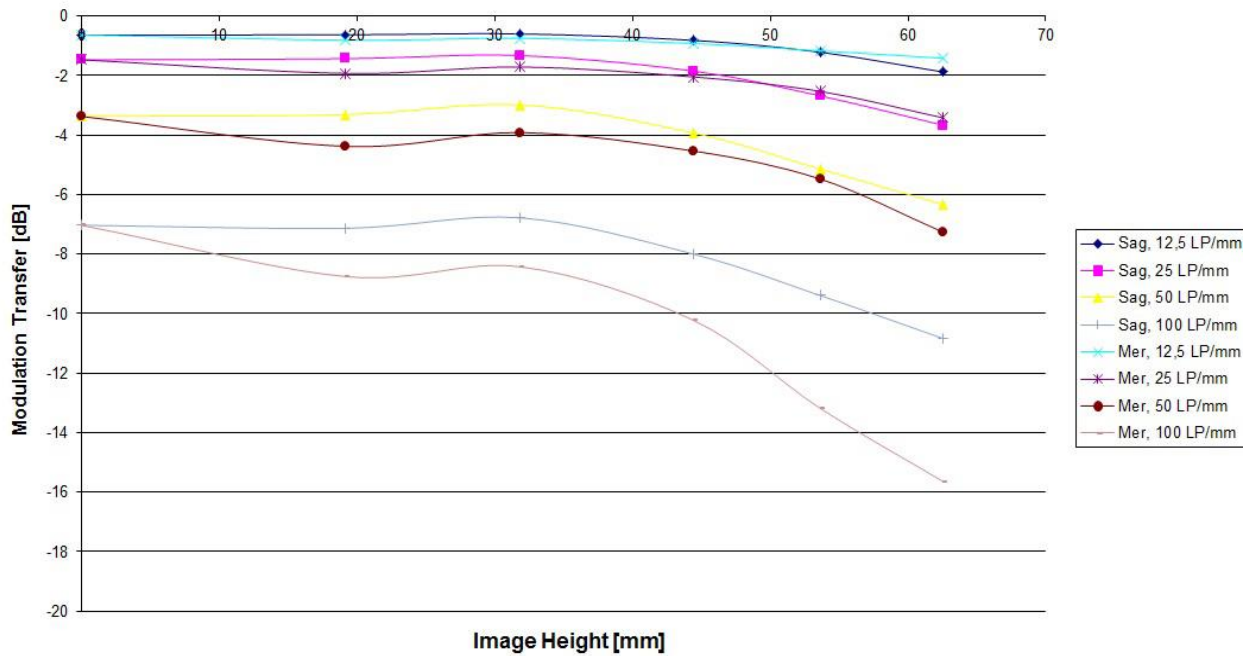
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic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

