Calibration Report

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-50319383-f80**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Date of Calibration:	**Jan-14-2016**
Date of Report:	**Jan-28-2016**
Revision of Camera:	**Rev03**
Version of Report:	**V01**

Calibration Report

Geometric Calibration

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-50319383-f80**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Panchromatic Camera:	**ck = 79.800 mm**
Multispectral Camera:	**ck = 79.800 mm**
Date of Calibration:	**Jan-14-2016**
Date of Report:	**Jan-28-2016**
Revision of Camera:	**Rev03**
Version of Report:	**V01**

Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track	68.016mm	13080pixel
	cross track	104.052mm	20010pixel
Image Extent		(-34.01, -52.02)mm	(34.01, 52.02)mm
Pixel Size		5.200µm*5.200µm	
Focal Length	ck	79.800 mm	± 0.002mm
Principal Point	X_ppa	0.000 mm	± 0.002mm
(Level 2)	Y_ppa	0.000 mm	± 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	68.016mm	4360pixel
	cross track	104.052mm	6670pixel
Image Extent		(-34.01, -52.02)mm	(34.01, 52.02)mm
Pixel Size		15.600µm*15.600µm	
Focal Length	ck	79.800 mm	
Principal Point	X_ppa	0.000 mm	± 0.002mm
(Level 2)	Y_ppa	0.000 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Individual Panchromatic Cone Data

Cone 0, Parametric Description, Not Effective in Output Image

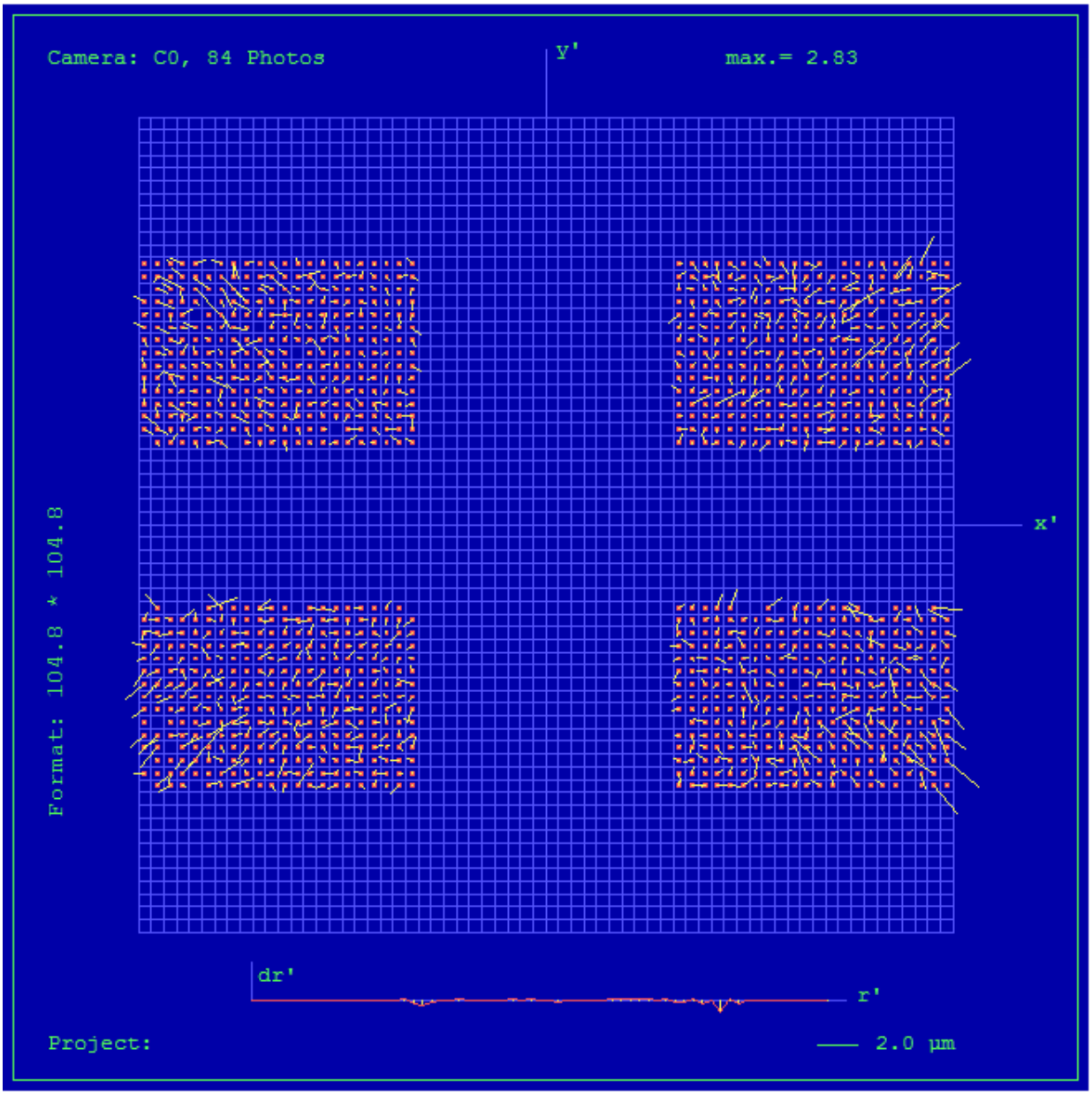
Cone # C0		
Lens	Linos Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linos GmbH, Germany	
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH	
Image Extent (nominally)	(-34.28, -52.22)mm	(34.28, 52.22)mm
Extent CCD 0	(-34.28, -52.22)mm	(-10.32, -16.28)mm
Extent CCD 1	(-34.28, 16.28)mm	(-10.32, 52.22)mm
Extent CCD 2	(10.32, -52.22)mm	(34.28, -16.28)mm
Extent CCD 3	(10.32, 16.28)mm	(34.28, 52.22)mm

Parameters	Shift X	ShiftY	Rotation	Scale
CCD0	5.0077717E-02mm ± 0.0004 mm	1.0382278E-01mm ± 0.0007 mm	-3.2561877E-02gon ± 0.0001 gon	1.0043834 ± 0.00005
CCD1	-1.6117846E-02mm ± 0.0004 mm	-1.2046403E-03mm ± 0.0007 mm	0.0000000E+00gon ± 0.0001 gon	1.0044253 ± 0.00005
CCD2	-3.4254117E-02mm ± 0.0004 mm	5.5875993E-02mm ± 0.0007 mm	-5.1022120E-02gon ± 0.0001 gon	1.0042695 ± 0.00005
CCD3	-8.4437277E-02mm ± 0.0004 mm	-4.6322900E-02mm ± 0.0007 mm	-7.2271638E-02gon ± 0.0001 gon	1.0038366 ± 0.00005

Radial Distortion

R [mm]	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0	65.0
dr [µm]	35.1	66.4	96.3	124.8	149.4	164.8	163.7	135.9	68.9	-52.3	-245.1	-529.6	-928.2

Cone 0, Residual Error Diagram

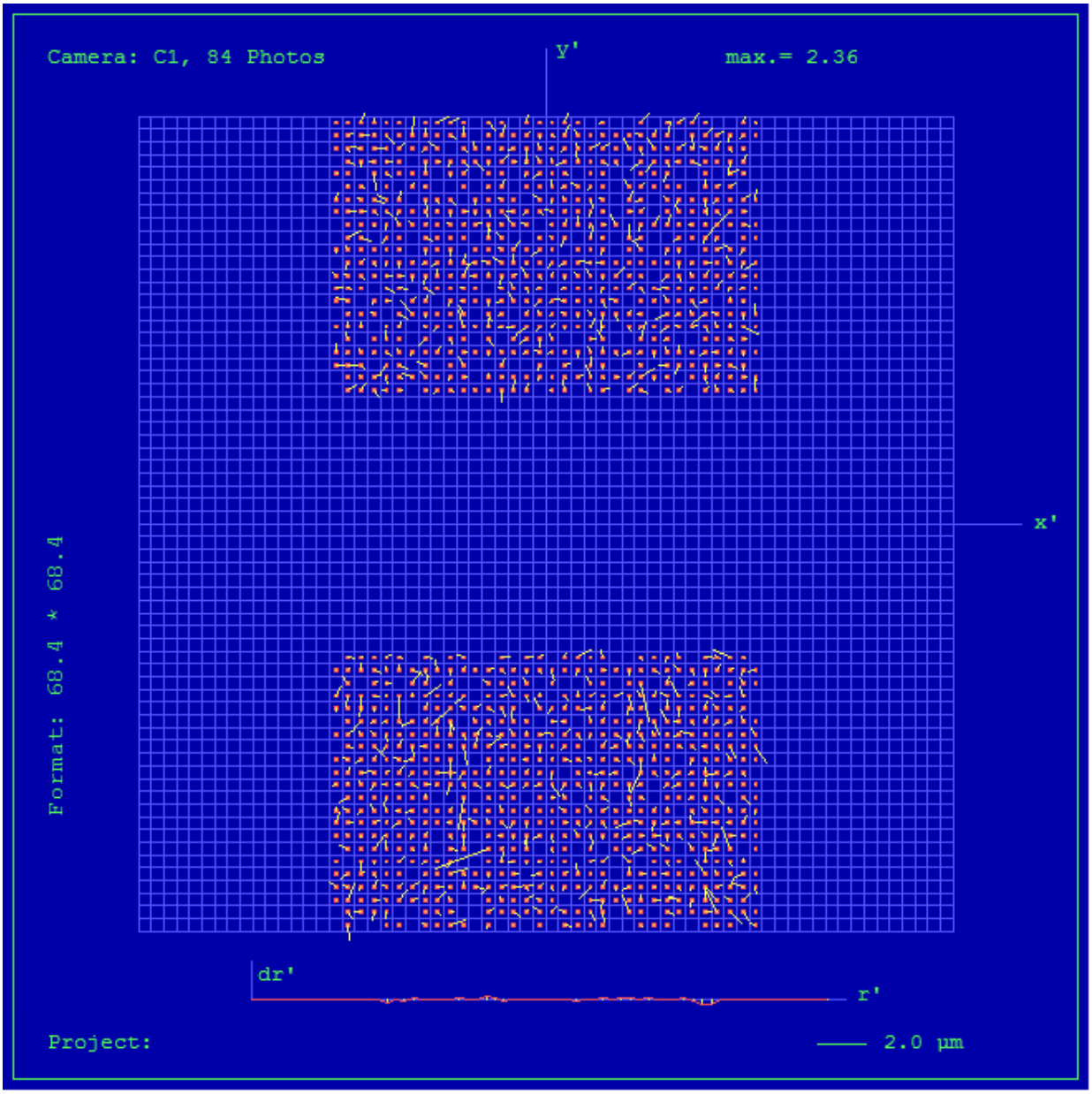


Residual Error (RMS): 0.66 µm

Cone 1, Parametric Description, Not Effective in Output Image

Cone # C1												
Lens	Linos Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linos GmbH, Germany											
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH											
Image Extent (nominally)	(-34.28, -17,97)mm							(34.28, 17.97)mm				
Extent CCD 0	(-34.28, -17.97)mm							(-10.42, 17.97)mm				
Extent CCD 1	(10.42, -17.97)mm							(34.28, 17.97)mm				
Parameters	Shift X		Shift Y		Rotation		Scale					
CCD0	-1.0940154E-02mm ± 0.0006 mm		3.1691855E-02mm ± 0.0005 mm		0.0000000E+00gon ± 0.0001 gon		1.0041352 ± 0.00005					
CCD1	-5.0943463E-02mm ± 0.0006 mm		8.2136307E-05mm ± 0.0005 mm		5.1376314E-02gon ± 0.0001 gon		1.0039358 ± 0.00005					
Radial Distortion												
R [mm]	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0
dr [µm]	12.6	24.2	35.7	46.4	53	50.2	30.5	-15.6	-100	-236.6	-441.5	-733

