Calibration Report

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-00017501-f80**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Date of Calibration:	**Feb-11-2015**
Date of Report:	**Mar-20-2015**
Revision of Camera:	**Rev01.00**
Version of Report:	**V01**

Calibration Report

Geometric Calibration

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-00017501-f80**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Panchromatic Camera:	**ck = 79.800 mm**
Multispectral Camera:	**ck = 79.800 mm**
Date of Calibration:	**Feb-11-2015**
Date of Report:	**Mar-20-2015**
Revision of Camera:	**Rev01.00**
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	-0.104 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	-0.104 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

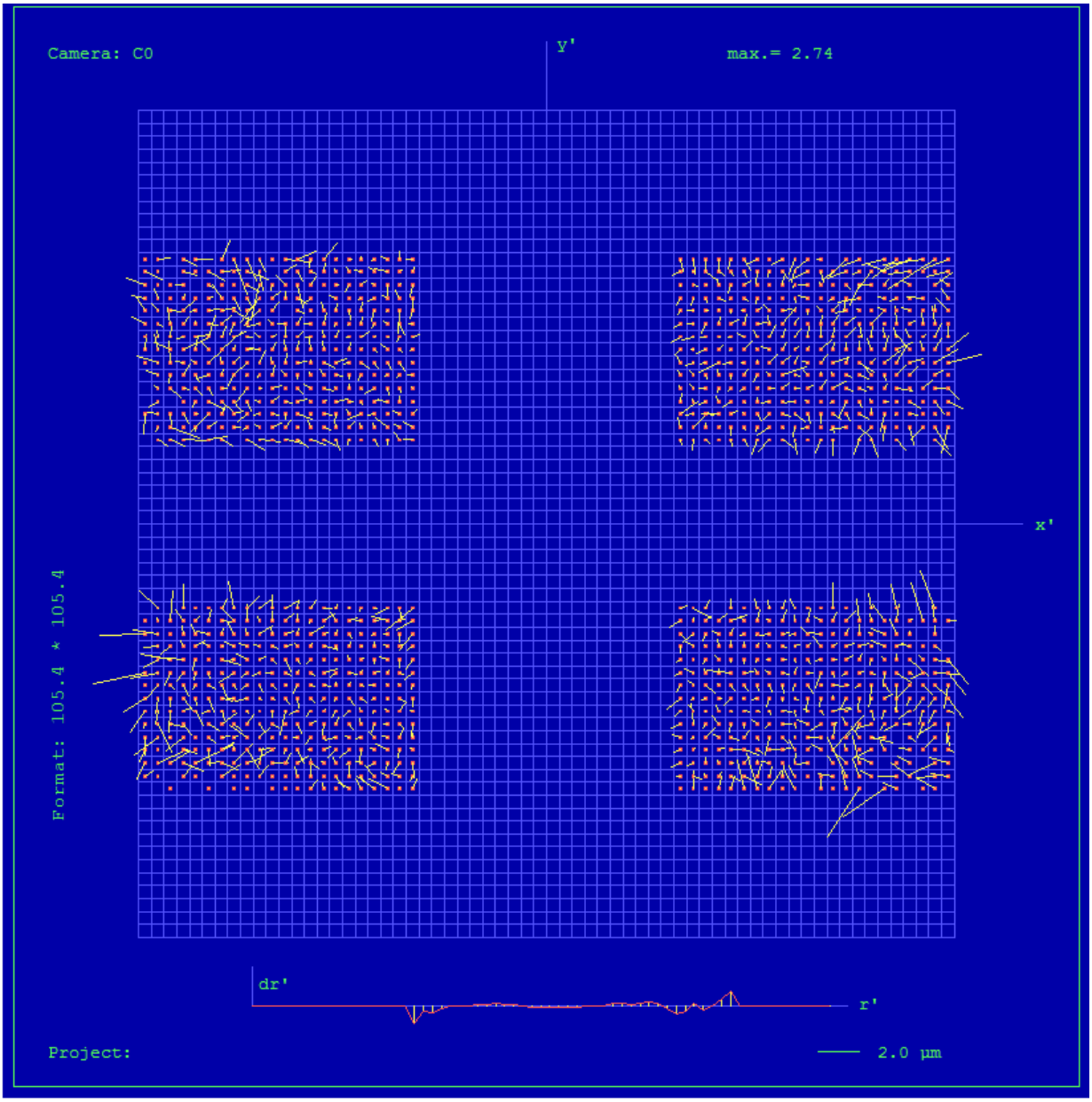
Cone # C0		
Lens	Linos Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linos GmbH, Germany	
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH	
Image Extent (nominally)	(-34.28, -52.22)mm	(34.28, 52.22)mm
Extent CCD 0	(-34.28, -52.22)mm	(-10.32, -16.28)mm
Extent CCD 1	(-34.28, 16.28)mm	(-10.32, 52.22)mm
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	8.1856945E-02 mm ± 0.0008 mm	1.0549482E-01 mm ± 0.0012 mm	-2.7158741E-02 gon ± 0.0001 gon	1.0064344 ± 0.00005
CCD1	1.0873511E-01 mm ± 0.0008 mm	-4.1700816E-02 mm ± 0.0012 mm	0.0000000 gon	1.0067468 ± 0.00005
CCD2	4.8585581E-02 mm ± 0.0008 mm	7.3177163E-02 mm ± 0.0012 mm	-3.0996614E-02 gon ± 0.0001 gon	1.0063298 ± 0.00005
CCD3	6.5765592E-02 mm ± 0.0008 mm	-5.6179179E-03 mm ± 0.0012 mm	3.4601202E-02 gon ± 0.0001 gon	1.0065161 ± 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]	36.2	68.0	98.2	126.6	150.9	165.9	164.1	135.4	67.3	-55.4	-250.4	-537.9	-940.5

Cone 0, Residual Error Diagram

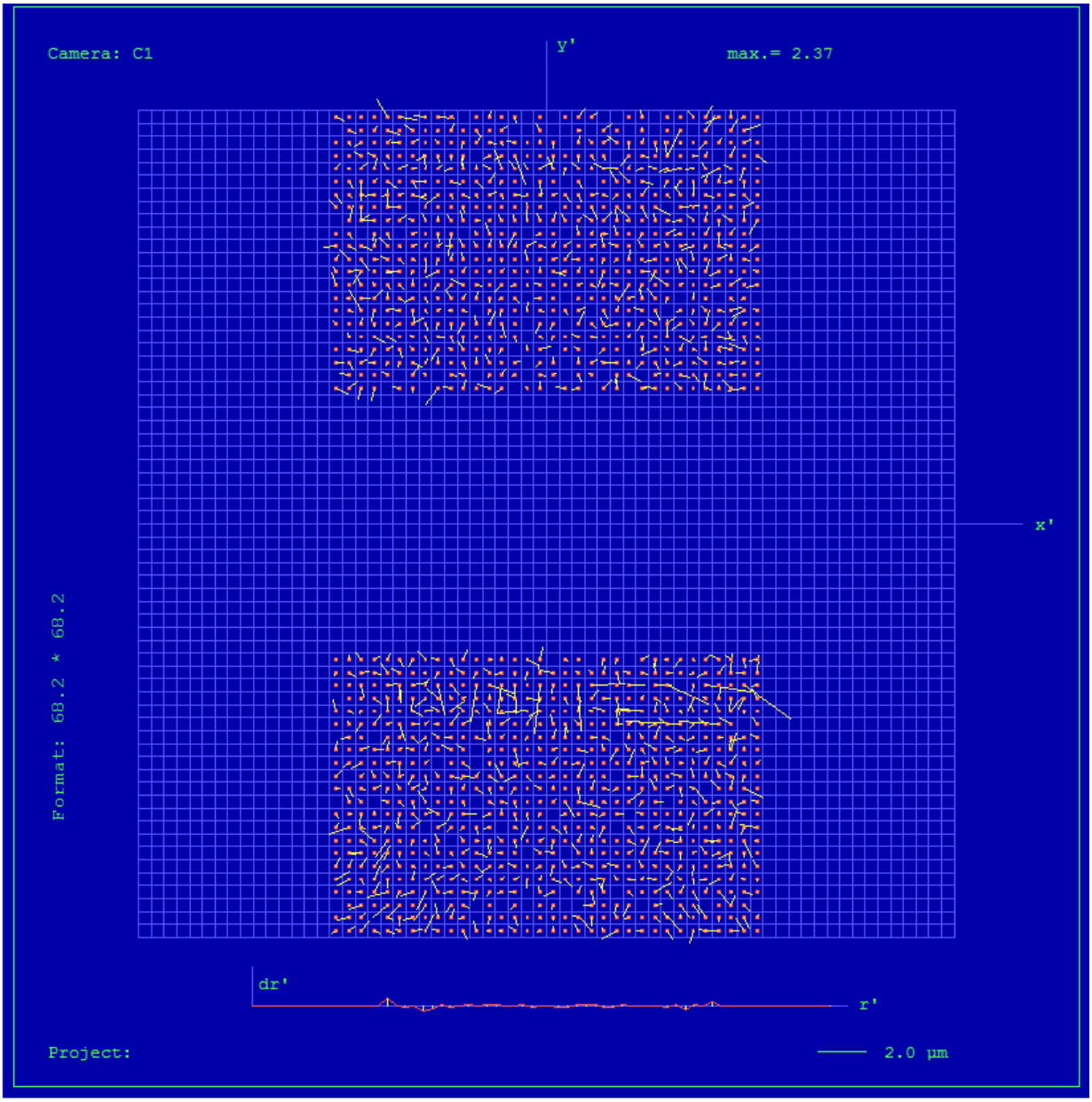


Residual Error (RMS): 1.43 µm

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	7.1392872E-02 mm ± 0.0012 mm		-2.6516788E-02 mm ± 0.0009 mm		0.0000000 gon		1.0023895 ± 0.00005					
CCD1	3.5416258E-02 mm ± 0.0012 mm		-9.9982107E-03 mm ± 0.0009 mm		3.5481155E-02 gon ± 0.0001 gon		1.0023664 ± 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]	13.7	26.2	38.5	49.6	56.4	53.8	34.5	-10.6	-93.0	-225.9	-424.8	-707.1