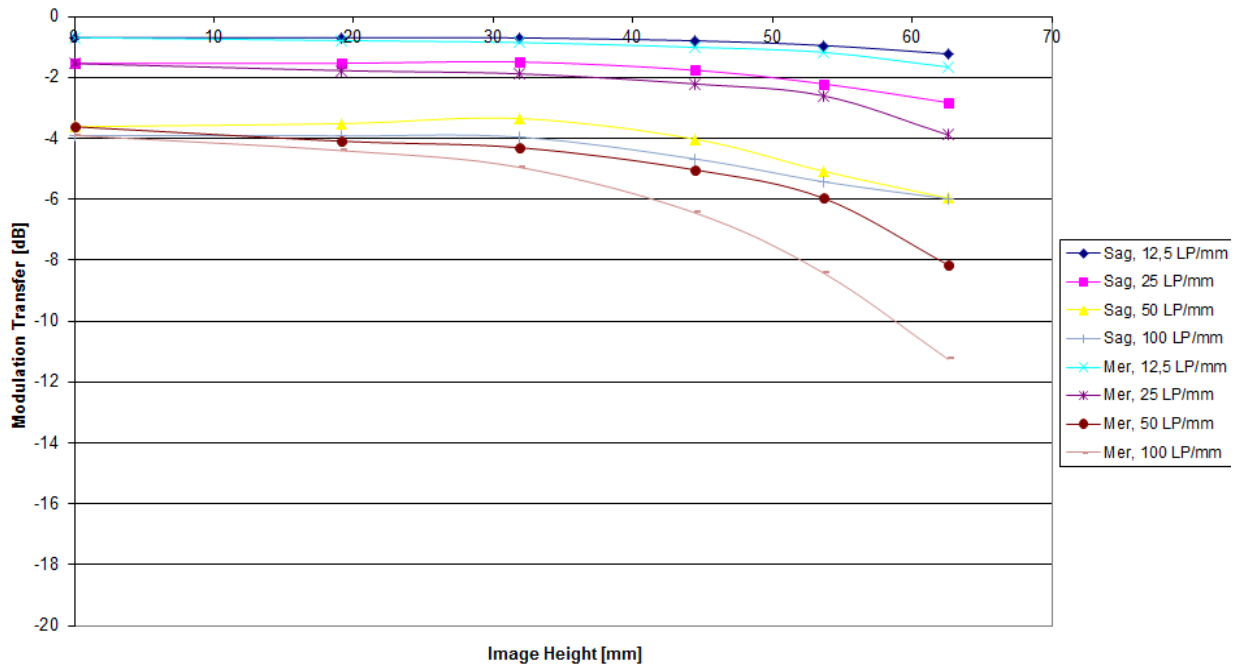


Modulation versus Image Height - Aperture f / 6.7

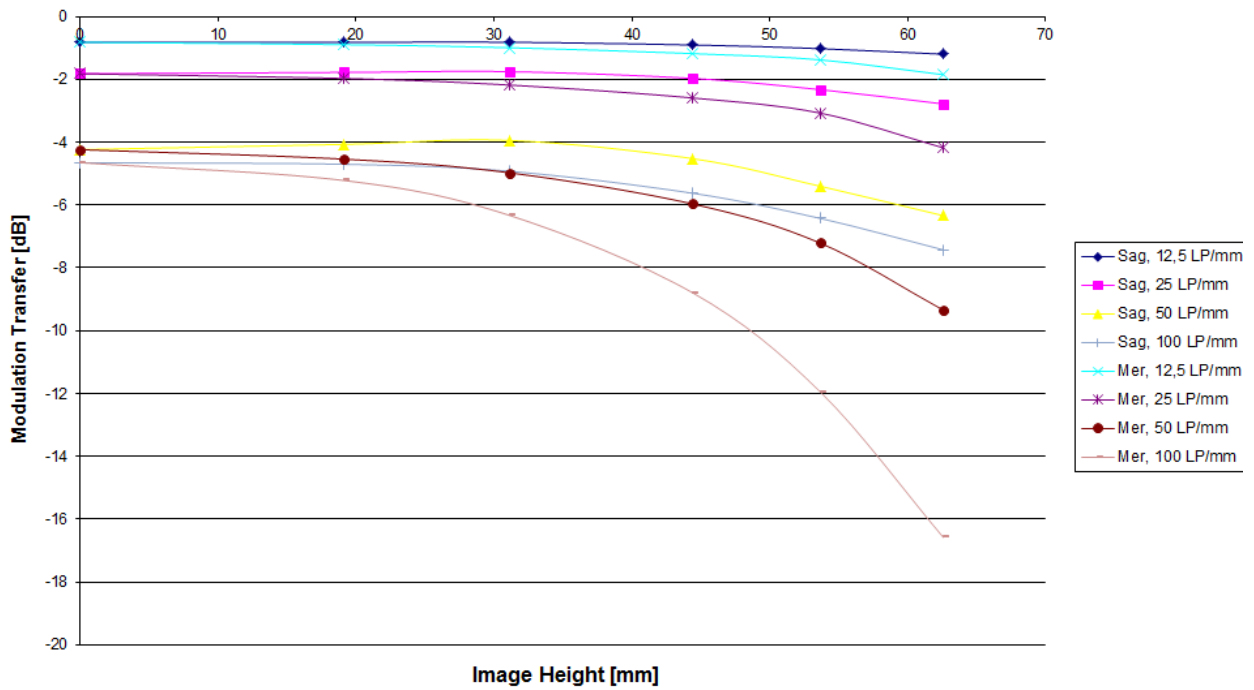