Cone 1, Residual Error Diagram



Residual Error (RMS): 0.50 µm

Cone 2, Parametric Description, Not Effective in Output Image

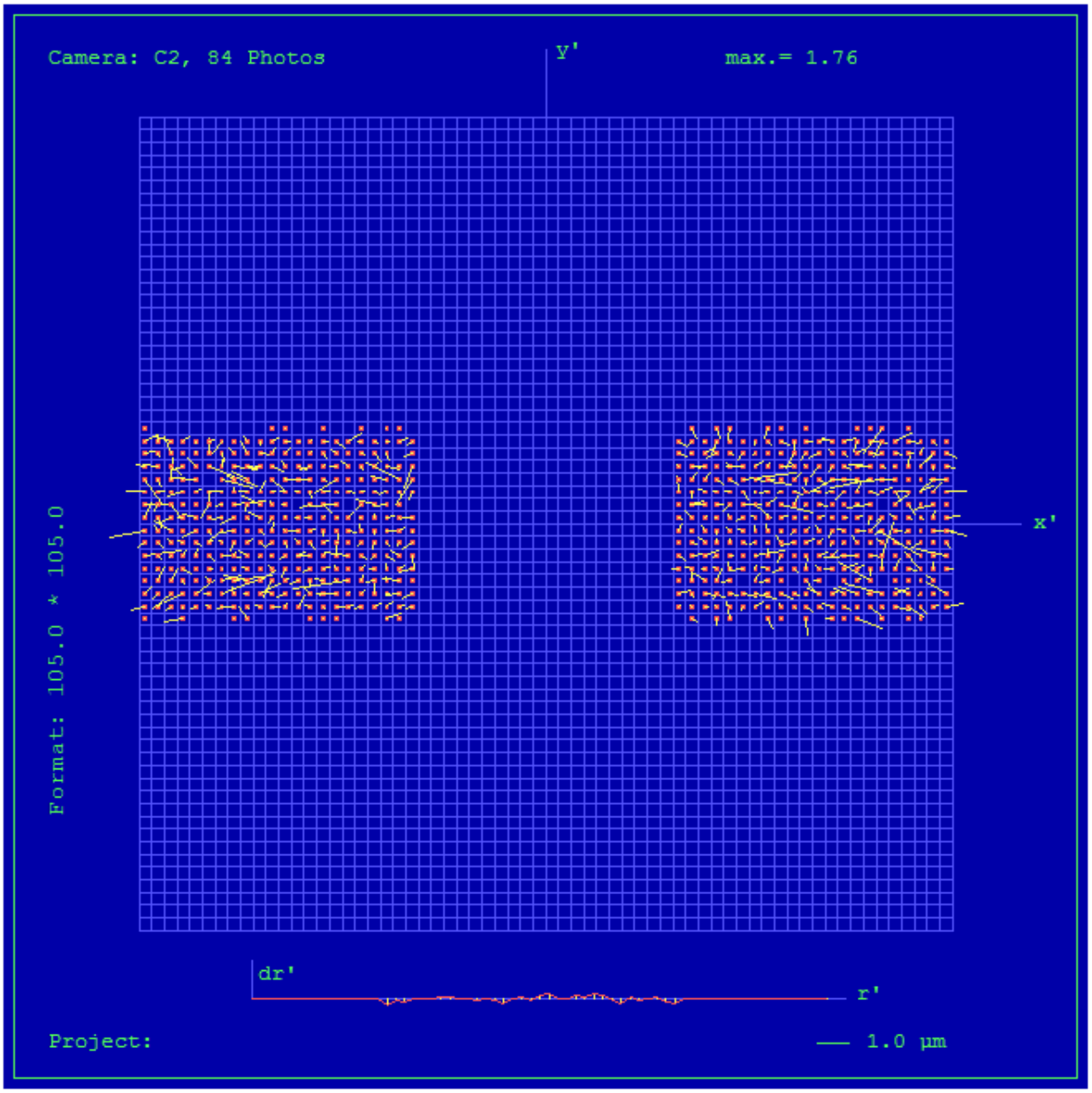
Cone # C2		
Lens	Linos Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linos GmbH, Germany	
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH	
Image Extent (nominally)	(-11.98, -52.22)mm	(11.98, 52.22)mm
Extent CCD 0	(-11.98, -52.22)mm	(11.98, -16.28)mm
Extent CCD 1	(-11.98, 16.28)mm	(11.98, 52.22)mm

Parameters	Shift X	ShiftY	Rotation	Scale
CCD0	-2.0951968E-02mm ± 0.0004 mm	1.9492393E-02mm ± 0.0016 mm	3.7992489E-02gon ± 0.0001 gon	1.0061044 ± 0.00005
CCD1	3.7681114E-02mm ± 0.0004 mm	5.1122635E-02mm ± 0.0016 mm	0.0000000E+00gon ± 0.0001 gon	1.0060939 ± 0.00005

Radial Distortion

R [mm]	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0
dr [µm]	34.2	65.9	97	127.1	153.3	170.5	171.2	145.2	80.4	-38.1	-227.4	-506.8

Cone 2, Residual Error Diagram

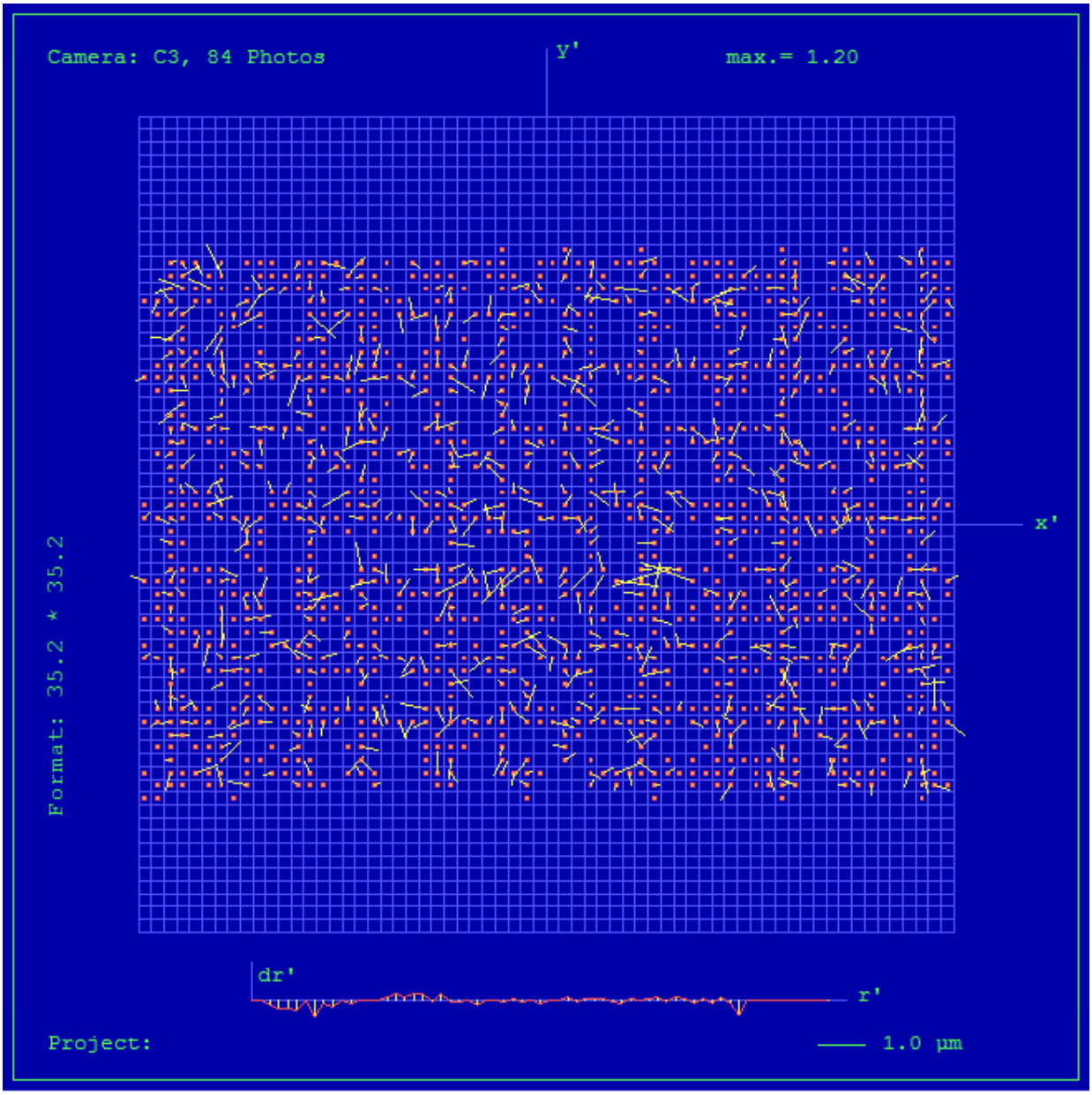


Residual Error (RMS): 0.57 µm

Cone 3, Parametric Description, Not Effective in Output Image

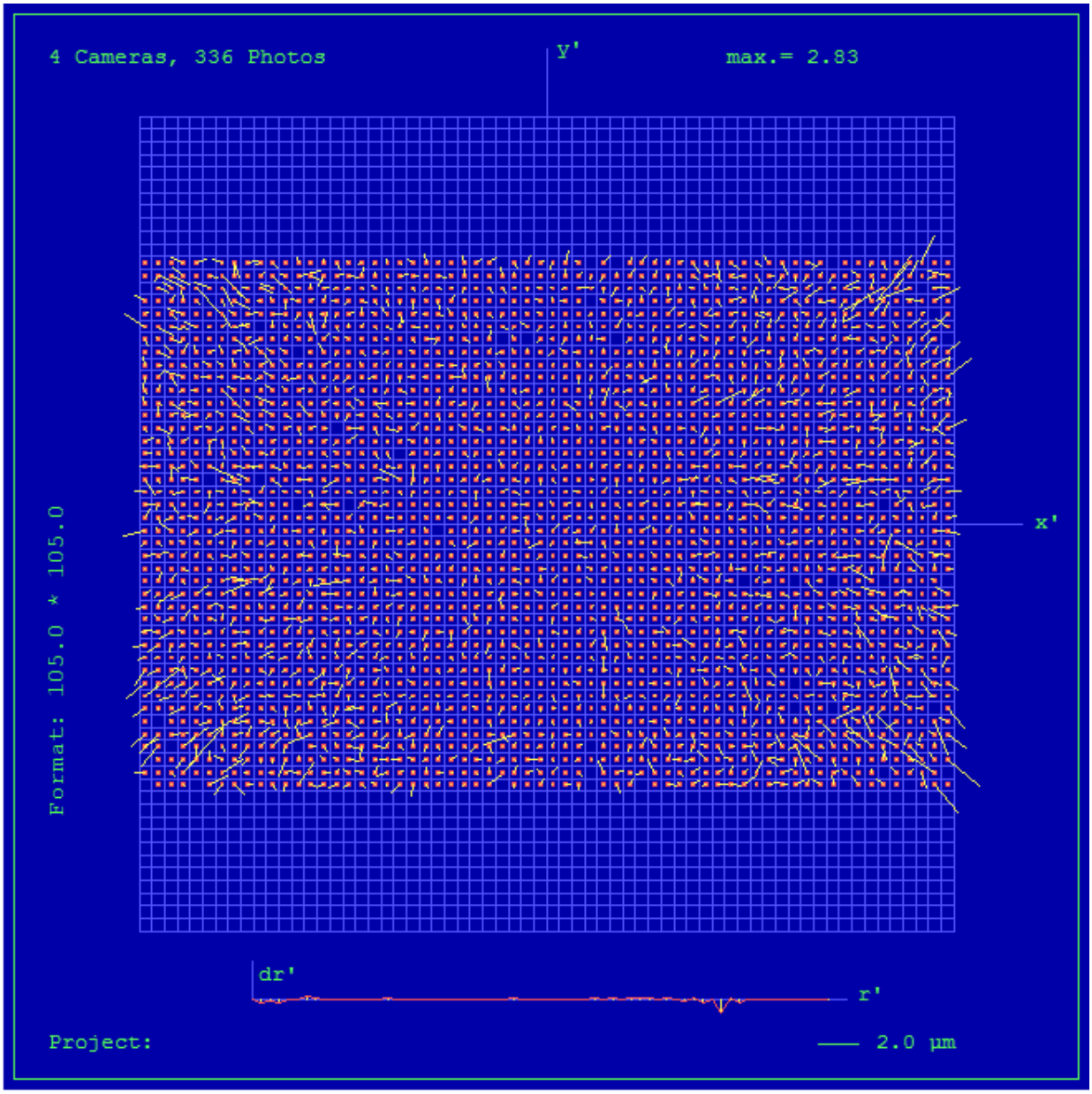
Cone # C3					
Lens	Linos Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linos GmbH, Germany				
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH				
Image Extent (nominally)	(-11.98, -17.97)mm		(11.98, 17.97)mm		
Extent CCD 0	(-11.98, -17.97)mm		(11.98 , 17.97)mm		
Parameters	Shift X	ShiftY	Rotation	Scale	
CCD0	5.5036478E-02mm ± 0.0008 mm	2.3262935E-02mm ± 0.0021 mm	0.0000000E+00gon ± 0.0001 gon	0.9998480 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	-2	-2.9	-3.6	-4	-4.3