Cone 1, Residual Error Diagram



Residual Error (RMS): 1.15 µm

Cone 2, Parametric Description, Not Effective in Output Image

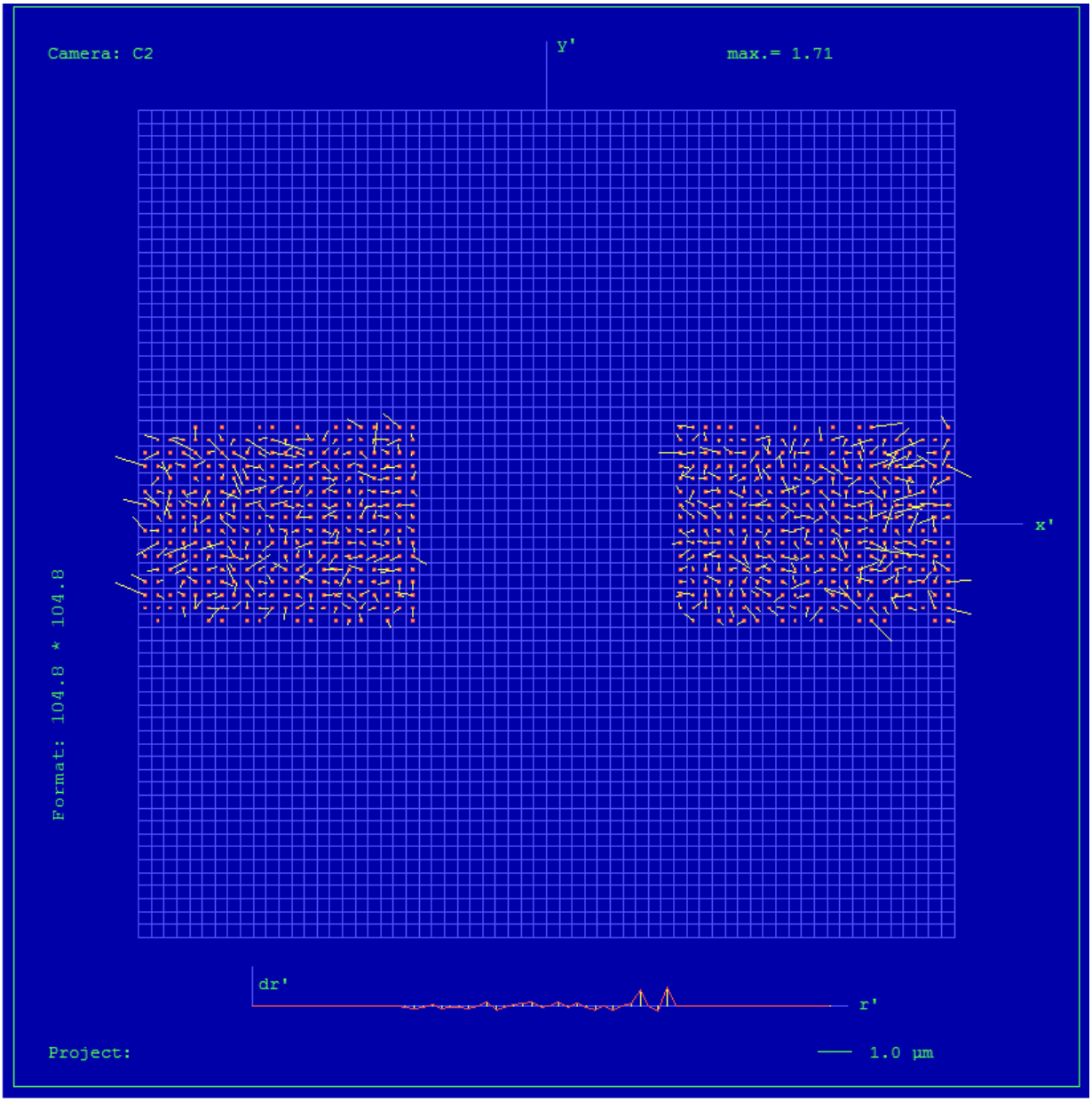
Cone # C2		
Lens	Linos Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linos GmbH, Germany	
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH	
Image Extent (nominally)	(-11.98, -52.22)mm	(11.98, 52.22)mm
Extent CCD 0	(-11.98, -52.22)mm	(11.98, -16.28)mm
Extent CCD 1	(-11.98, 16.28)mm	(11.98, 52.22)mm

Parameters	Shift X	ShiftY	Rotation	Scale
CCD0	6.1833971E-02 mm ± 0.0007 mm	7.1906884E-02 mm ± 0.0030 mm	-4.6063624E-02 gon ± 0.0001 gon	1.0069575 ± 0.00005
CCD1	7.0200334E-02 mm ± 0.0007 mm	2.1428379E-02 mm ± 0.0030 mm	0.0000000 gon	1.0072300 ± 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]	36.7	70.7	104.0	136.0	163.8	181.9	182.7	156.0	89.1	-32.9	-227.6	-514.8