Modulation versus Image Height - Aperture f / 8

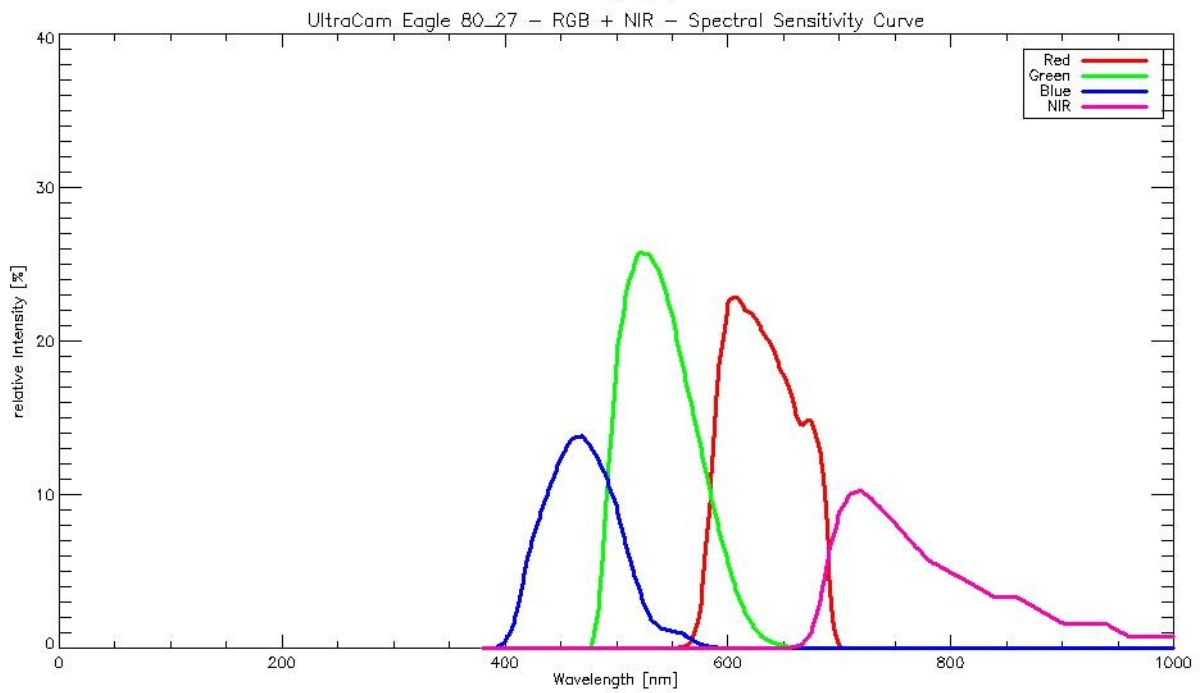
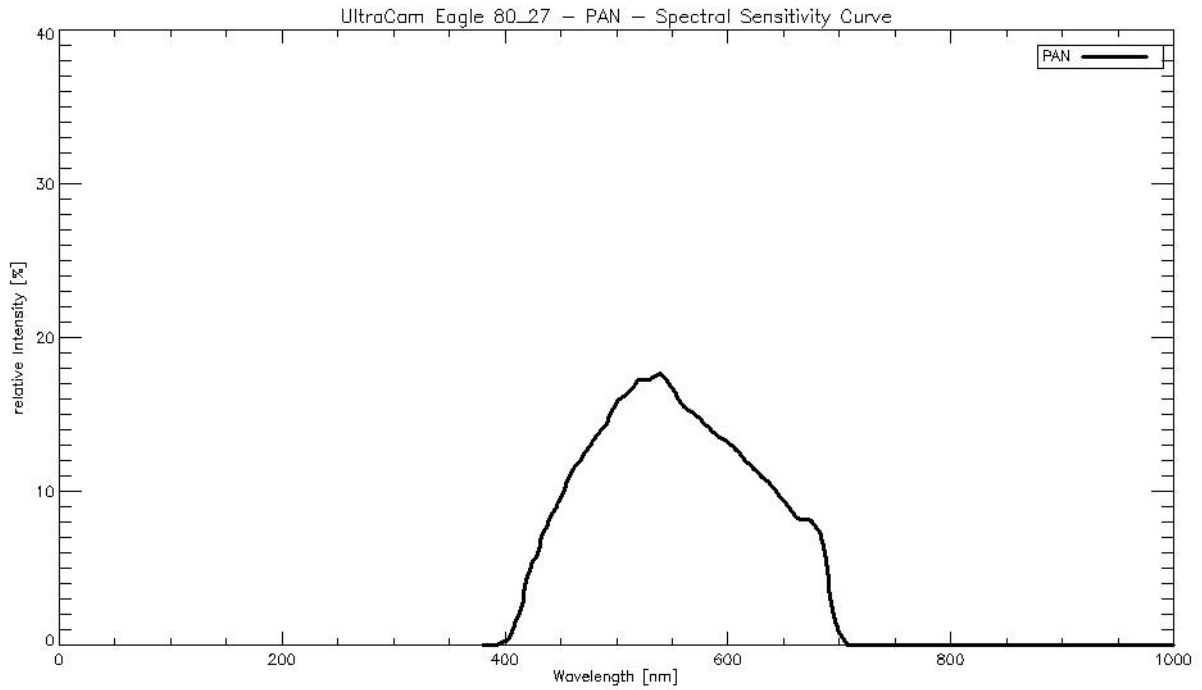