Cone 3, Residual Error Diagram



Residual Error (RMS): 0.43 µm

Full Pan Image, Residual Error Diagram



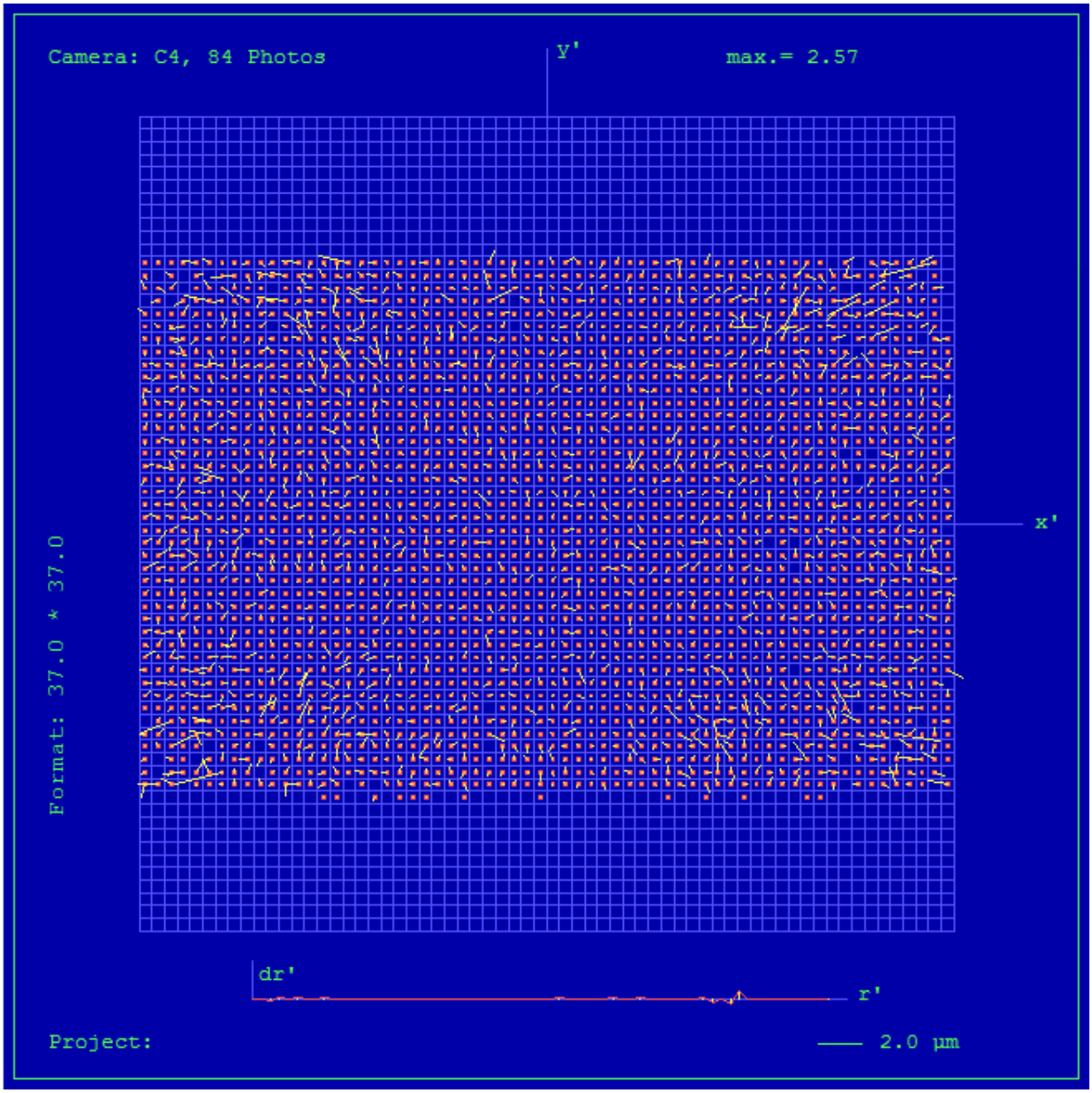
Residual Error (RMS): 0.55 µm

Individual Multispectral Cone Data

Cone 4, Parametric Description, Not Effective in Output Image

Cone # C4 (red)					
Lens	Linos Vexcel HR Digaron 1:4/27mm Linos GmbH, Germany				
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH				
Image Extent (nominally)	(-11.98, -17.97)mm		(11.98, 17.97)mm		
Extent CCD 0	(-11.98, -17.97)mm		(11.98 , 17.97)mm		
Parameters	Shift X	ShiftY	Rotation	Scale	
CCD0	-6.4147438E-02mm ± 0.0000 mm	-4.6550349E-02mm ± 0.0001 mm	0.0000000E+00gon ± 0.0001 gon	1.0551183 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	117.5	158.4	181	183.9	169.1

Cone 4, Residual Error Diagram

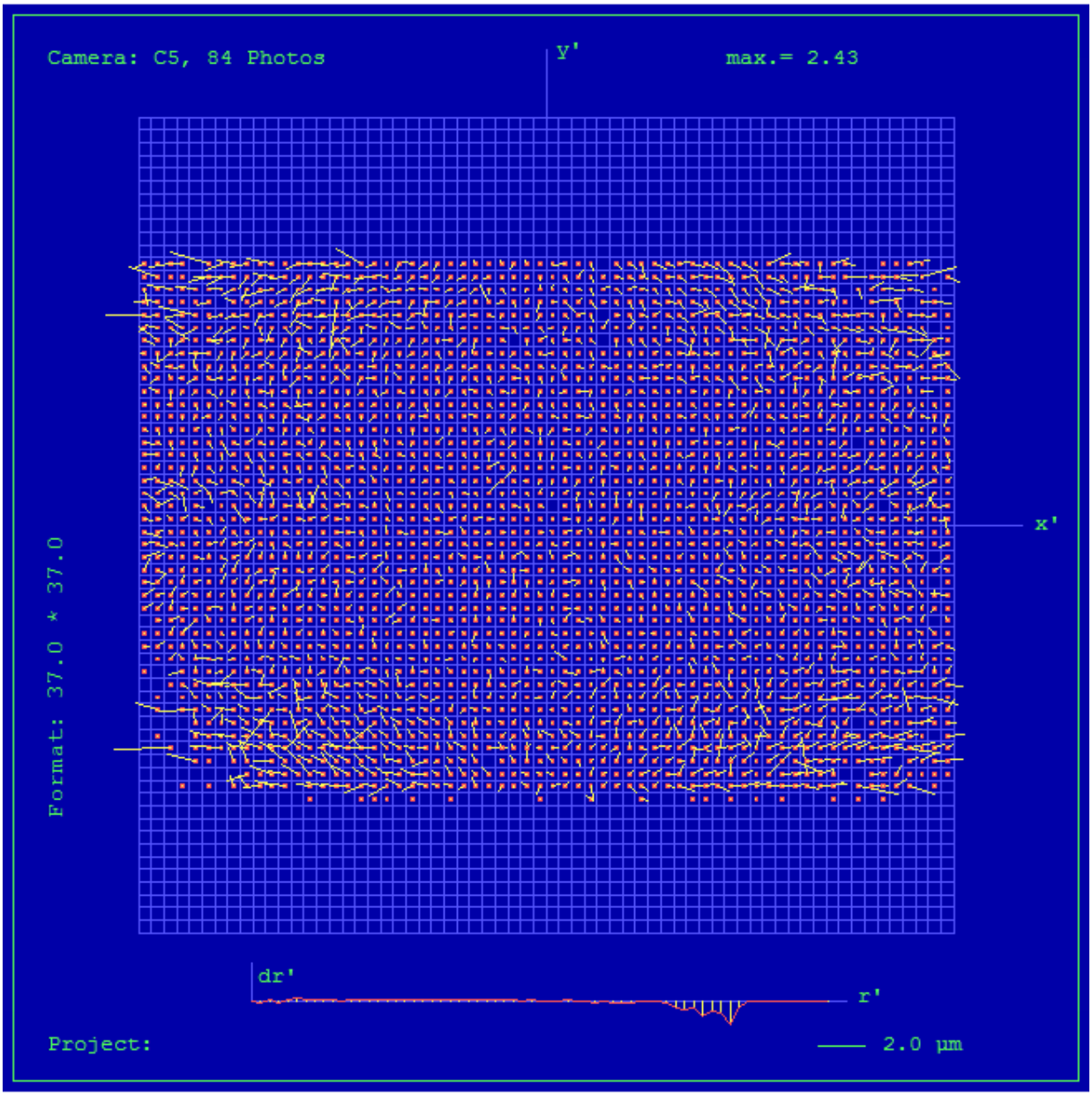


Residual Error (RMS): 0.49 µm

Cone 5, Parametric Description, Not Effective in Output Image

Cone # C5 (green)					
Lens	Linos Vexcel HR Digaron 1:4/27mm Linos GmbH, Germany				
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH				
Image Extent (nominally)	(-11.98, -17.97)mm		(11.98, 17.97)mm		
Extent CCD 0	(-11.98, -17.97)mm		(11.98 , 17.97)mm		
Parameters	Shift X	Shift Y	Rotation	Scale	
CCD0	-6.9436138E-03mm ± 0.0000 mm	-6.8576738E-02mm ± 0.0001 mm	0.0000000E+00gon ± 0.0001 gon	1.0534565 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	115.8	155.7	177.5	180.2	165.9

Cone 5, Residual Error Diagram

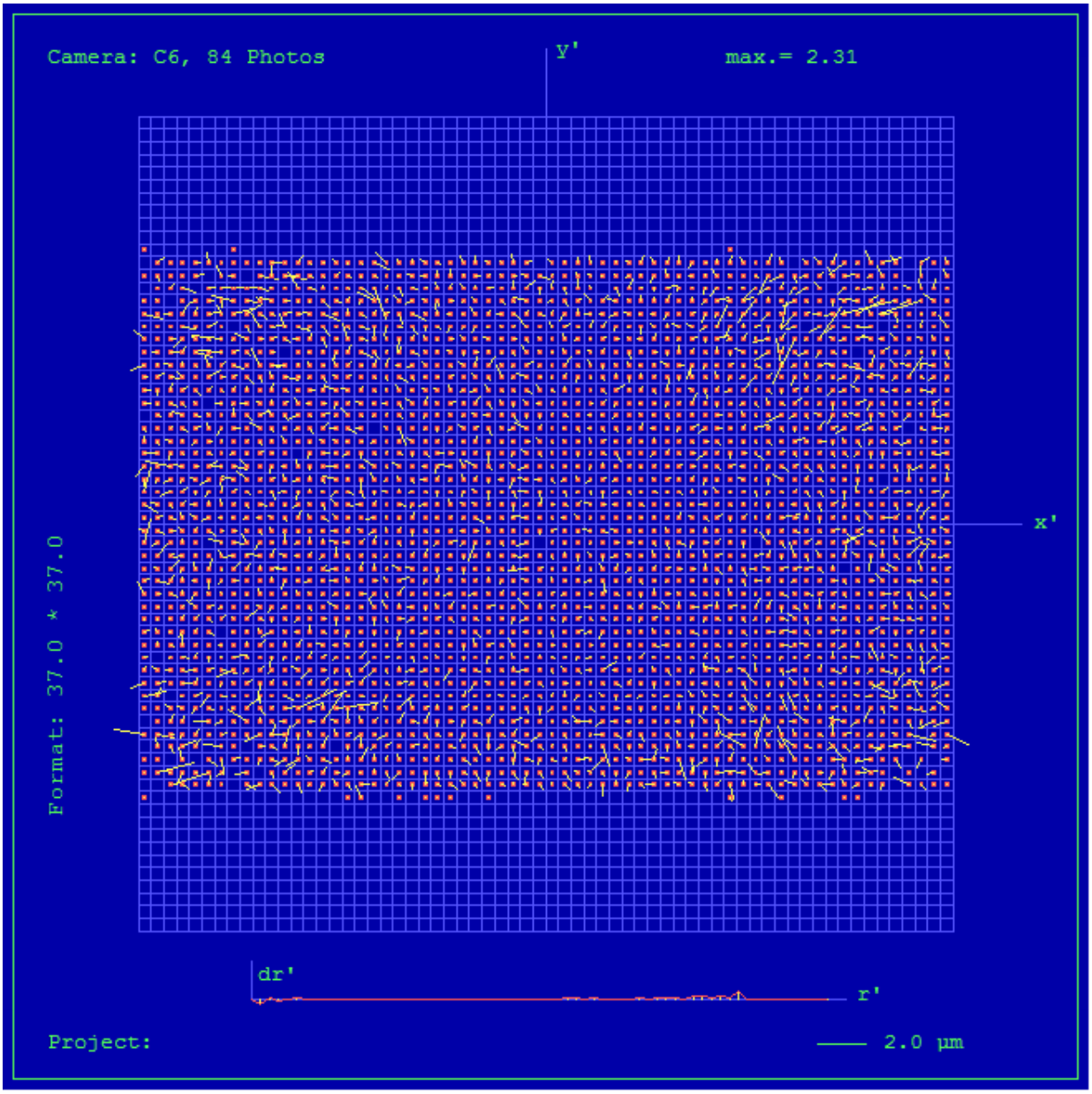


Residual Error (RMS): 0.50 µm

Cone 6, Parametric Description, Not Effective in Output Image

Cone # C6 (blue)					
Lens	Linos Vexcel HR Digaron 1:4/27mm Linos GmbH, Germany				
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH				
Image Extent (nominally)	(-11.98, -17.97)mm		(11.98, 17.97)mm		
Extent CCD 0	(-11.98, -17.97)mm		(11.98 , 17.97)mm		
Parameters	Shift X	ShiftY	Rotation	Scale	
CCD0	-3.1463194E-02mm ± 0.0000 mm	-1.5696244E-02mm ± 0.0001 mm	0.0000000E+00gon ± 0.0001 gon	1.0539814 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	115	155.1	177.1	180.1	165.9