Cone 2, Residual Error Diagram

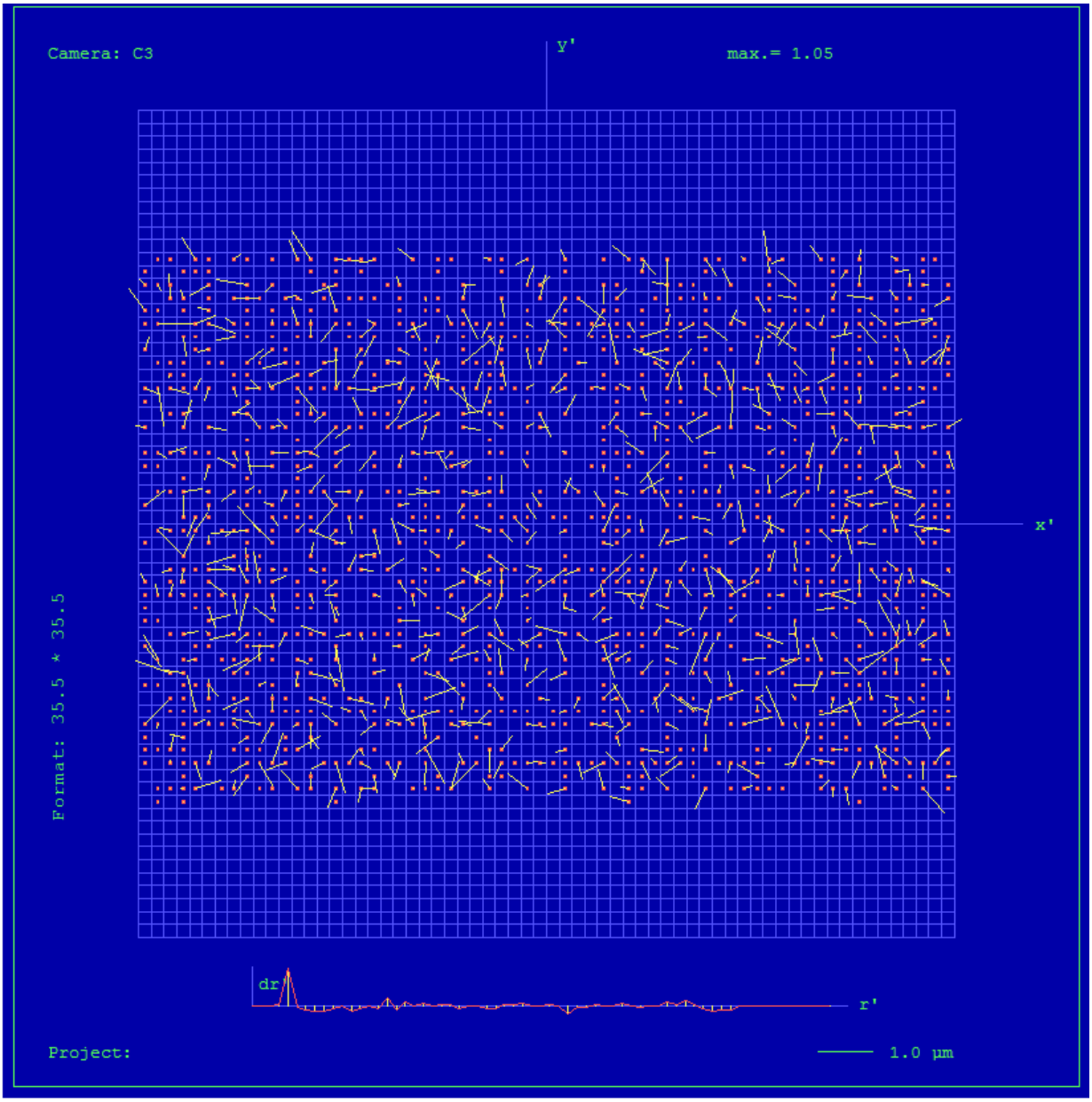


Residual Error (RMS): 1.08 µm

Cone 3, Parametric Description, Not Effective in Output Image

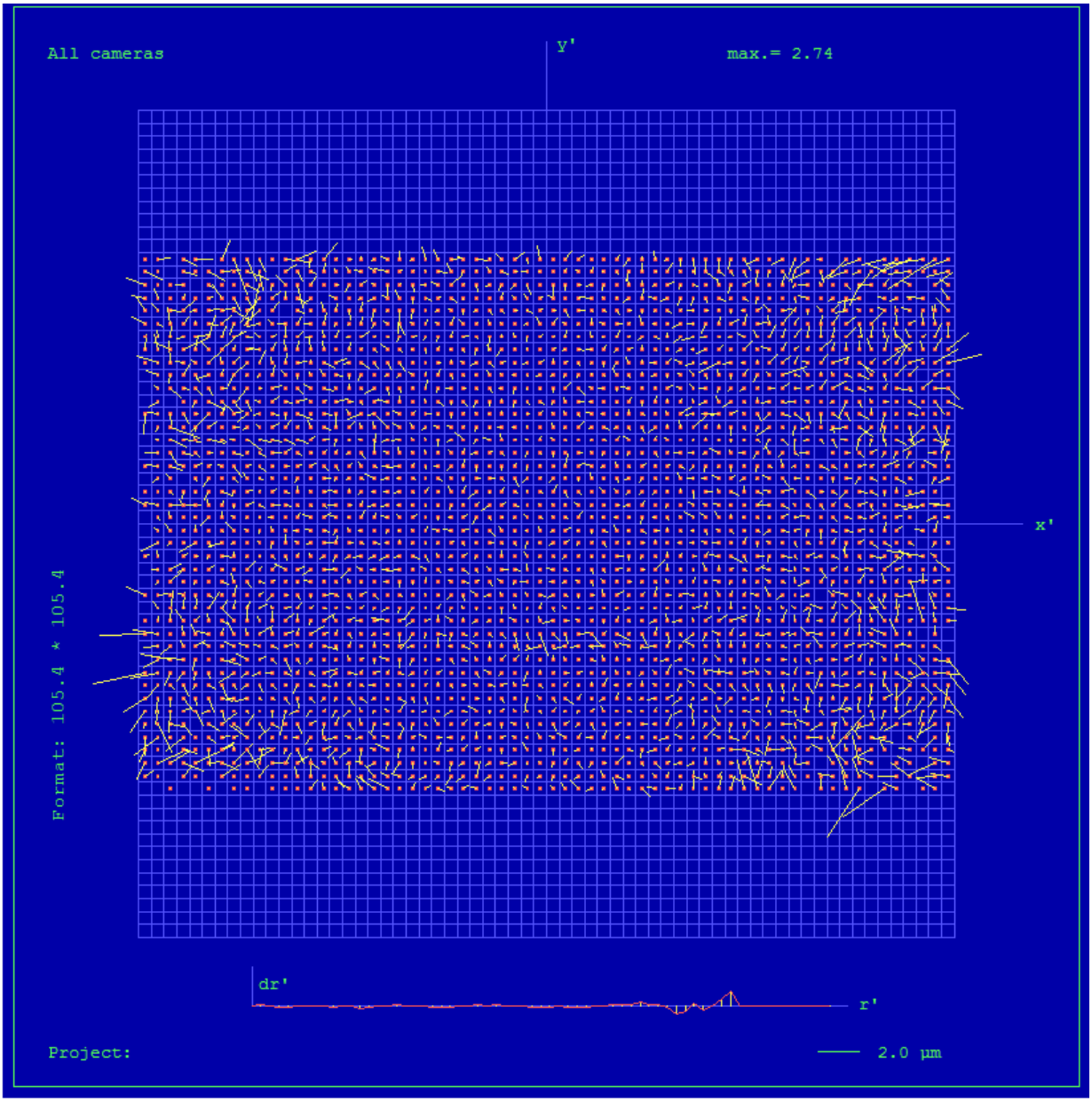
Cone # C3					
Lens	Linos Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linos GmbH, Germany				
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH				
Image Extent (nominally)	(-11.98, -17.97)mm		(11.98, 17.97)mm		
Extent CCD 0	(-11.98, -17.97)mm		(11.98 , 17.97)mm		
Parameters	Shift X	ShiftY	Rotation	Scale	
CCD0	7.1099143E-02 mm ± 0.0016 mm	-7.2709915E-03 mm ± 0.0038 mm	0.0000000 gon	0.9997681 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	0.6	1.9	2.4	1.4	-0.9

Cone 3, Residual Error Diagram



Residual Error (RMS): 0.62 µm

Full Pan Image, Residual Error Diagram



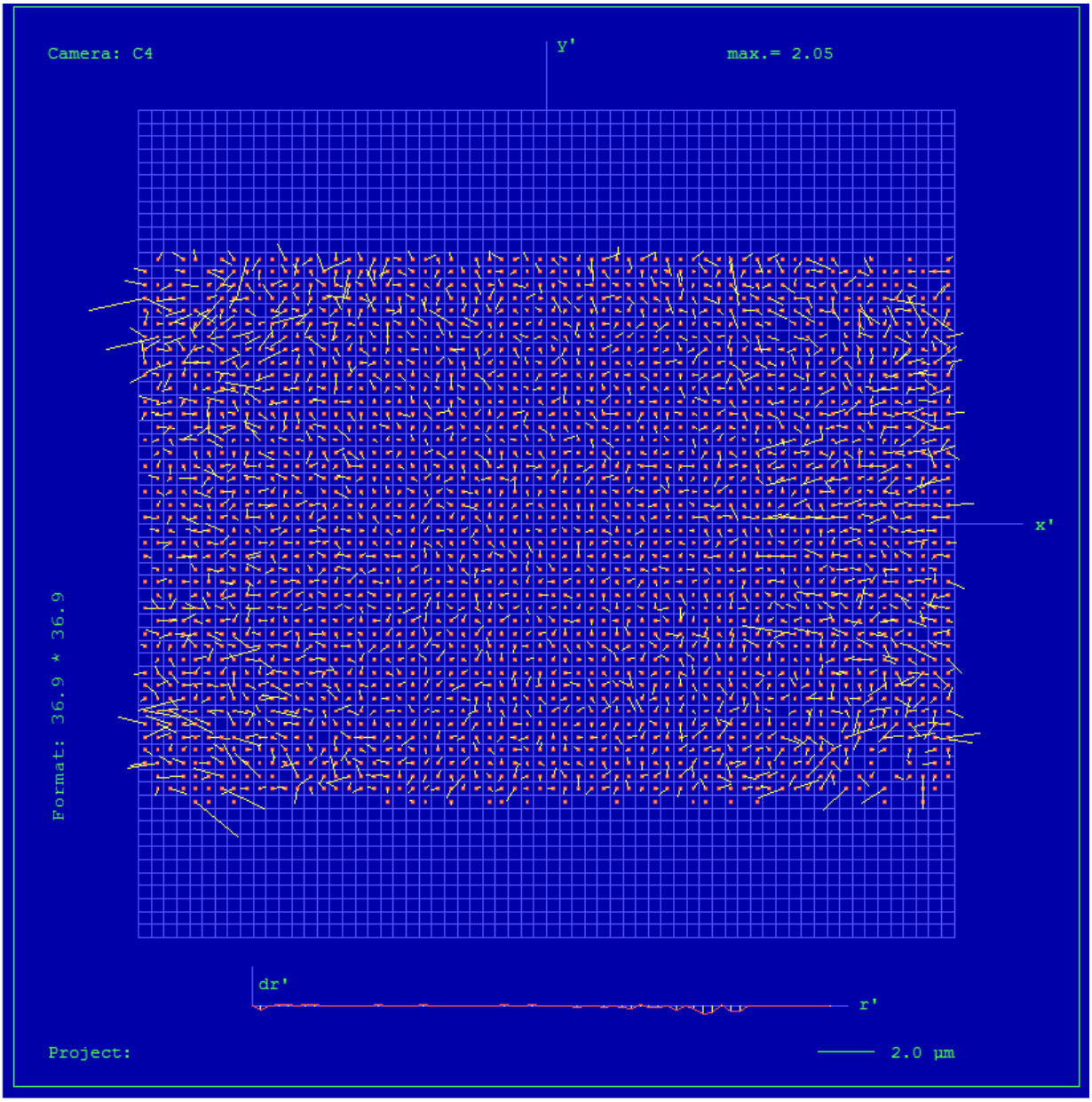
Residual Error (RMS): 1.02 µm

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	7.2003511E-02 mm ± 0.0001 mm	-4.9306713E-02 mm ± 0.0001 mm	0.0000000 gon	1.0531988 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	115.7	178.3	167.3	115.3	119.1