Modulation versus Image Height - Aperture f / 9.5





Spectral Sensitivity





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Radiometric Calibration

Camera: UltraCam Eagle M3
Serial: 431S31385X112156-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

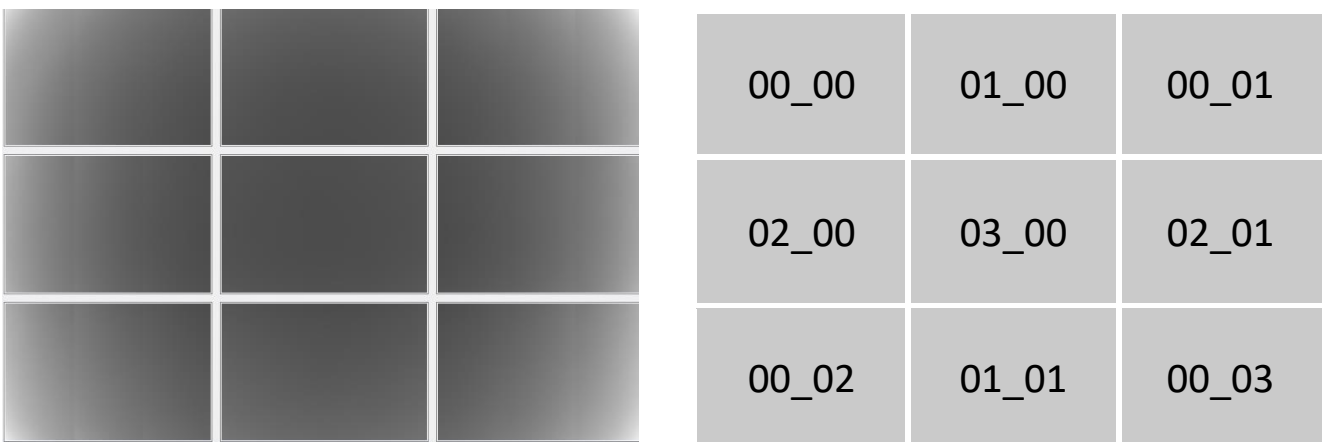
Calibration Date: Jan-21-2019
Date of Report: Mar-15-2019
Camera Revision: Rev01.00
Version of Report: V01