Cone 6, Residual Error Diagram

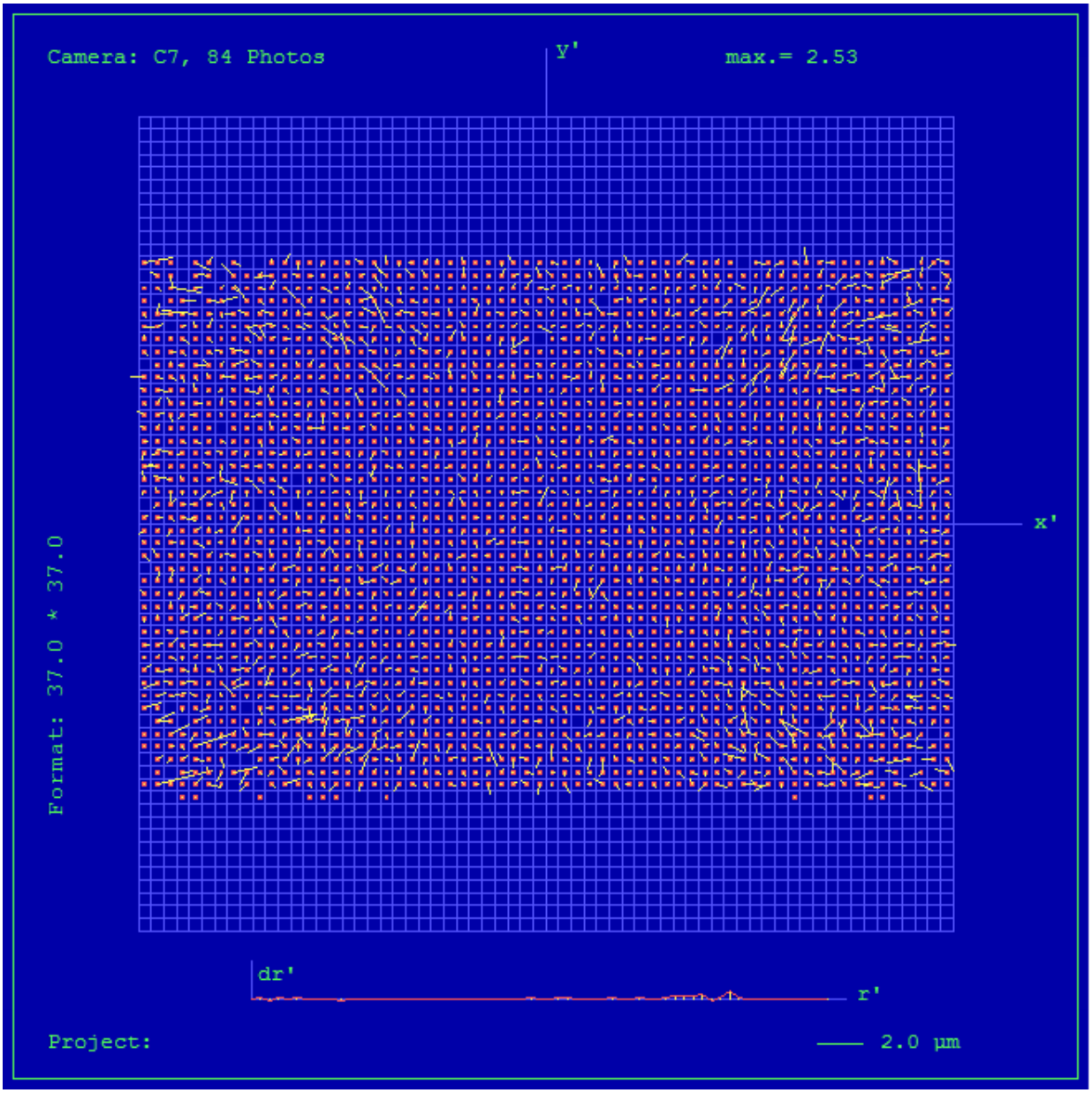


Residual Error (RMS): 0.49 µm

Cone 7, Parametric Description, Not Effective in Output Image

Cone # C7 (NIR)					
Lens	Linos Vexcel HR Digaron 1:4/27mm Linos GmbH, Germany				
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH				
Image Extent (nominally)	(-11.98, -17.97)mm		(11.98, 17.97)mm		
Extent CCD 0	(-11.98, -17.97)mm		(11.98 , 17.97)mm		
Parameters	Shift X	ShiftY	Rotation	Scale	
CCD0	2.6959715E-02mm ± 0.0000 mm	-4.0481015E-02mm ± 0.0001 mm	0.0000000E+00gon ± 0.0001 gon	1.0563754 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	116.8	157.4	179.8	182.8	168.6

Cone 7, Residual Error Diagram



Residual Error (RMS): 0.50 µm

Explanations:

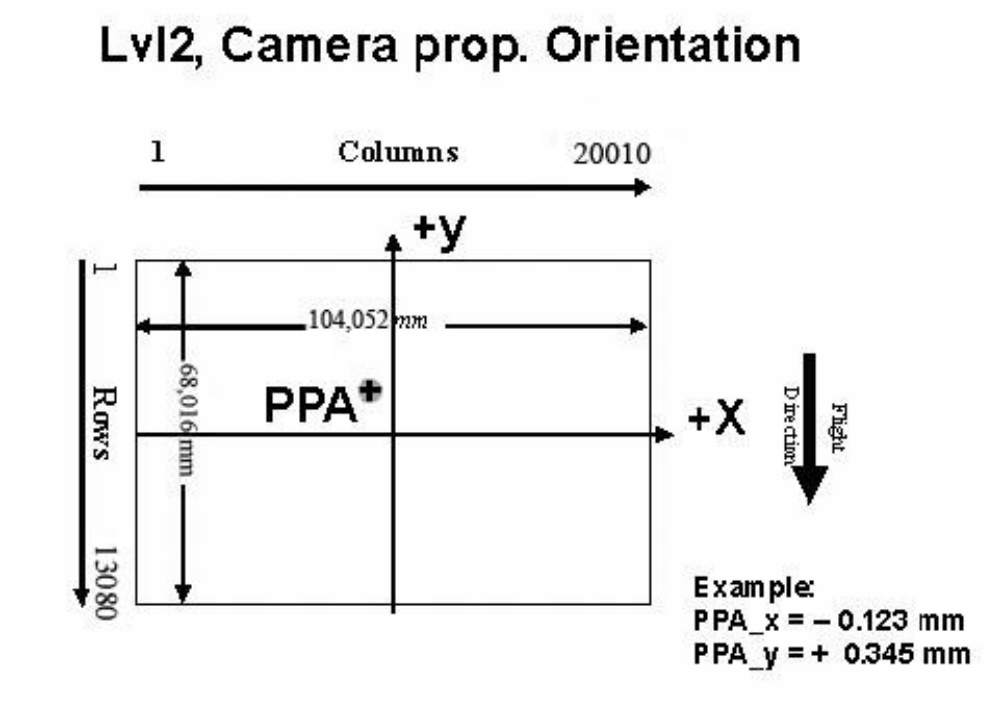
1) Calibration Method:

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 : 19482
Number of point measurements for the multispectral camera : 77958

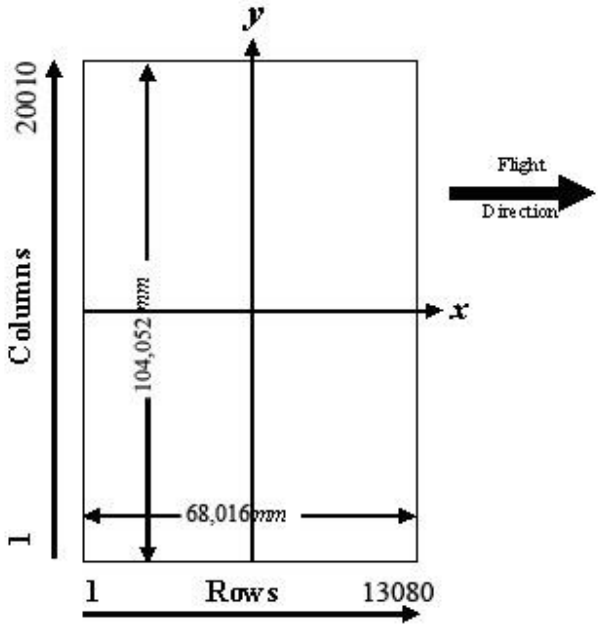
Determination of the image parameters by Least Squares Adjustment.
Software used for the adjustment: BINGO (GIP Eng. Aalen, Germany)

2) Level 2 Image Coordinate System: PAN 20010 pixel by 13080 pixel
MS 6670 pixel by 4360 pixel

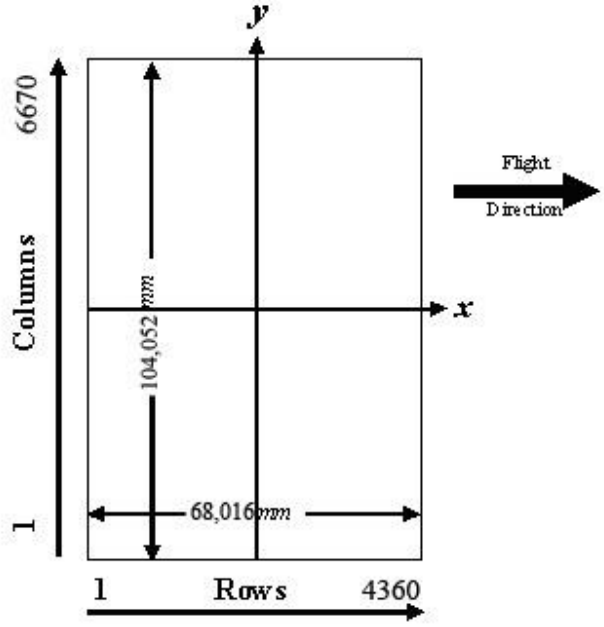


The image coordinate system of the Level 2 images is shown in the above figure. The level 2 image consists of 20010 columns and 13080 rows, which leads to a total image format of 104.052 x 68.016 mm. The coordinate of the principal point in the level 2 image is given on page 3 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).

3) Level 3 Image Coordinate System: PAN 20010 pixel by 13080 pixel
(after rotation of 270° CW) MS 6670 pixel by 4360 pixel



Panchromatic Image Format



Multispectral Image Format

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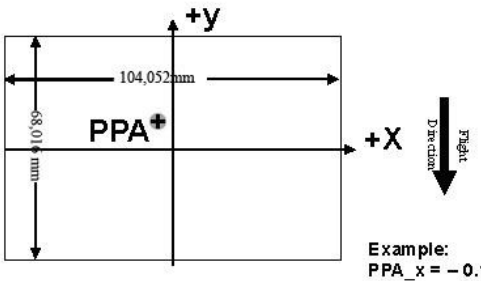
4) Position of Principal Point in Level 3 Image

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 3 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

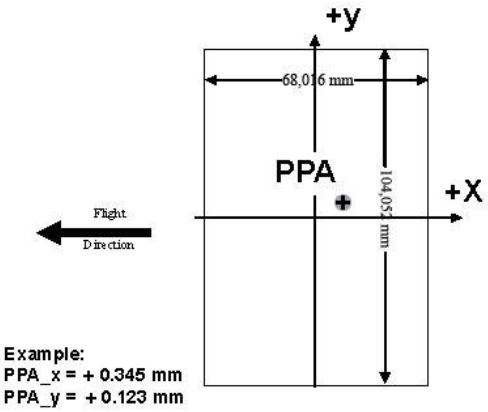
The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

Lvl3, Rotation 0 deg clockwise



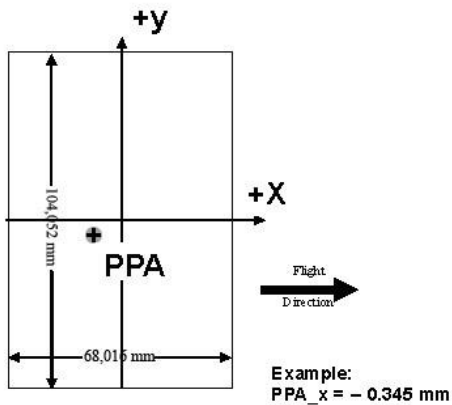
Example:
PPA_x = – 0.123 mm
PPA_y = + 0.345 mm

Lvl3, Rotation 90 deg clockwise



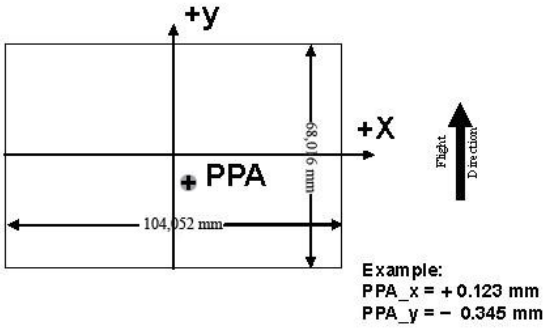
Example:
PPA_x = + 0.345 mm
PPA_y = + 0.123 mm