Cone 4, Residual Error Diagram

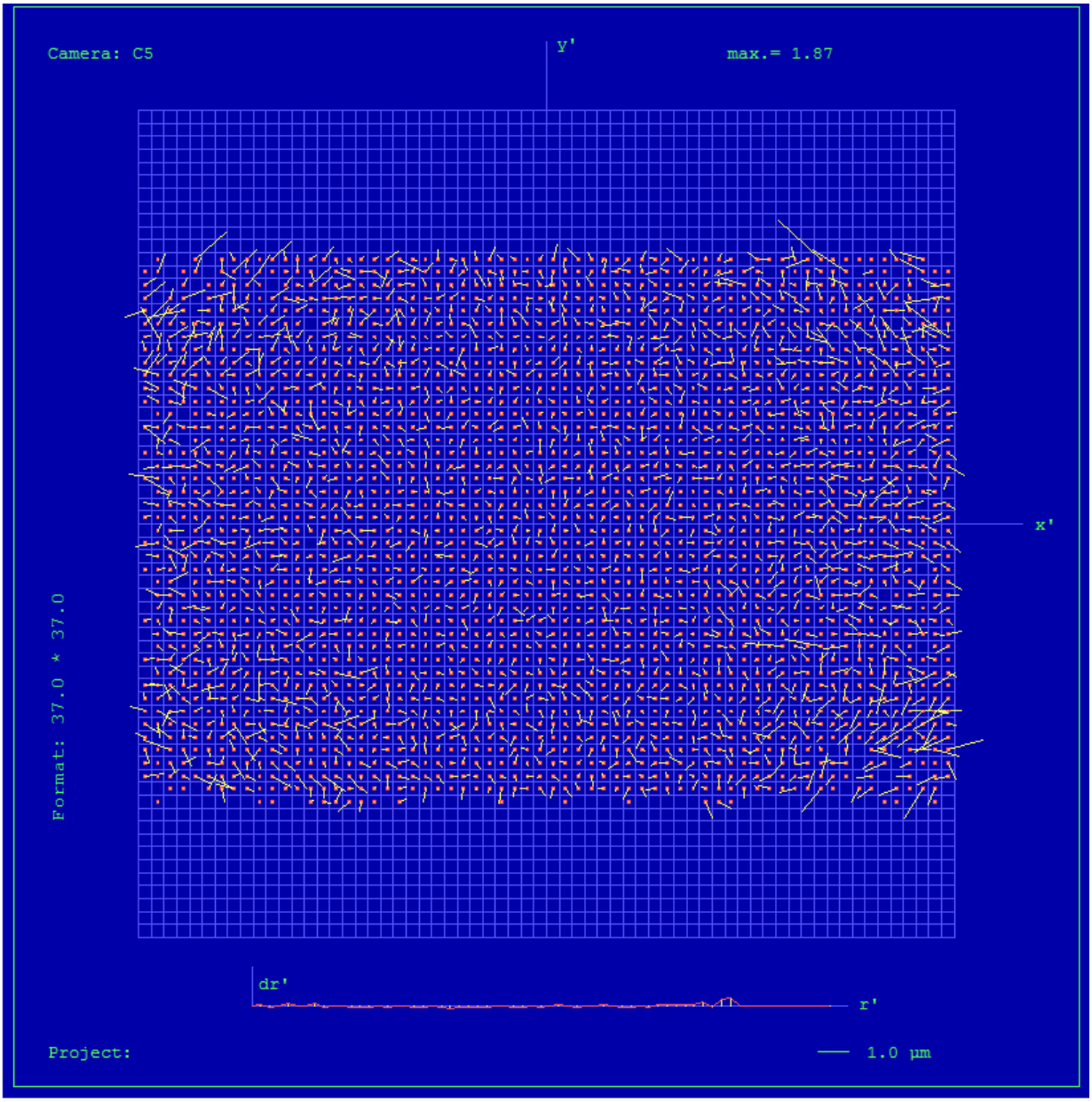


Residual Error (RMS): 0.90 µm

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	3.3840290E-02 mm ± 0.0001 mm	-9.7161956E-02 mm ± 0.0001 mm	0.0000000 gon	1.0552505 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	114.3	175.9	165.2	114.4	115.1

Cone 5, Residual Error Diagram

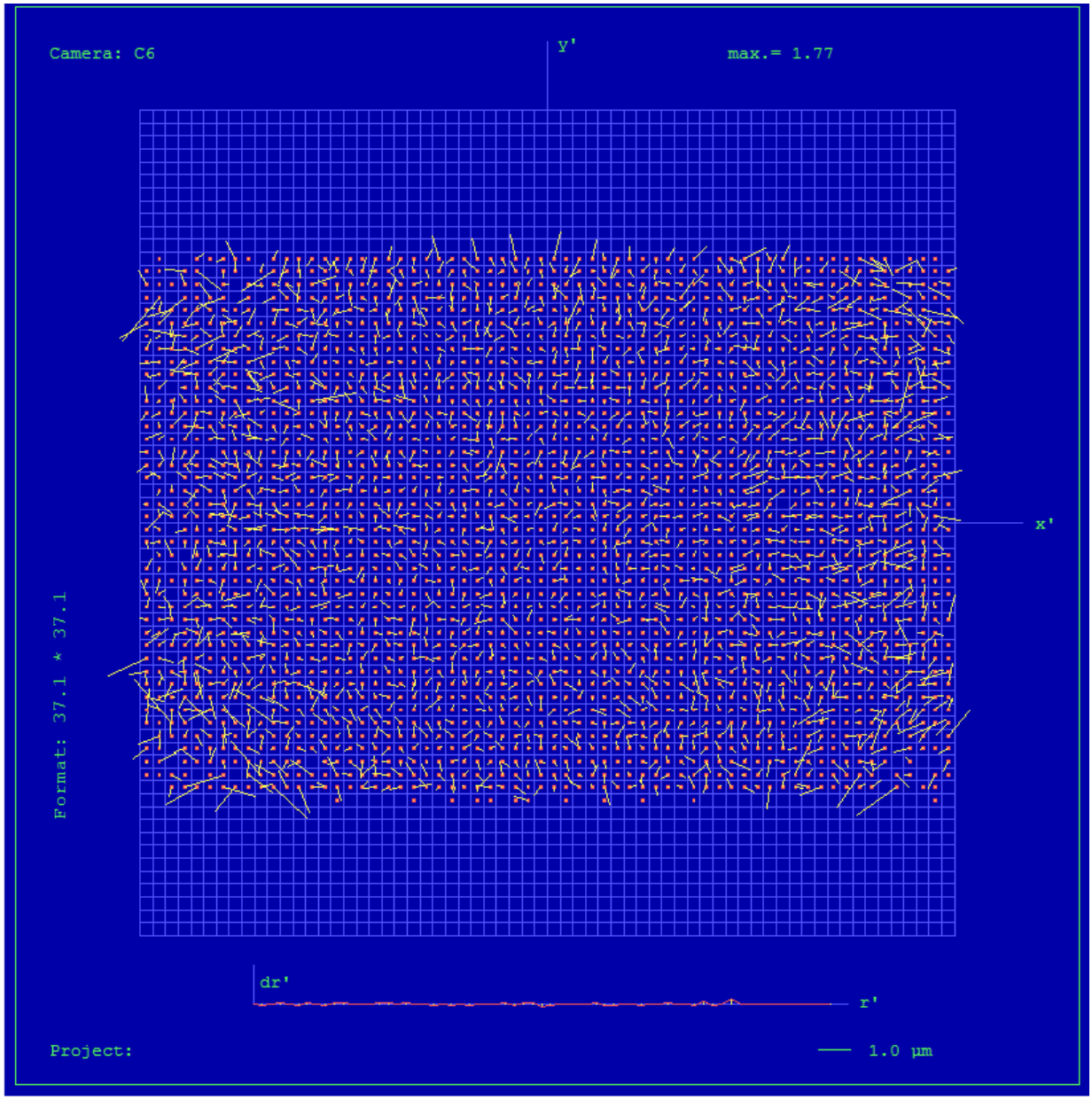


Residual Error (RMS): 0.87 µm

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	8.6082825E-02 mm ± 0.0001 mm	-5.5401058E-02 mm ± 0.0001 mm	0.0000000 gon	1.0535126 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	112.2	172.1	160.7	109.3	108.2

Cone 6, Residual Error Diagram

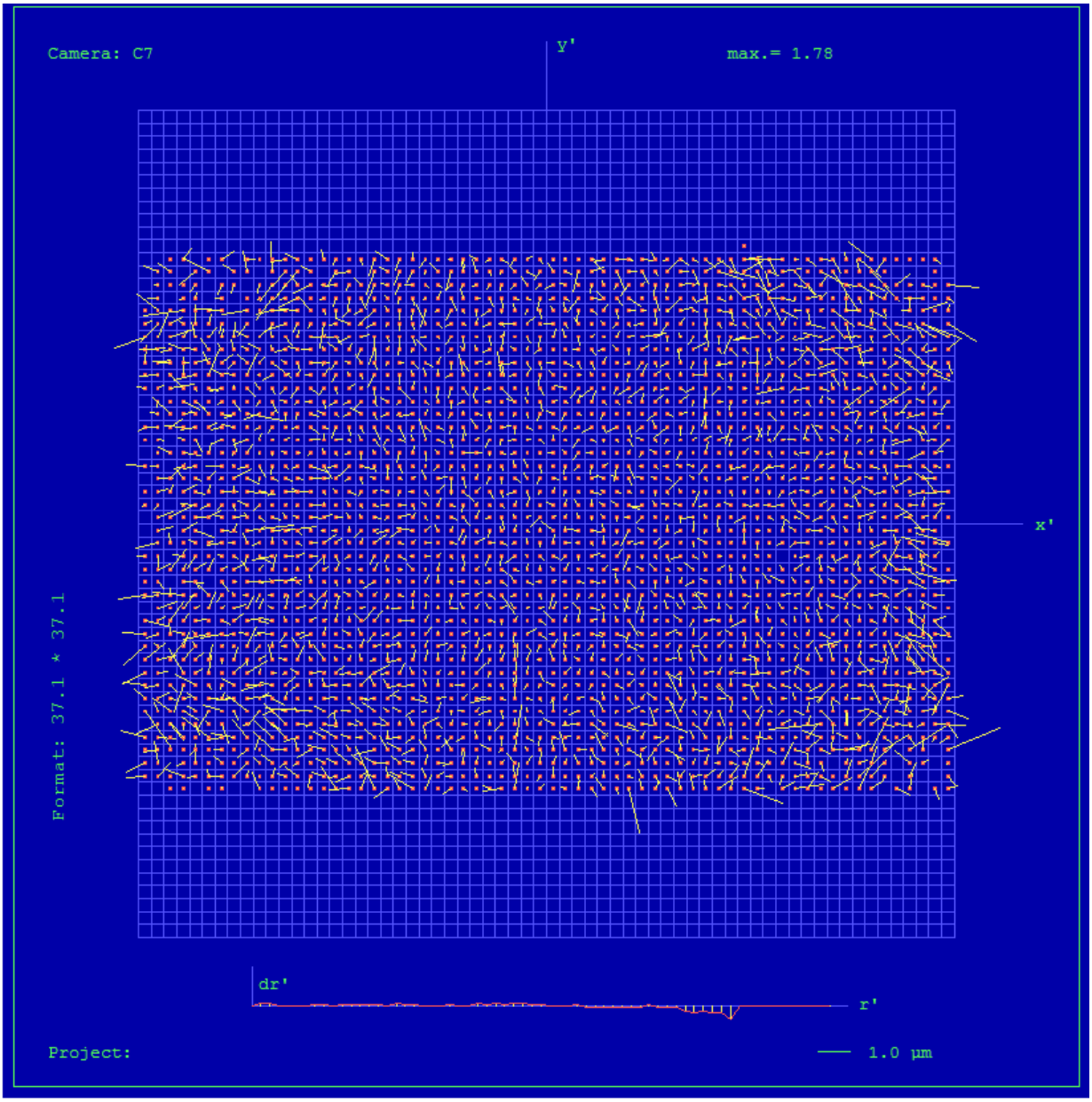


Residual Error (RMS): 0.90 µm

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	9.7030692E-02 mm ± 0.0001 mm	1.2481036E-02 mm ± 0.0001 mm	0.0000000 gon	1.0575659 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	117.0	180.1	168.4	116.2	129.9