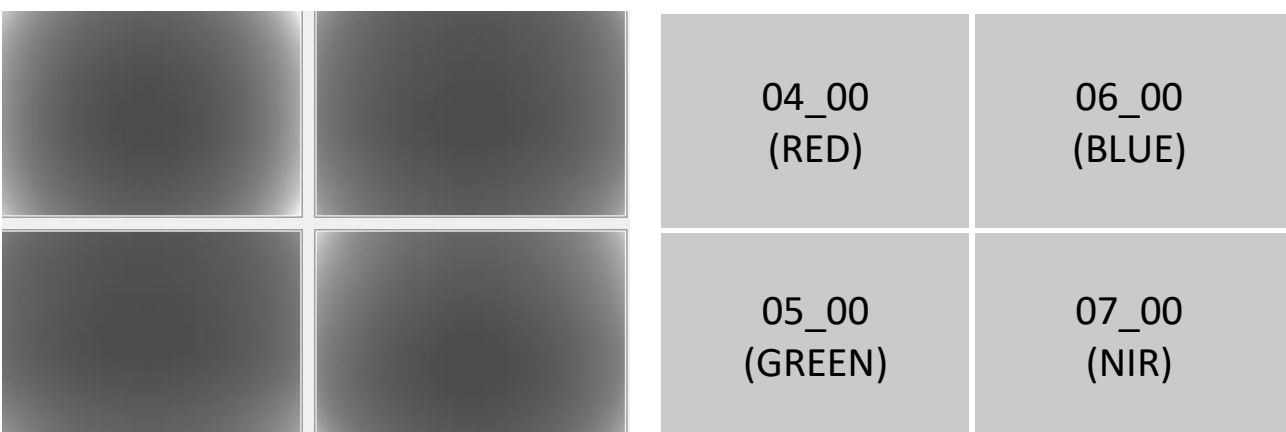
Calibration of Vignetting for working Aperture F6.7

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

Graphical Overview of Pan Sensors:



Graphical Overview of Multispectral Sensors:





Dead Pixel Report:

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

PIXEL: 971/5576
PIXEL: 4225/2281
PIXEL: 5327/1459
PIXEL: 6027/5418
PIXEL: 6641/1511
PIXEL: 6752/3919
PIXEL: 6977/5049
PIXEL: 7561/5245
PIXEL: 8373/5873
PIXEL: 203/2373
COLUMN: 8889/ 586

C00-01

PIXEL: 384/4774
PIXEL: 769/1377
PIXEL: 769/1378
PIXEL: 3239/3063
PIXEL: 3533/2882
PIXEL: 3580/4260
PIXEL: 3727/5835
PIXEL: 3931/1321
PIXEL: 4396/3380
PIXEL: 4418/4895
PIXEL: 4995/ 136
PIXEL: 6277/3308
PIXEL: 6498/3051
PIXEL: 6903/2311
PIXEL: 42/ 92
PIXEL: 1142/3996
PIXEL: 1143/3996
PIXEL: 8571/ 429
PIXEL: 8945/5751

C00-02

PIXEL: 4959/4131
PIXEL: 5795/4558
PIXEL: 6172/5719
PIXEL: 6287/3668
PIXEL: 8941/5146
PIXEL: 102/2517
PIXEL: 114/1027
PIXEL: 269/4622
PIXEL: 344/3329
PIXEL: 4258/1134



PIXEL: 4258/1135

C00-03

PIXEL: 2091/2108
PIXEL: 2091/2912
PIXEL: 2091/4662
PIXEL: 2760/5545
PIXEL: 2794/ 172
PIXEL: 6385/2502
PIXEL: 6618/3503
PIXEL: 7866/4350
PIXEL: 8783/4846
PIXEL: 163/3966
PIXEL: 5753/3592
PIXEL: 8926/ 457

C01-00

PIXEL: 188/2501
PIXEL: 491/1274
PIXEL: 1755/4013

C01-01

PIXEL: 2214/5517
PIXEL: 3260/3715
PIXEL: 4992/4707
PIXEL: 1315/ 850

C02-00

PIXEL: 5201/3813
PIXEL: 7350/4455

C02-01

PIXEL: 775/5123
PIXEL: 775/5124
PIXEL: 3036/5346
PIXEL: 3344/5015
PIXEL: 7676/4997
PIXEL: 8554/4975
PIXEL: 5530/2938
PIXEL: 9043/ 75
PIXEL: 9043/ 88
PIXEL: 9043/ 187