Lvl3, Rotation 270 deg clockwise



Example:
PPA_x = – 0.345 mm
PPA_y = – 0.123 mm

Lvl3, Rotation 180 deg clockwise



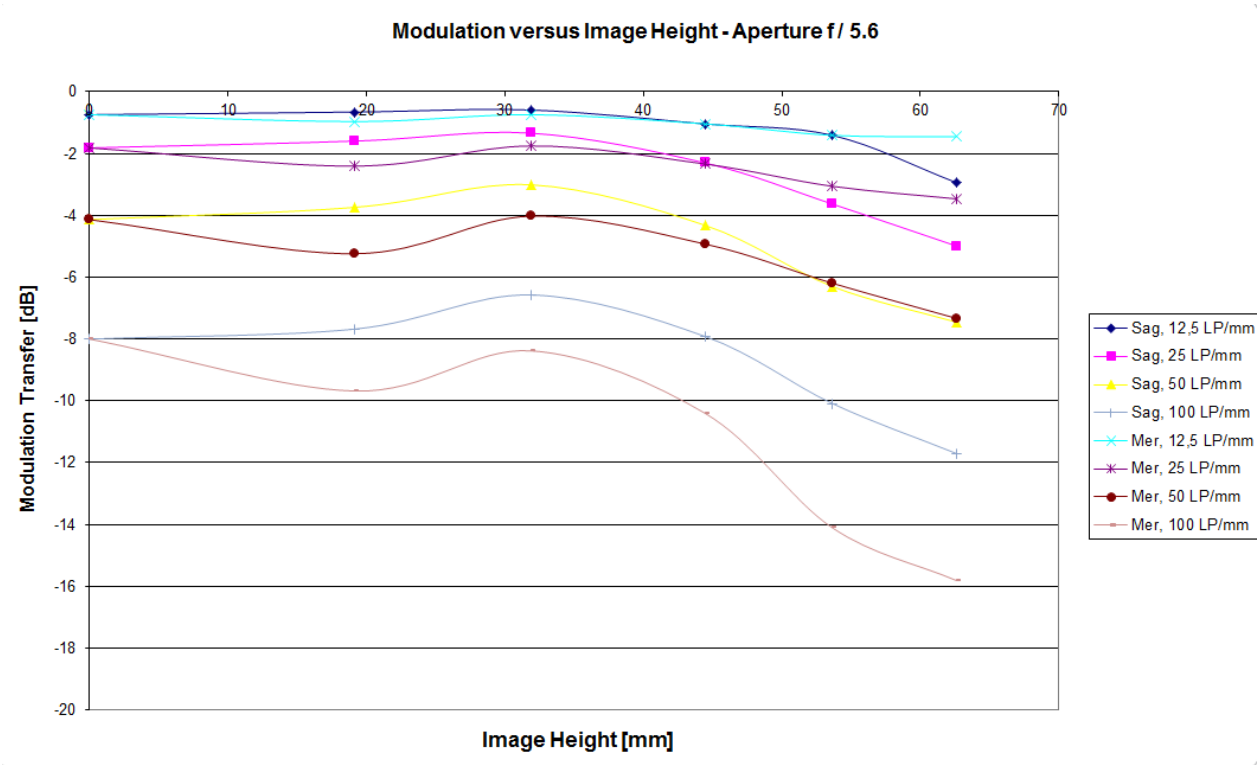
Example:
PPA_x = + 0.123 mm
PPA_y = – 0.345 mm

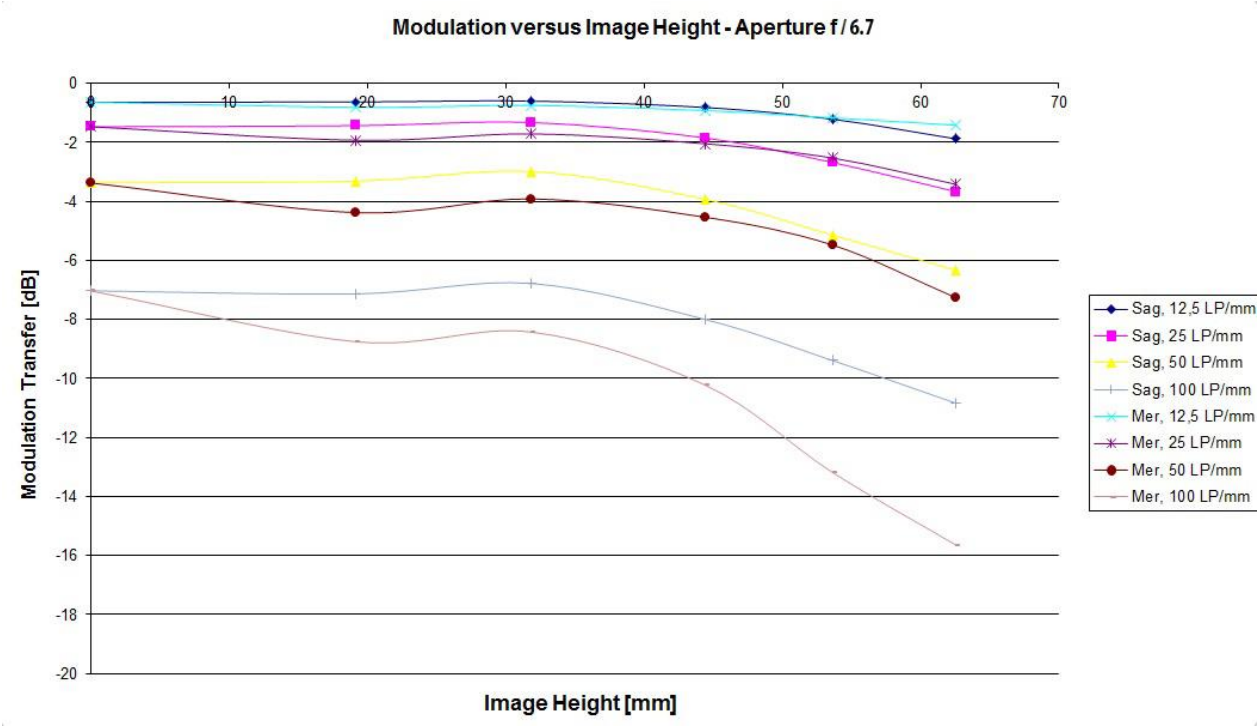
Lens Resolving Power

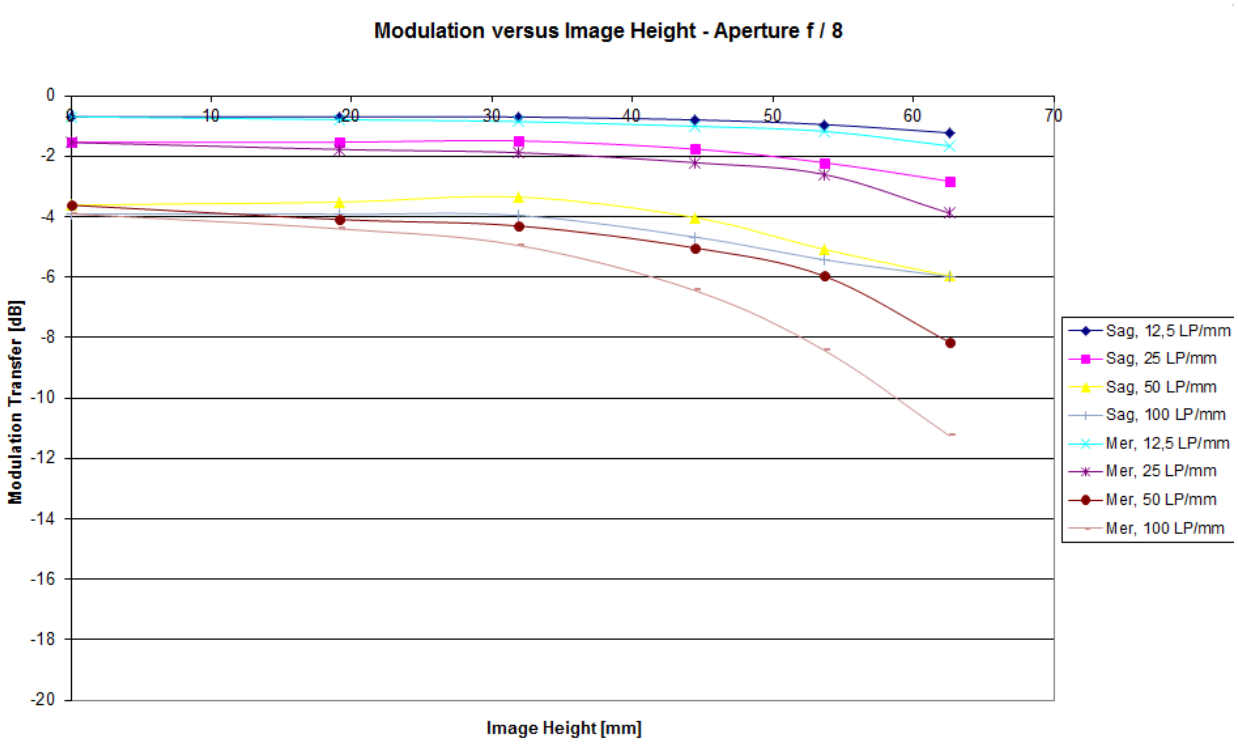
The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones. Please note that these values have been calculated and can vary up to 10% with optics from production (especially at high LP's).

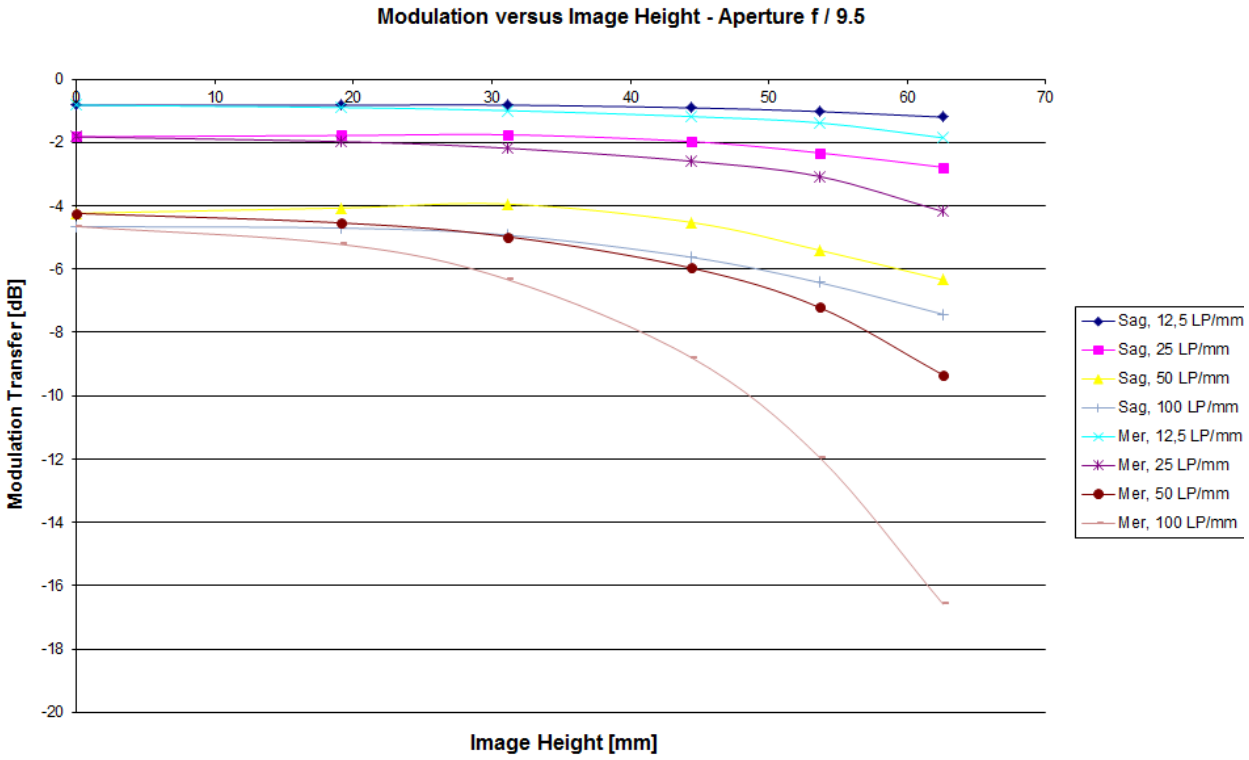
The curves are given for the meridonial (tangential) and sagital (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

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

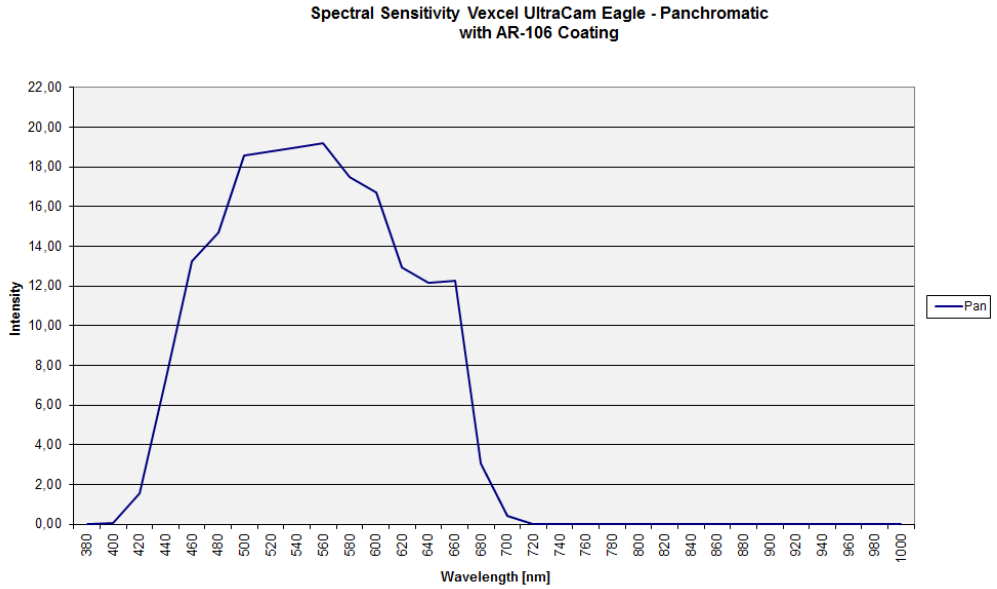

Modulation versus Image Height - Aperture f / 5.6
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm

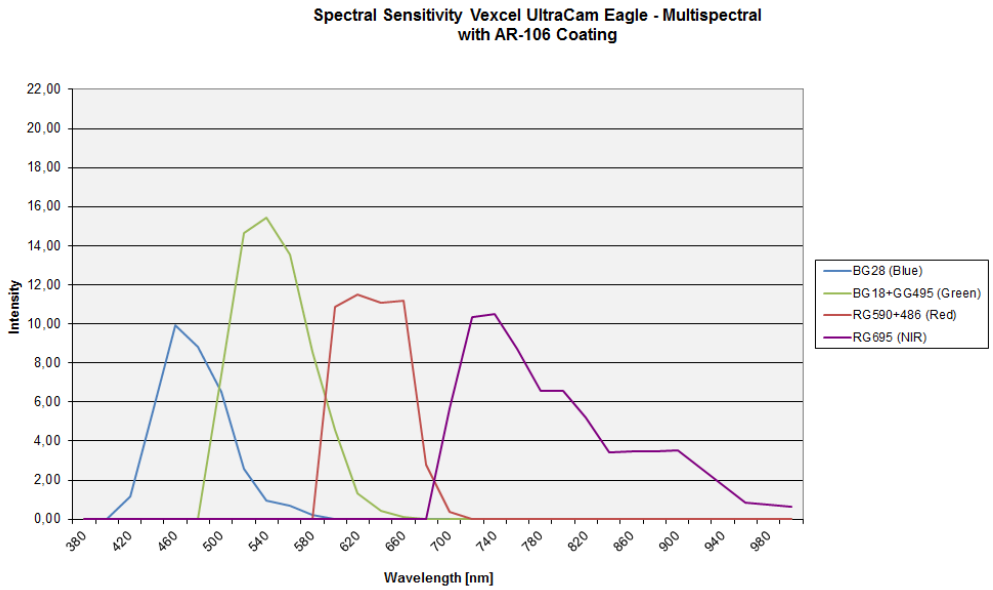

Modulation versus Image Height - Aperture f / 6.7
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm


Modulation versus Image Height - Aperture f / 8
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm


Modulation versus Image Height - Aperture f / 9.5
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm

Spectral Sensitivity





Calibration Report

Radiometric Calibration

Camera: **UltraCam Eagle, S/N UC-Eagle-1-50319383-f80**

Manufacturer: **Vexcel Imaging GmbH, A-8010 Graz, Austria**

	PAN	R, G, NIR	B
Aperture	F5.6	F8.0	F5.6
	F6.7	F9.3	F6.5
	F8	F11	F8
	F9.5	F13	F9.5
	F11	F16	F11
	F13	F19	F13
	F16	F22	F16
	F22	F27	F22

Date of Calibration: **Jan-14-2016**
Date of Report: **Jan-28-2016**
Revision of Camera: **Rev03**
Version of Report: **V01**

Calibration of Vignetting for Aperture Setting 1

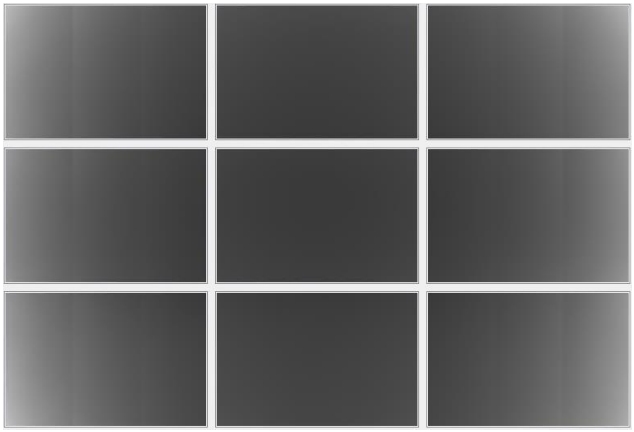
	PAN	R, G, NIR	B
Aperture	F5.6	F8.0	F5.6

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 5.6	1.00	4.00
00_01	f / 5.6	1.00	4.00
00_02	f / 5.6	1.00	4.00
00_03	f / 5.6	1.00	4.00
01_00	f / 5.6	1.00	2.00
01_01	f / 5.6	1.00	2.00
02_00	f / 5.6	1.00	3.00
02_01	f / 5.6	1.00	3.00
03_00	f / 5.6	1.00	2.00
04_00 (red)	f / 8	1.00	5.00
05_00 (green)	f / 8	1.00	3.00
06_00 (blue)	f / 5.6	1.00	3.00
07_00 (NIR)	f / 8	1.00	4.00

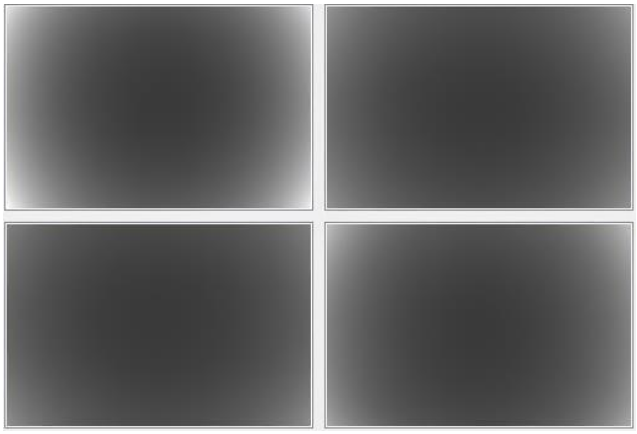
Calibration of Vignetting for Aperture Setting 1

Graphical Overview of Pan Sensor Gain Values:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensor Gain Values:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Calibration of Vignetting for Aperture Setting 2

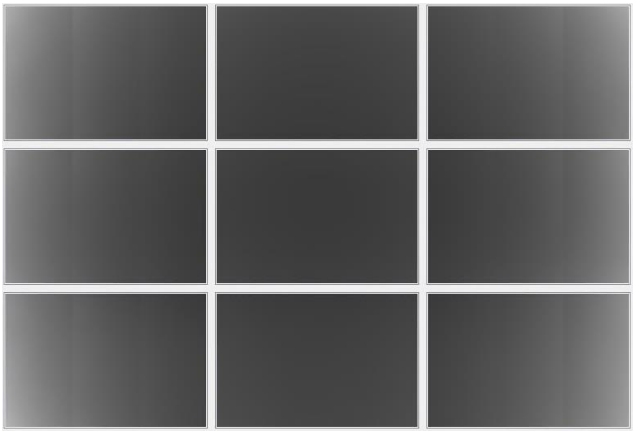
	PAN	R, G, NIR	B
Aperture	F6.7	F9.3	F6.7

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 6.5	1.00	4.00
00_01	f / 6.5	1.00	3.00
00_02	f / 6.5	1.00	4.00
00_03	f / 6.5	1.00	3.00
01_00	f / 6.5	1.00	2.00
01_01	f / 6.5	1.00	2.00
02_00	f / 6.5	1.00	3.00
02_01	f / 6.5	1.00	3.00
03_00	f / 6.5	1.00	2.00
04_00 (red)	f / 9.3	1.00	5.00
05_00 (green)	f / 9.3	1.00	3.00
06_00 (blue)	f / 6.5	1.00	3.00
07_00 (NIR)	f / 9.3	1.00	4.00

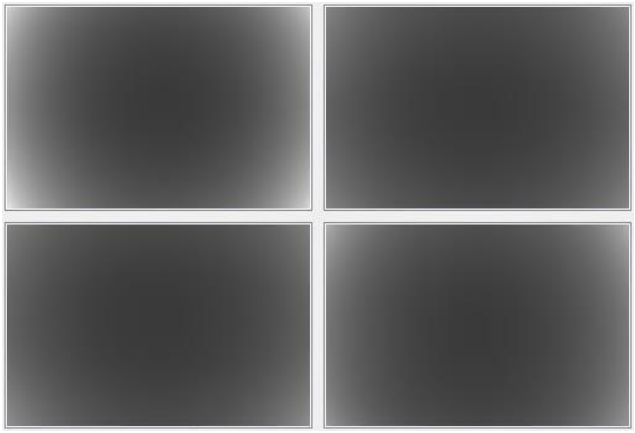
Calibration of Vignetting for Aperture Setting 2

Graphical Overview of Pan Sensor Gain Values:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensor Gain Values:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Calibration of Vignetting for Aperture Setting 3

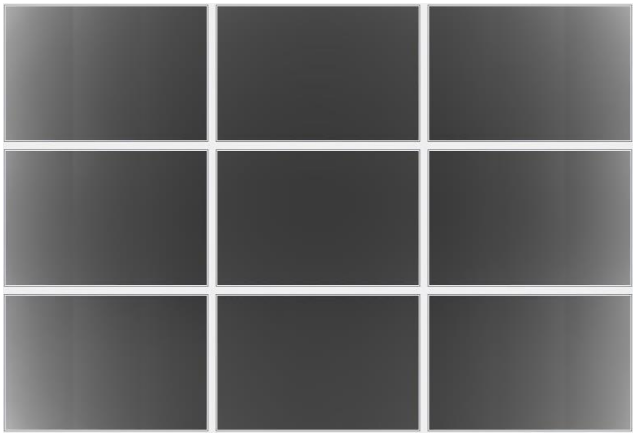
	PAN	R, G, NIR	B
Aperture	F8	F11	F8

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 8	1.00	3.00
00_01	f / 8	1.00	3.00
00_02	f / 8	1.00	4.00
00_03	f / 8	1.00	3.00
01_00	f / 8	1.00	2.00
01_01	f / 8	1.00	2.00
02_00	f / 8	1.00	3.00
02_01	f / 8	1.00	3.00
03_00	f / 8	1.00	2.00
04_00 (red)	f / 11	1.00	4.00
05_00 (green)	f / 11	1.00	3.00
06_00 (blue)	f / 8	1.00	3.00
07_00 (NIR)	f / 11	1.00	3.00

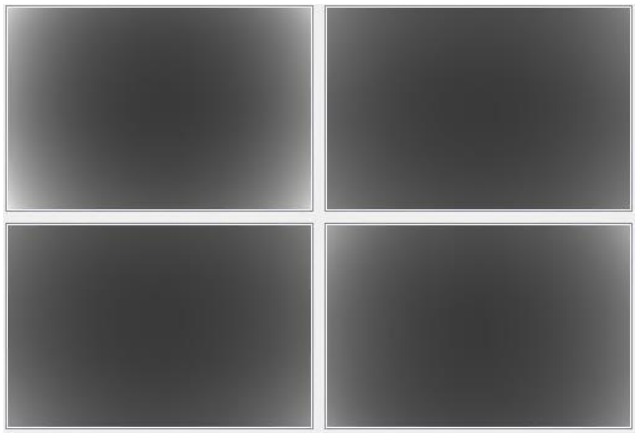
Calibration of Vignetting for Aperture Setting 3

Graphical Overview of Pan Sensor Gain Values:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensor Gain Values:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Calibration of Vignetting for Aperture Setting 4

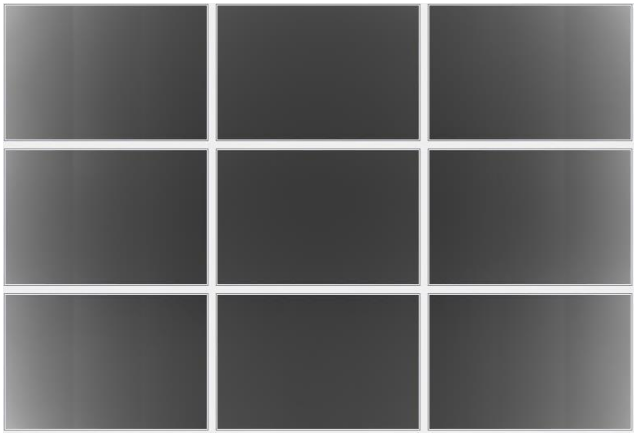
	PAN	R, G, NIR	B
Aperture	F9.5	F13	F9.5

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 9.5	1.00	3.00
00_01	f / 9.5	1.00	3.00
00_02	f / 9.5	1.00	4.00
00_03	f / 9.5	1.00	3.00
01_00	f / 9.5	1.00	2.00
01_01	f / 9.5	1.00	2.00
02_00	f / 9.5	1.00	3.00
02_01	f / 9.5	1.00	3.00
03_00	f / 9.5	1.00	2.00
04_00 (red)	f / 13	1.00	4.00
05_00 (green)	f / 13	1.00	3.00
06_00 (blue)	f / 9.5	1.00	3.00
07_00 (NIR)	f / 13	1.00	3.00

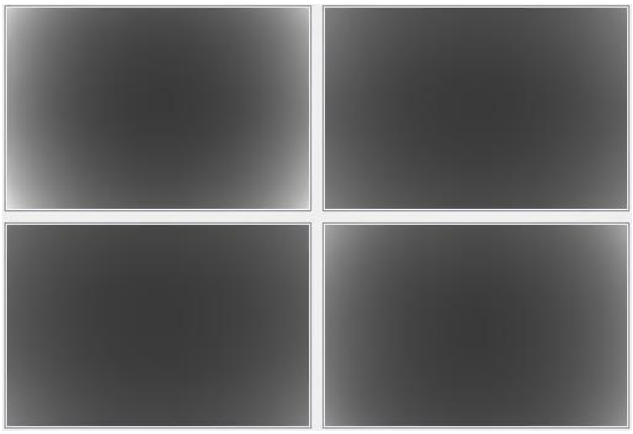
Calibration of Vignetting for Aperture Setting 4