Cone 7, Residual Error Diagram



Residual Error (RMS): 0.91 µm

Explanations:

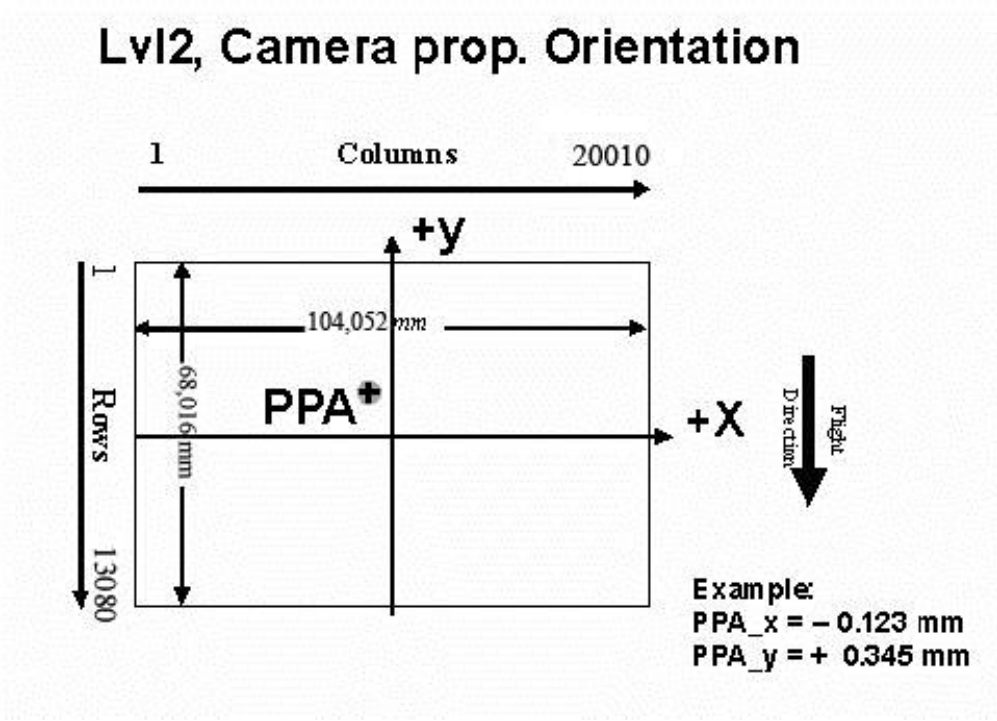
1) Calibration Method:

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 : 19278
Number of point measurements for the multispectral camera : 75368

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

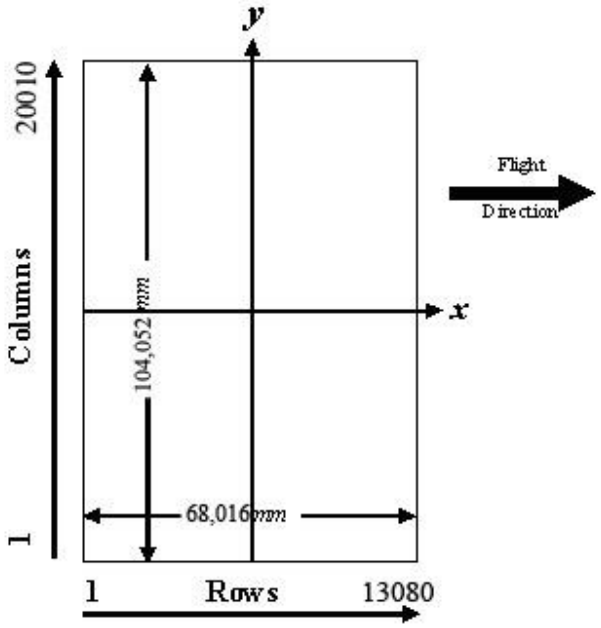
2) Level 2 Image Coordinate System: PAN 20010 pixel by 13080 pixel
MS 6670 pixel by 4360 pixel



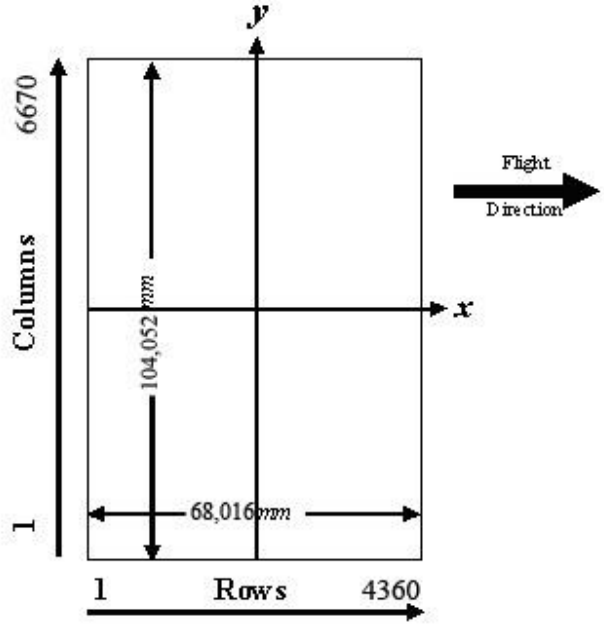
The image coordinate system of the Level 2 images is shown in the above figure. The level 2 image consists of 20010 columns and 13080 rows, which leads to a total image format of 104.052 x 68.016 mm. The coordinate of the principal point in the level 2 image is given on page 3 of this report. The above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

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

PAN 20010 pixel by 13080 pixel
MS 6670 pixel by 4360 pixel



Panchromatic Image Format



Multispectral Image Format

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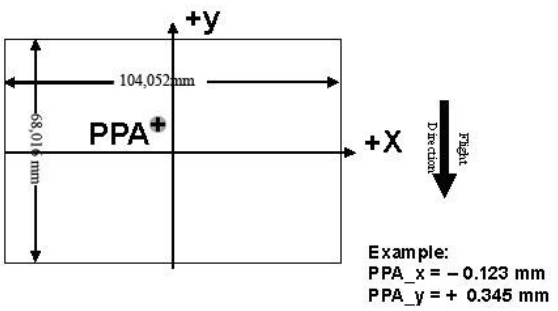
4) Position of Principal Point in Level 3 Image

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	-	-0.104	0.000
Level 3	0	-0.104	0.000
Level 3	90	0.000	0.104
Level 3	180	0.104	0.000
Level 3	270	0.000	-0.104

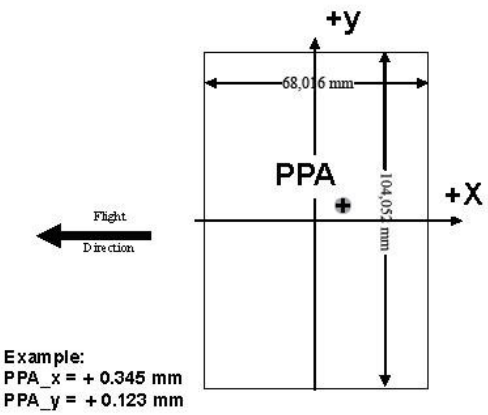
The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

Lvl3, Rotation 0 deg clockwise



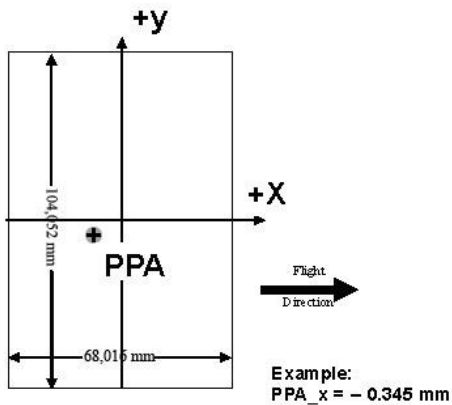
Example:
PPA_x = – 0.123 mm
PPA_y = + 0.345 mm

Lvl3, Rotation 90 deg clockwise



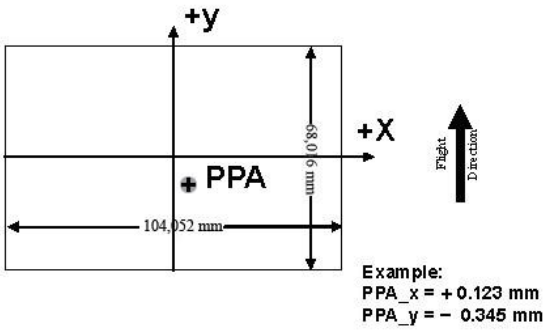
Example:
PPA_x = + 0.345 mm
PPA_y = + 0.123 mm