C03-00

PIXEL: 4192/1358

C04-00

PIXEL: 3165/2085
PIXEL: 5540/5089
PIXEL: 3161/5263
PIXEL: 3459/3441



C05-00

PIXEL: 1846/ 938
PIXEL: 5355/1474
PIXEL: 6079/3047
PIXEL: 8579/3729
PIXEL: 93/5167
PIXEL: 627/4692

C06-00

PIXEL: 1085/ 324
PIXEL: 8855/4924
PIXEL: 7587/5822
PIXEL: 2865/4414

C07-00

PIXEL: 78/5695
PIXEL: 182/5785
PIXEL: 271/5621
PIXEL: 5378/5538

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

Camera: UltraCam Eagle M3
Serial: 431S31385X112156-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 Date: Jan-21-2019
Date of Report: Mar-15-2019
Camera Revision: Rev01.00
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 16 05 80	6.37	6.53	6.82	7.03	7.16	7.26	7.38	7.77	+/- 0.2
C1 (Pan)	12 10 09 97	6.71	6.93	7.22	7.47	7.63	7.84	7.85	8.26	+/- 0.2
C2 (Pan)	12 09 11 90	6.25	6.48	6.81	6.91	7.13	7.21	7.31	7.63	+/- 0.2
C3 (Pan)	12 05 85 26	5.95	6.16	6.46	6.63	6.80	6.90	7.10	7.37	+/- 0.2
C4 (Red)	12 31 58 05	7.07	7.07	7.23	7.34	7.41	7.47	7.59	7.71	+/- 0.2
C5 (Green)	12 31 07 58	6.53	6.61	6.75	6.87	6.96	7.01	7.10	7.35	+/- 0.2
C6 (Blue)	12 12 06 27	6.82	6.86	6.86	6.89	7.05	7.11	7.12	7.54	+/- 0.2
C7 (NIR)	12 21 58 28	7.45	7.47	7.57	7.73	7.85	7.94	8.10	8.25	+/- 0.2



ULTRACAM

Electronics and Sensor Calibration

Camera: UltraCam Eagle M3
Serial: 431S31385X112156-f80

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

Calibration Date: Jan-21-2019
Date of Report: Mar-15-2019
Camera Revision: Rev01.00
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 4458/046	22.80	6.10
00_01	FTF9060-M	18 7966/026	23.00	6.18
00_02	FTF9060-M	18 7966/067	22.60	6.52
00_03	FTF9060-M	18 7966/025	23.20	6.35
01_00	FTF9060-M	19 2209/005	22.40	6.66
01_01	FTF9060-M	18 7966/055	22.20	6.65
02_00	FTF9060-M	18 4458/045	22.80	6.14
02_01	FTF9060-M	18 4458/057	22.60	6.31
03_00	FTF9060-M	18 7966/080	22.60	6.62
04_00 (red)	FTF9060-M	18 4458/042	22.60	6.05
05_00 (green)	FTF9060-M	19 2209/041	21.40	6.84
06_00 (blue)	FTF9060-M	19 2209/078	21.60	6.41
07_00 (NIR)	FTF9060-M	19 2209/017	22.00	6.67



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 4458/046	13580	12550
00_01	FTF9060-M	18 7966/026	13800	12880
00_02	FTF9060-M	18 7966/067	13960	12940
00_03	FTF9060-M	18 7966/025	13520	12380
01_00	FTF9060-M	19 2209/005	14290	13080
01_01	FTF9060-M	18 7966/055	13960	12860
02_00	FTF9060-M	18 4458/045	13380	12840
02_01	FTF9060-M	18 4458/057	13540	12730
03_00	FTF9060-M	18 7966/080	14040	13200
04_00 (red)	FTF9060-M	18 4458/042	13580	12710
05_00 (green)	FTF9060-M	19 2209/041	14050	13010
06_00 (blue)	FTF9060-M	19 2209/078	14340	13440
07_00 (NIR)	FTF9060-M	19 2209/017	14250	13280



ULTRACAM

Summary

Camera:	UltraCam Eagle M3
Serial:	431S31385X112156-f80
Calibration Date:	Jan-21-2019
Date of Report:	Mar-15-2019
Camera Revision:	Rev01.00
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