Graphical Overview of Pan Sensor Gain Values:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensor Gain Values:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Calibration of Vignetting for Aperture Setting 5

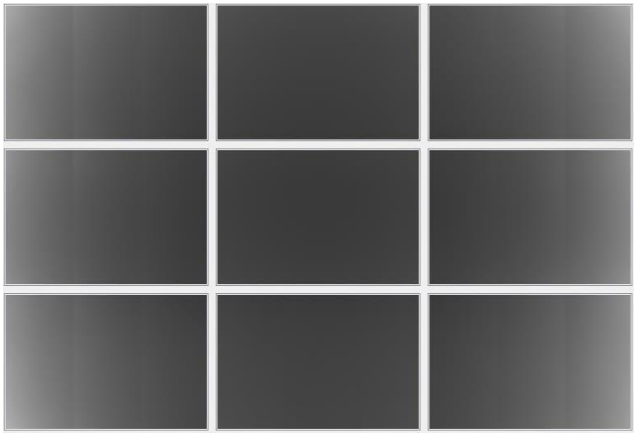
	PAN	R, G, NIR	B
Aperture	F11	F16	F11

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 11	1.00	3.00
00_01	f / 11	1.00	3.00
00_02	f / 11	1.00	4.00
00_03	f / 11	1.00	3.00
01_00	f / 11	1.00	2.00
01_01	f / 11	1.00	2.00
02_00	f / 11	1.00	3.00
02_01	f / 11	1.00	3.00
03_00	f / 11	1.00	2.00
04_00 (red)	f / 16	1.00	4.00
05_00 (green)	f / 16	1.00	3.00
06_00 (blue)	f / 11	1.00	3.00
07_00 (NIR)	f / 16	1.00	3.00

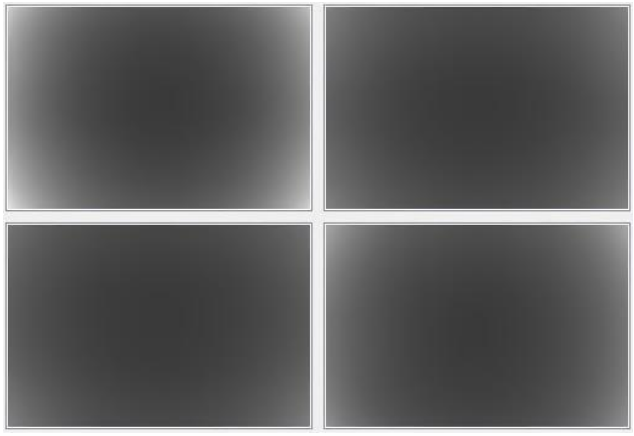
Calibration of Vignetting for Aperture Setting 5

Graphical Overview of Pan Sensor Gain Values:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensor Gain Values:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Calibration of Vignetting for Aperture Setting 6

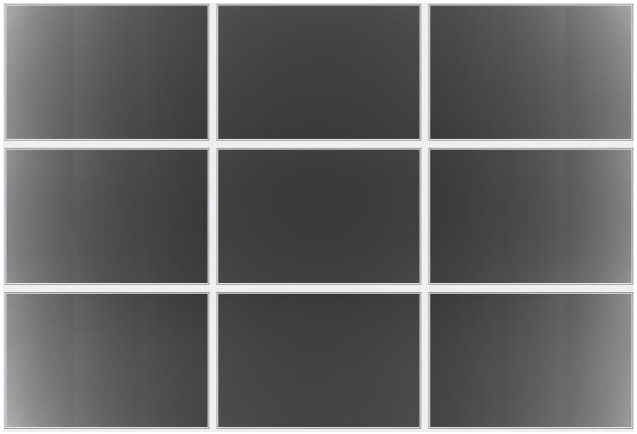
	PAN	R, G, NIR	B
Aperture	F13	F19	F13

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 13	1.00	3.00
00_01	f / 13	1.00	3.00
00_02	f / 13	1.00	4.00
00_03	f / 13	1.00	3.00
01_00	f / 13	1.00	2.00
01_01	f / 13	1.00	2.00
02_00	f / 13	1.00	3.00
02_01	f / 13	1.00	3.00
03_00	f / 13	1.00	2.00
04_00 (red)	f / 19	1.00	4.00
05_00 (green)	f / 19	1.00	3.00
06_00 (blue)	f / 13	1.00	3.00
07_00 (NIR)	f / 19	1.00	3.00

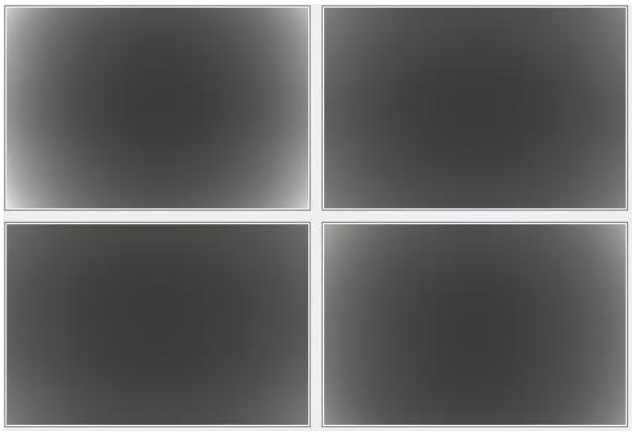
Calibration of Vignetting for Aperture Setting 6

Graphical Overview of Pan Sensor Gain Values:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensor Gain Values:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Calibration of Vignetting for Aperture Setting 7

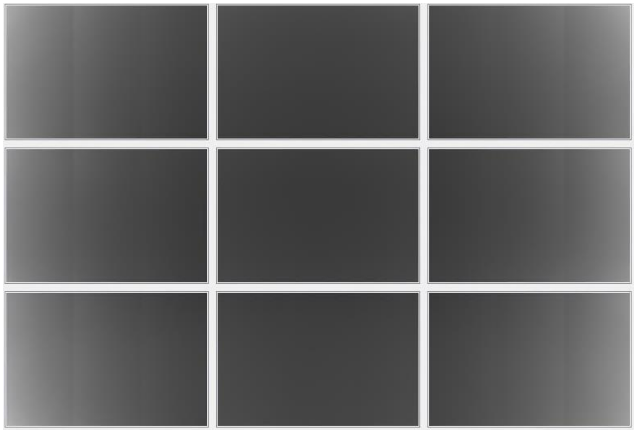
	PAN	R, G, NIR	B
Aperture	F16	F22	F16

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 16	1.00	3.00
00_01	f / 16	1.00	3.00
00_02	f / 16	1.00	4.00
00_03	f / 16	1.00	3.00
01_00	f / 16	1.00	2.00
01_01	f / 16	1.00	2.00
02_00	f / 16	1.00	3.00
02_01	f / 16	1.00	3.00
03_00	f / 16	1.00	2.00
04_00 (red)	f / 22	1.00	4.00
05_00 (green)	f / 22	1.00	3.00
06_00 (blue)	f / 16	1.00	3.00
07_00 (NIR)	f / 22	1.00	3.00

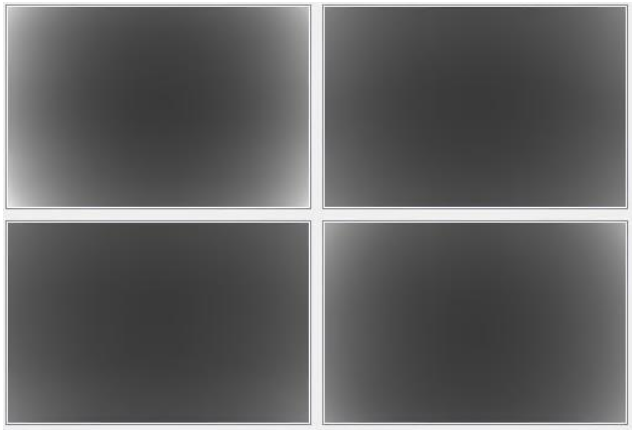
Calibration of Vignetting for Aperture Setting 7

Graphical Overview of Pan Sensor Gain Values:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensor Gain Values:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Calibration of Vignetting for Aperture Setting 8

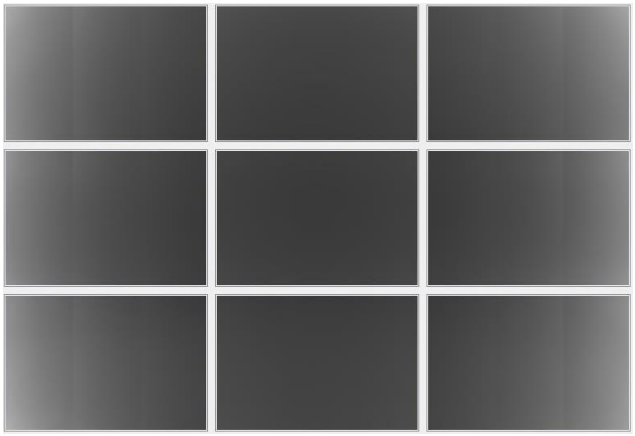
	PAN	R, G, NIR	B
Aperture	F22	F27	F22

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 22	1.00	3.00
00_01	f / 22	1.00	3.00
00_02	f / 22	1.00	4.00
00_03	f / 22	1.00	3.00
01_00	f / 22	1.00	2.00
01_01	f / 22	1.00	2.00
02_00	f / 22	1.00	3.00
02_01	f / 22	1.00	3.00
03_00	f / 22	1.00	2.00
04_00 (red)	f / 27	1.00	4.00
05_00 (green)	f / 27	1.00	3.00
06_00 (blue)	f / 22	1.00	3.00
07_00 (NIR)	f / 27	1.00	3.00

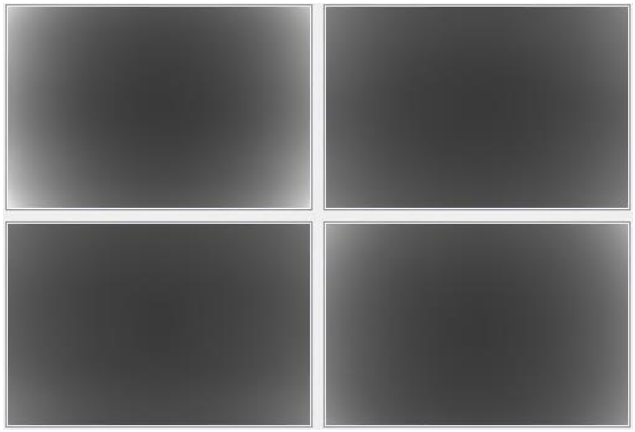
Calibration of Vignetting for Aperture Setting 8

Graphical Overview of Pan Sensor Gain Values:



00_00	01_00	00_01
02_00	03_00	02_01
00_02	01_01	00_03

Graphical Overview of Multispectral Sensor Gain Values:



04_00 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Defective Pixel Report:

Sensor		
Anomaly Type	X	Y

C00-00

PIXEL: 1318/3743
PIXEL: 1414/1364
PIXEL: 1695/ 738
PIXEL: 1803/4197
PIXEL: 2267/1263
PIXEL: 2284/4400
PIXEL: 2293/ 332
PIXEL: 2360/1247
PIXEL: 2569/3386
PIXEL: 2617/ 666
PIXEL: 3885/ 647
PIXEL: 3909/3509
PIXEL: 4141/3052
PIXEL: 4417/3968
PIXEL: 4851/1360
PIXEL: 4905/2138
PIXEL: 5059/2807
PIXEL: 5976/ 728
PIXEL: 6002/2188
PIXEL: 6440/2783
PIXEL: 4018/3892
PIXEL: 4018/3893
PIXEL: 4956/3705
PIXEL: 4957/3705
PIXEL: 4019/3892
PIXEL: 4019/3893
PIXEL: 4017/3892
PIXEL: 4956/3704
PIXEL: 3518/ 376
PIXEL: 3519/ 376
PIXEL: 1722/ 94
PIXEL: 2192/ 33
PIXEL: 63/ 18
COLUMN: 6757/2039

C00-01

PIXEL: 109/3301
PIXEL: 768/2165
PIXEL: 815/2156
PIXEL: 963/ 695
PIXEL: 1312/ 790
PIXEL: 2161/1326
PIXEL: 2182/3165
PIXEL: 2672/2623
PIXEL: 2844/3451
PIXEL: 3591/1391
PIXEL: 4102/3119
PIXEL: 4280/3677
PIXEL: 4330/4255
PIXEL: 4547/ 245

PIXEL: 4858/2507
PIXEL: 5279/2419
PIXEL: 5392/3221
PIXEL: 5418/ 220
PIXEL: 5670/1008
PIXEL: 6539/2603
PIXEL: 4668/4571
PIXEL: 4669/4571
PIXEL: 4670/4571
PIXEL: 4670/4572
PIXEL: 4669/4572
PIXEL: 4669/4570
PIXEL: 4668/4570
PIXEL: 4668/4572