Lvl3, Rotation 270 deg clockwise



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

Lvl3, Rotation 180 deg clockwise



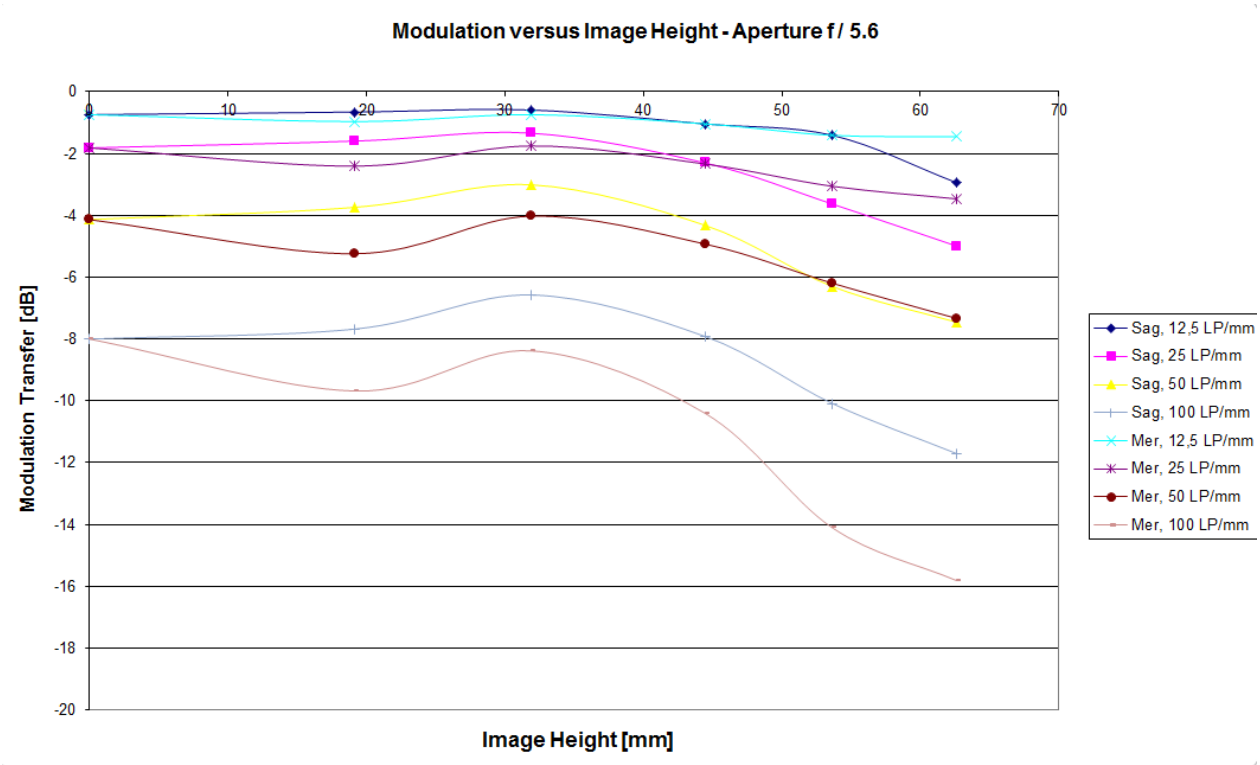
Example:
PPA_x = + 0.123 mm
PPA_y = – 0.345 mm

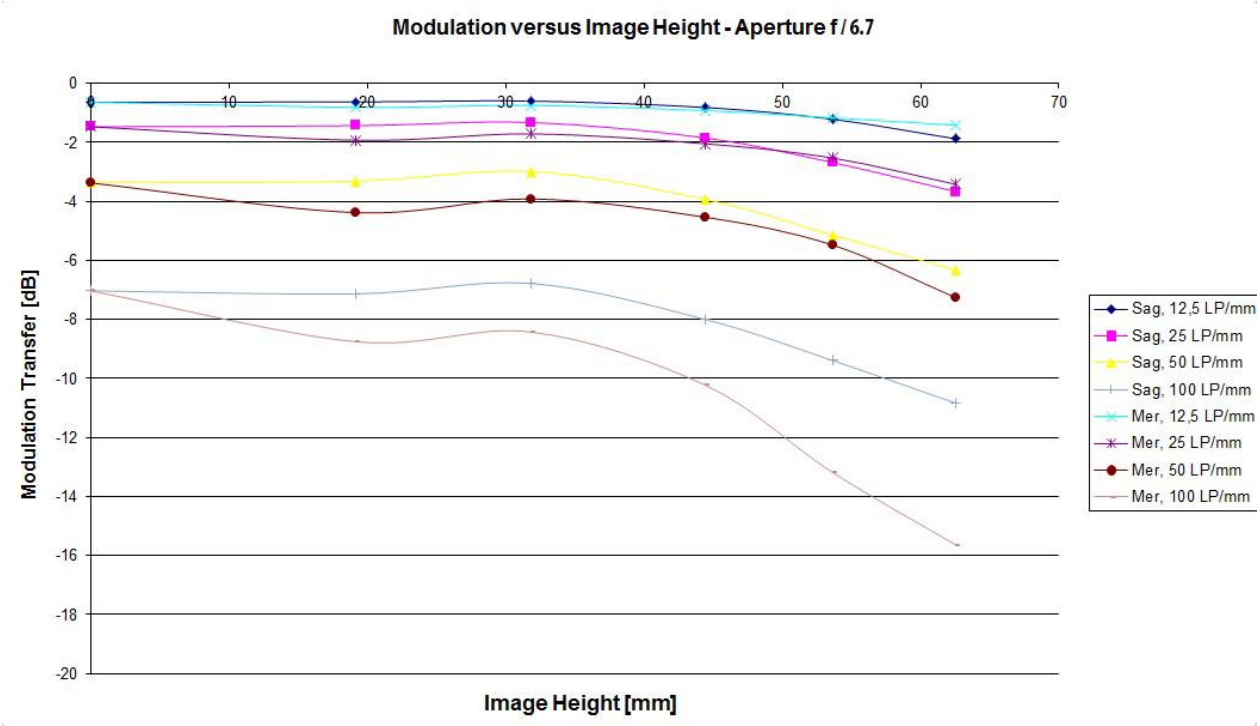
Lens Resolving Power

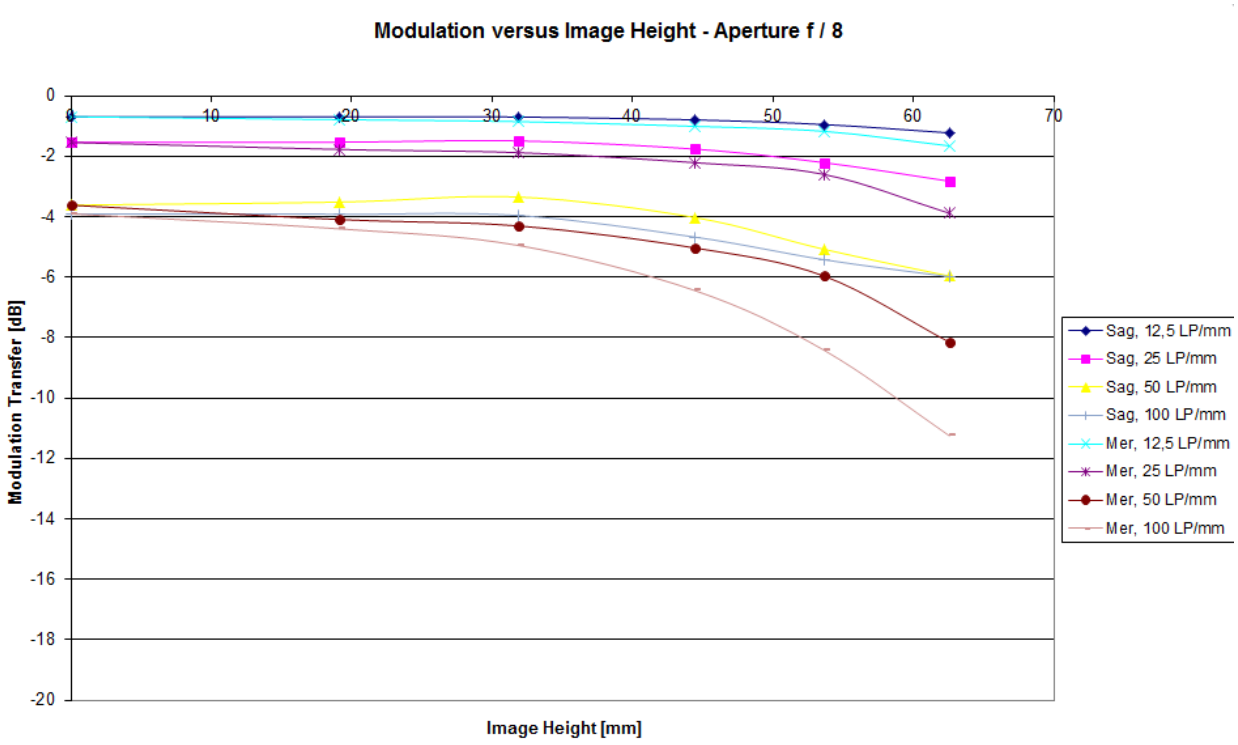
The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones. Please note that these values have been calculated and can vary up to 10% with optics from production (especially at high LP's).

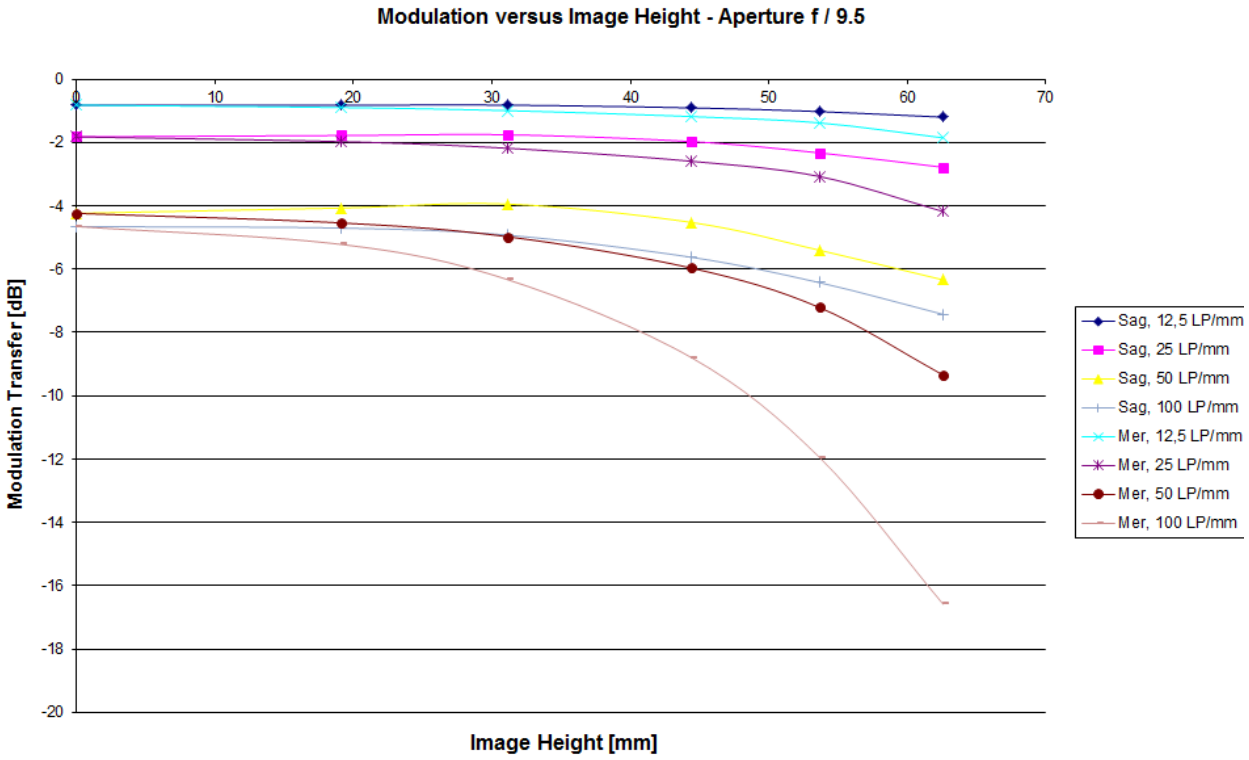
The curves are given for the meridonial (tangential) and sagital (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

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

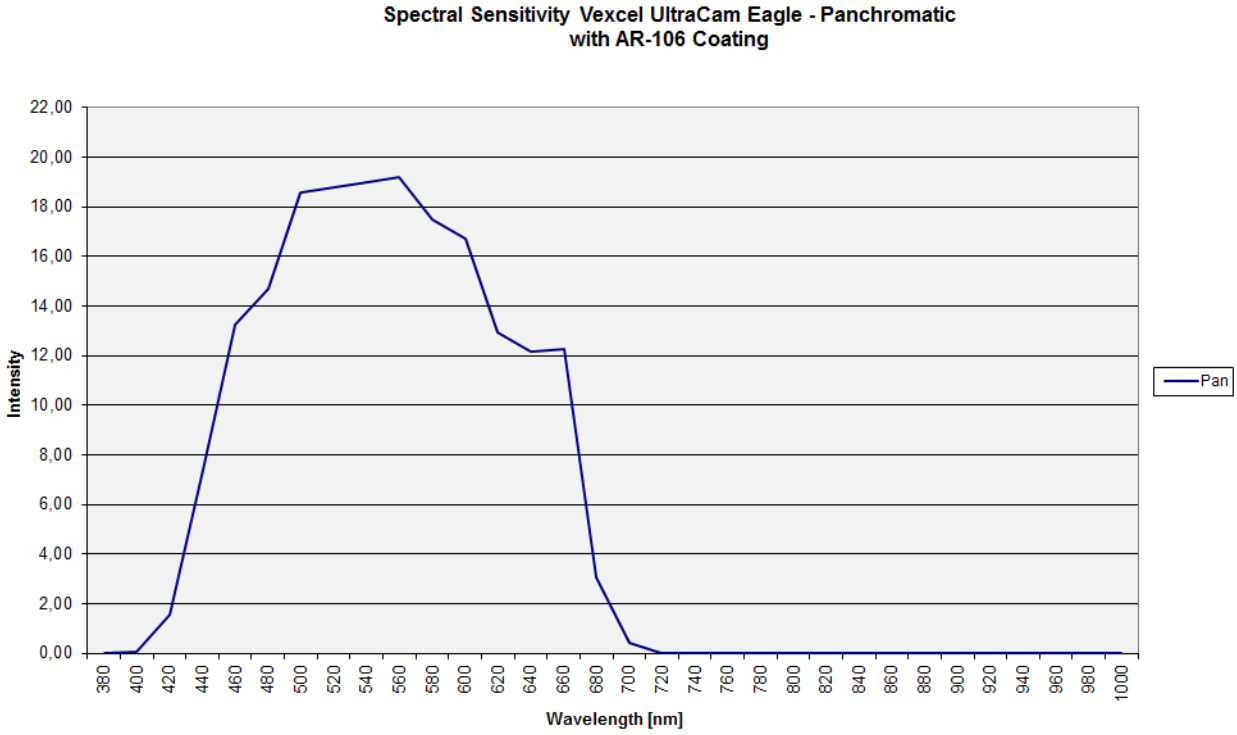

Modulation versus Image Height - Aperture f / 5.6
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm

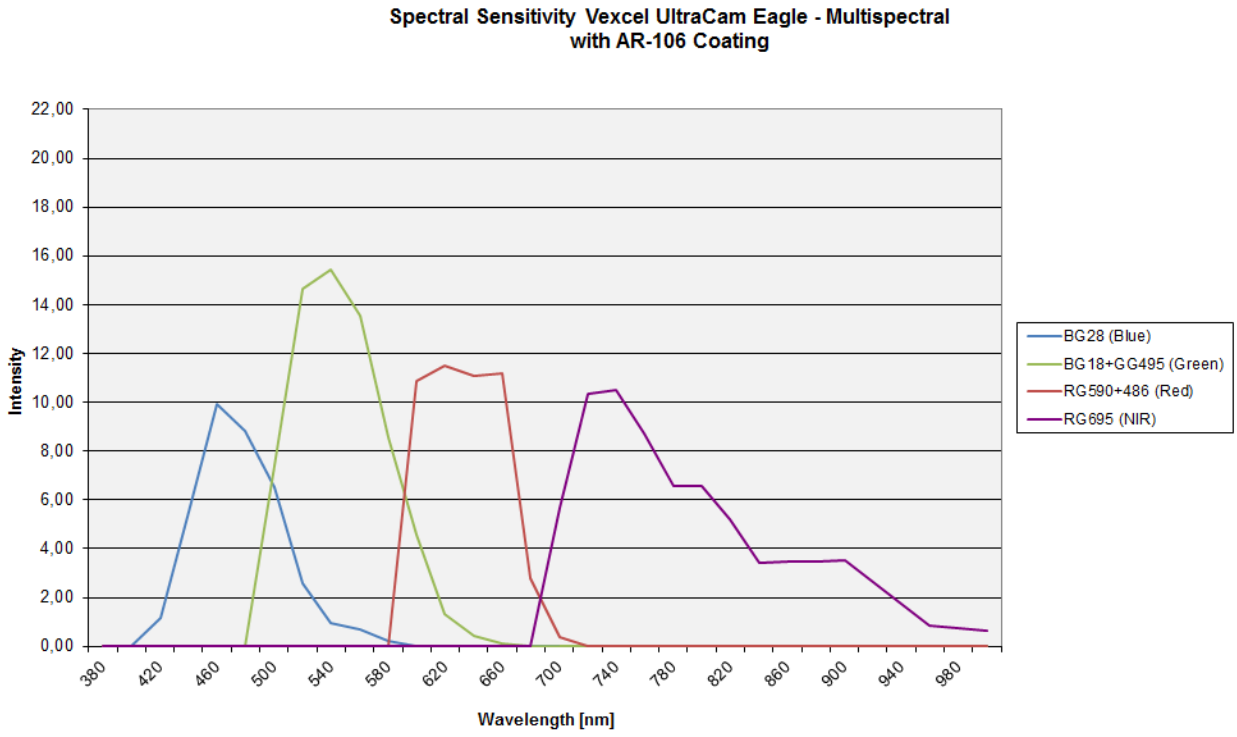

Modulation versus Image Height - Aperture f / 6.7
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm


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-1-00017501-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: **Feb-11-2015**
Date of Report: **Mar-20-2015**
Revision of Camera: **Rev01.00**
Version of Report: **V01**