C00-02

PIXEL: 1096/ 195
PIXEL: 1097/ 195
PIXEL: 101/1003
PIXEL: 464/ 134
PIXEL: 1015/3652
PIXEL: 2373/4146
PIXEL: 2413/ 734
PIXEL: 3533/2337
PIXEL: 4333/ 991
PIXEL: 4392/1373
PIXEL: 5381/2243
PIXEL: 5549/3102
PIXEL: 6259/1898
PIXEL: 6949/1862
PIXEL: 1095/ 196
PIXEL: 1096/ 196
PIXEL: 1098/ 195
PIXEL: 6329/ 602
PIXEL: 4189/4613
PIXEL: 4189/4612
PIXEL: 4189/4611
PIXEL: 4189/4609
PIXEL: 4190/4610
PIXEL: 4191/4612
PIXEL: 4191/4613

C00-03

PIXEL: 329/2295
PIXEL: 588/2222
PIXEL: 1025/1805
PIXEL: 1716/3137
PIXEL: 1871/4184
PIXEL: 2524/ 872
PIXEL: 2579/4605
PIXEL: 2810/3399
PIXEL: 2861/ 435
PIXEL: 2868/ 787
PIXEL: 3238/4183
PIXEL: 3503/3719
PIXEL: 3630/3104
PIXEL: 3777/ 684
PIXEL: 3913/4053
PIXEL: 4006/2198
PIXEL: 4105/3026
PIXEL: 4179/3674
PIXEL: 4265/2934

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PIXEL:   4299/ 748
PIXEL:   4413/2254
PIXEL:   4557/1357
PIXEL:   5429/1656
PIXEL:   5661/4548
PIXEL:   6495/4623
PIXEL:   6653/ 455
PIXEL:   1657/3399
COLUMN:  4632/1246
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C01-00

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PIXEL:    256/1880
PIXEL:   1453/4347
PIXEL:   1889/4571
PIXEL:   1931/4513
PIXEL:   2354/4401
PIXEL:   3231/1170
PIXEL:   3335/3505
PIXEL:   4143/2465
PIXEL:   4204/4377
PIXEL:   5571/ 226
PIXEL:   5963/3754
PIXEL:   6033/2785
PIXEL:     63/4246
PIXEL:     77/ 146
PIXEL:    358/4249
PIXEL:    792/ 811
PIXEL:    829/ 806
PIXEL:   2292/1180
PIXEL:   2293/1179
PIXEL:   2293/1180
PIXEL:   3878/ 642
PIXEL:   3878/ 643
PIXEL:   5322/2473
PIXEL:    357/4249
PIXEL:    358/4248
PIXEL:   2292/1179
PIXEL:   2293/1178
PIXEL:   3879/ 642
PIXEL:   3879/ 643
PIXEL:   5323/2473
PIXEL:   5323/2472
PIXEL:   5322/2472
PIXEL:   4548/4616
PIXEL:   4549/4616
PIXEL:   4548/4617
PIXEL:   4426/4594
PIXEL:   3184/1763
PIXEL:    117/1243
PIXEL:   3237/  32
PIXEL:   3236/  33
PIXEL:   3236/  32
PIXEL:   3236/  31
```

C01-01

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PIXEL:    792/ 601
PIXEL:   2537/1141
PIXEL:   2773/3945
PIXEL:   3713/4325
PIXEL:   4044/4089
PIXEL:   4224/ 918
PIXEL:   5198/2887
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PIXEL:  5482/ 746
PIXEL:   154/  40
PIXEL:   247/4265
PIXEL:   247/4266
PIXEL:   248/4265
PIXEL:   248/4266
PIXEL:  1799/1331
PIXEL:  1800/1331
PIXEL:  1801/1331
PIXEL:  2413/1096
PIXEL:    43/  32
PIXEL:  6799/ 364
PIXEL:  6799/ 363
PIXEL:  6797/ 363
PIXEL:  6797/ 362
PIXEL:  6799/ 362
PIXEL:   291/4609
PIXEL:   291/4608
PIXEL:   292/4610
PIXEL:   292/4609
PIXEL:   204/4574
PIXEL:   205/4574
```

C02-00

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PIXEL:   336/2712
PIXEL:   346/ 225
PIXEL:   485/1811
PIXEL:  2656/2560
PIXEL:  2972/1959
PIXEL:  4659/2662
PIXEL:  5041/2934
PIXEL:  5128/ 451
PIXEL:  6067/3816
PIXEL:  6084/1568
PIXEL:  6113/2915
PIXEL:  1594/1549
PIXEL:  1595/1549
PIXEL:  3158/ 707
PIXEL:  3159/ 707
PIXEL:  3158/ 708
PIXEL:  4939/ 498
PIXEL:  4941/ 500
PIXEL:  4941/ 499
PIXEL:  6929/1620
PIXEL:  6928/1620
PIXEL:  6929/1619
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C02-01

```
PIXEL:   183/2167
PIXEL:   673/4171
PIXEL:  1544/1256
PIXEL:  1766/2986
PIXEL:  2677/1352
PIXEL:  3510/ 842
PIXEL:  3625/1933
PIXEL:  3625/1934
PIXEL:  3888/1764
PIXEL:  4029/2247
PIXEL:  4130/1229
PIXEL:  4392/3718
PIXEL:  5898/2481
PIXEL:  6178/ 995
```

```
PIXEL:   6808/1786
PIXEL:   6934/3171
PIXEL:    145/3292
PIXEL:   3620/4353
PIXEL:   4988/2042
PIXEL:   4988/2043
PIXEL:   1928/  92
PIXEL:   1929/  93
PIXEL:   1930/  93
PIXEL:   1930/  94
PIXEL:   1929/  94
PIXEL:   1928/  93
PIXEL:    237/  89
PIXEL:   4989/2043
PIXEL:   2680/3465
PIXEL:   3621/4353
```

C03-00

```
PIXEL:     61/ 321
PIXEL:    398/1925
PIXEL:   1248/ 598
PIXEL:   1698/ 153
PIXEL:   2651/ 241
PIXEL:   2966/3691
PIXEL:   3091/3603
PIXEL:   3631/4106
PIXEL:   4923/1826
PIXEL:   4975/3230
PIXEL:   5830/1961
PIXEL:   6419/1235
PIXEL:   6547/4303
PIXEL:   6547/4304
PIXEL:   6548/4304
PIXEL:   6734/3883
PIXEL:    513/  81
PIXEL:    514/  81
PIXEL:    515/  81
PIXEL:    516/  81
PIXEL:    512/  81
PIXEL:    891/  93
PIXEL:    892/  93
PIXEL:    215/ 282
PIXEL:    215/ 281
PIXEL:    214/ 281
PIXEL:    216/ 281
PIXEL:    216/ 282
PIXEL:    214/ 282
PIXEL:   2375/ 459
PIXEL:   6087/4144
PIXEL:   6086/4144
PIXEL:   6087/4143
PIXEL:     46/4590
```

C04-00

```
PIXEL:    547/1916
PIXEL:   1606/3487
PIXEL:   3624/2130
PIXEL:   4642/1226
PIXEL:   6695/2185
PIXEL:     28/  84
```

C05-00

```
PIXEL:   481/ 463
PIXEL:   496/4250
PIXEL:   550/ 114
PIXEL:  2633/3025
PIXEL:  5070/2279
PIXEL:  5389/2146
PIXEL:  5917/4297
PIXEL:  6229/1855
PIXEL:  6642/1054
PIXEL:  2247/ 504
PIXEL:  6027/  24
PIXEL:  1563/4208
```

C06-00

```
PIXEL:   565/4024
PIXEL:   389/3129
PIXEL:   475/4328
PIXEL:   595/ 806
PIXEL:   631/3351
PIXEL:   662/  15
PIXEL:  1076/ 352
PIXEL:  1147/3181
PIXEL:  1585/3978
PIXEL:  1768/2974
PIXEL:  2043/4127
PIXEL:  2401/ 615
PIXEL:  3140/1384
PIXEL:  3159/2210
PIXEL:  3686/2795
PIXEL:  4187/ 805
PIXEL:  4637/1646
PIXEL:  4675/3160
PIXEL:  4827/2221
PIXEL:  4869/2678
PIXEL:  5199/1719
PIXEL:  5328/2995
PIXEL:  5380/2709
PIXEL:  5778/1849
PIXEL:  5908/3136
PIXEL:  6448/1813
PIXEL:  6656/3452
PIXEL:  6688/2208
PIXEL:  6773/3340
PIXEL:   565/4023
PIXEL:  4951/4043
PIXEL:  4951/4044
PIXEL:  4952/4044
PIXEL:  6699/ 198
PIXEL:  1076/ 353
```

C07-00

```
PIXEL:  1308/1694
PIXEL:  1557/4267
PIXEL:  1756/ 761
PIXEL:  2150/ 502
PIXEL:  2193/2235
PIXEL:  2626/2609
PIXEL:  3366/3708
PIXEL:  5567/3560
PIXEL:  6391/ 721
```

```
PIXEL:   405/4430
PIXEL:  1234/  46
PIXEL:  1234/  47
PIXEL:  1235/  49
PIXEL:  1236/  45
PIXEL:  1236/  46
PIXEL:  1235/  46
PIXEL:  1476/2280
 PIXEL:  2569/3386
PIXEL:   148/1312
PIXEL:   209/3986
PIXEL:   438/ 669
PIXEL:   466/ 681
PIXEL:   659/ 998
PIXEL:   695/ 353
PIXEL:   850/ 217
PIXEL:  2402/4014
PIXEL:  4018/3892
PIXEL:  4018/3893
PIXEL:  4956/3705
PIXEL:  4957/3705
PIXEL:    63/  18
PIXEL:  2671/4576
```

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.

Calibration Report

Shutter Calibration

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-50319383-f80**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Panchromatic Camera:	**4 * Prontor Magnetic 0** **Prontor-Werk Alfred Gauthier GmbH, Germany**
Multispectral Camera:	**4 * Prontor Magnetic 0** **Prontor-Werk Alfred Gauthier GmbH, Germany**
Date of Calibration:	**Jan-14-2016**
Date of Report:	**Jan-28-2016**
Revision of Camera:	**Rev03**
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 4CCD)	12 15 42 95	11.26	11.61	12.09	12.41	12.7	12.99	13.23	13.69	+/- 0.2
C1 (Pan 2CCD V)	12 15 42 86	10.73	11.1	11.55	11.95	12.31	12.56	12.64	12.97	+/- 0.2
C2 (Pan 2CCD H)	12 15 43 00	11.55	11.93	12.55	12.83	13.32	13.67	13.85	13.95	+/- 0.2
C3 (Pan Central)	12 15 42 98	11.49	11.99	12.41	12.93	13.14	13.52	13.52	14.12	+/- 0.2
C4 (Red)	12 12 05 88	12.61	12.61	12.84	13.22	13.22	13.28	13.28	13.59	+/- 0.2
C5 (Green)	12 12 06 38	13.35	13.35	13.7	13.87	14.05	14.23	14.23	14.36	+/- 0.2
C6 (Blue)	12 12 06 30	12.25	12.4	12.4	12.59	12.77	13.13	13.13	13.48	+/- 0.2
C7 (NIR)	12 12 05 87	14	14.13	14.48	14.68	14.98	14.98	15.11	15.11	+/- 0.2

Calibration Report

Electronics and Sensor Calibration

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-50319383-f80**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Panchromatic Camera:	**9 * FTF7046-M Area CCD Sensor by DALSA**
Multispectral Camera:	**4 * FTF7046-M Area CCD Sensor by DALSA**
Date of Calibration:	**Jan-14-2016**
Date of Report:	**Jan-28-2016**
Revision of Camera:	**Rev03**
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]
00_00	FTF7046-M	15 1276/034	24.40
00_01	FTF7046-M	15 1276/035	24.20
00_02	FTF7046-M	15 1276/033	25.00
00_03	FTF7046-M	15 1276/032	24.20
01_00	FTF7046-M	14 9219/032	23.60
01_01	FTF7046-M	14 8779/045	24.40
02_00	FTF7046-M	14 9895/006	24.20
02_01	FTF7046-M	15 1276/023	23.40
03_00	FTF7046-M	15 0541/009	23.60
04_00 (red)	FTF7046-M	15 0541/037	23.60
05_00 (green)	FTF7046-M	15 0541/033	23.60
06_00 (blue)	FTF7046-M	15 7349/048	24.40
07_00 (NIR)	FTF7046-M	15 0541/031	23.40

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 1276/034	13300
00_01	FTF7046-M	15 1276/035	13210
00_02	FTF7046-M	15 1276/033	13140
00_03	FTF7046-M	15 1276/032	13470
01_00	FTF7046-M	14 9219/032	13720
01_01	FTF7046-M	14 8779/045	13900
02_00	FTF7046-M	14 9895/006	13970
02_01	FTF7046-M	15 1276/023	14130
03_00	FTF7046-M	15 0541/009	13540
04_00 (red)	FTF7046-M	15 0541/037	13950
05_00 (green)	FTF7046-M	15 0541/033	13920
06_00 (blue)	FTF7046-M	15 7349/048	13620
07_00 (NIR)	FTF7046-M	15 0541/031	13290

Calibration Report

Summary

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-50319383-f80**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Date of Calibration:	**Jan-14-2016**
Date of Report:	**Jan-28-2016**
Revision of Camera:	**Rev03**
Version of Report:	**V01**

The following calibrations have been performed for the above mentioned digital aerial mapping camera:

- Geometric Calibration
- Verification of Lens Quality and Sensor Adjustment
- Radiometric Calibration
- Calibration of Defective Pixel Elements
- 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

Ing. Peter Prassl
Senior Calibration Engineer
Vexcel Imaging GmbH