Calibration of Vignetting for Aperture Setting 1

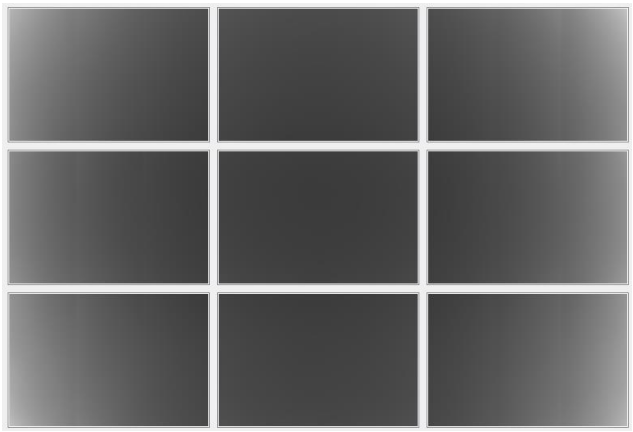
	PAN	R, G, NIR	B
Aperture	F5.6	F8.0	F5.6

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

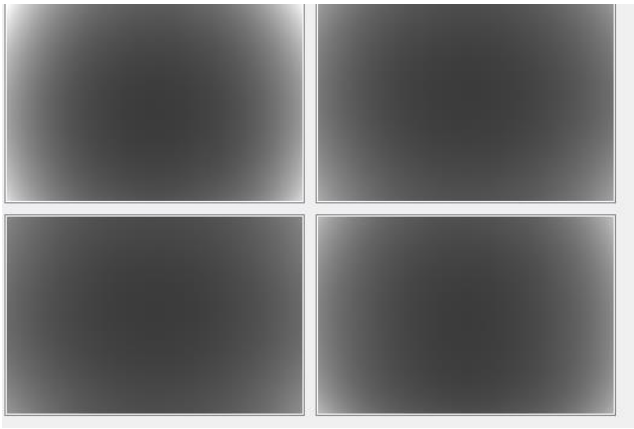
Calibration of Vignetting for Aperture Setting 1

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

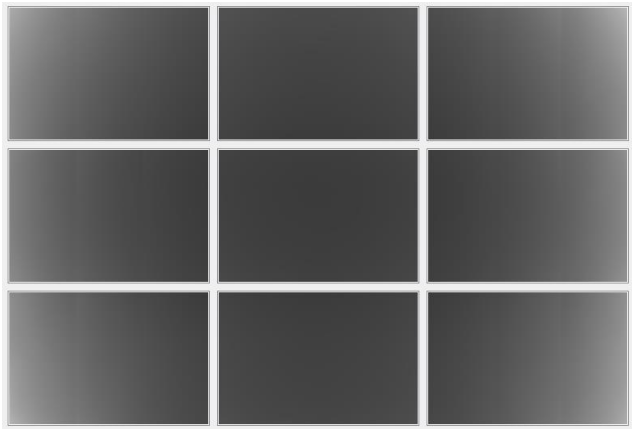
	PAN	R, G, NIR	B
Aperture	F6.7	F9.3	F6.7

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 6.5	1.00	3.00
00_01	f / 6.5	1.00	4.00
00_02	f / 6.5	1.00	4.00
00_03	f / 6.5	1.00	4.00
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	4.00
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	3.00

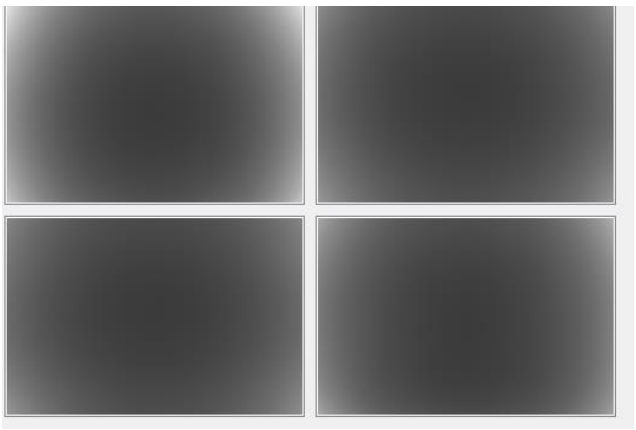
Calibration of Vignetting for Aperture Setting 2

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

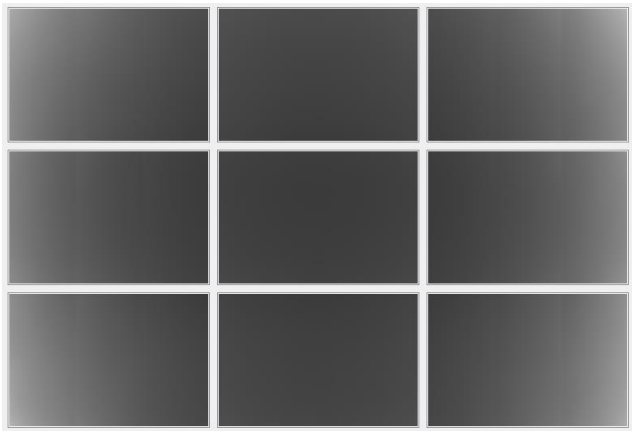
	PAN	R, G, NIR	B
Aperture	F8	F11	F8

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	4.00
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

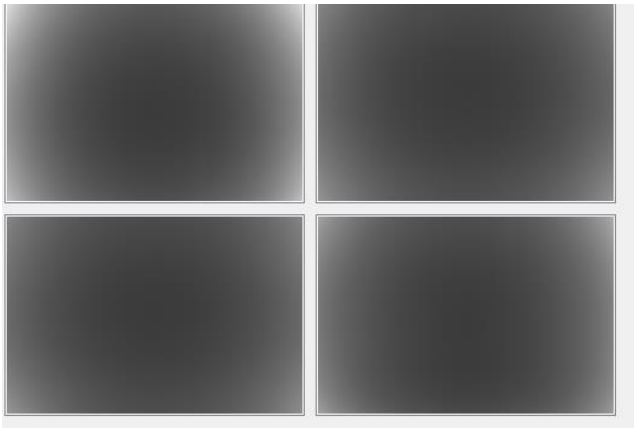
Calibration of Vignetting for Aperture Setting 3

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

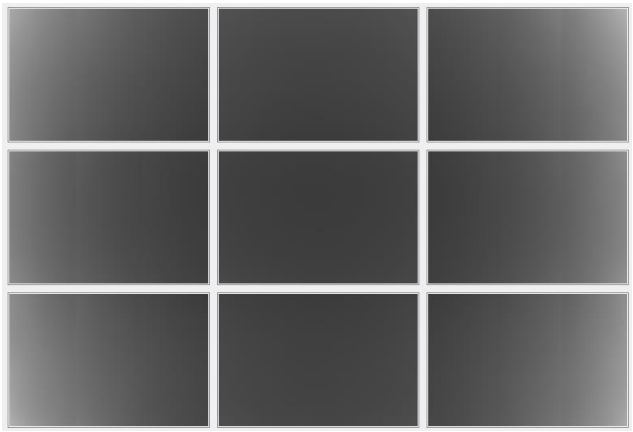
	PAN	R, G, NIR	B
Aperture	F9.5	F13	F9.5

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	4.00
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

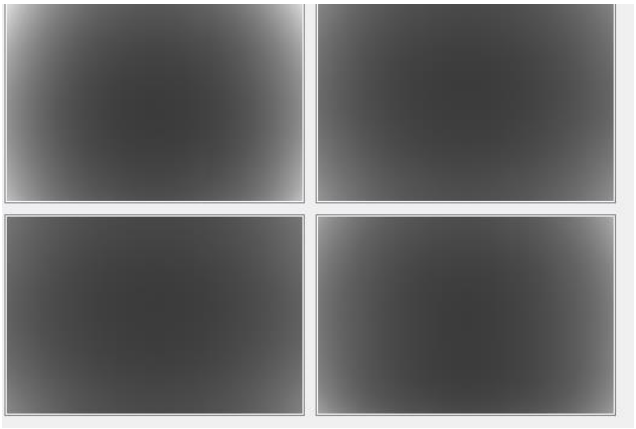
Calibration of Vignetting for Aperture Setting 4

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

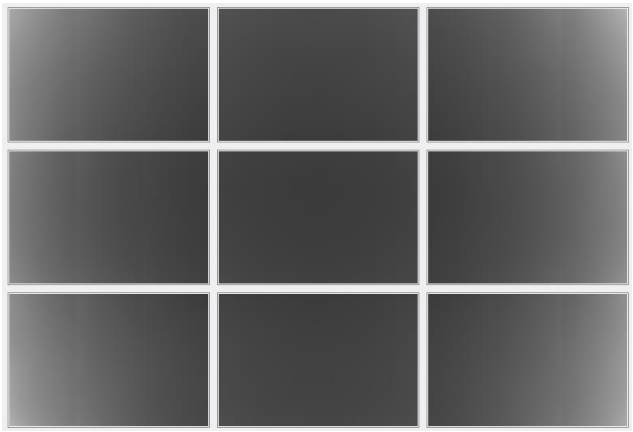
	PAN	R, G, NIR	B
Aperture	F11	F16	F11

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	4.00
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

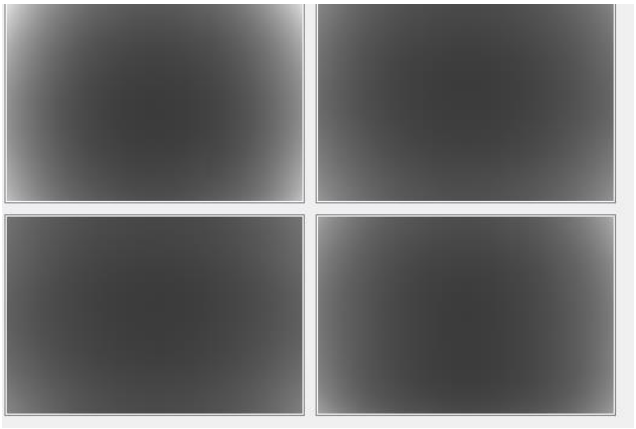
Calibration of Vignetting for Aperture Setting 5

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

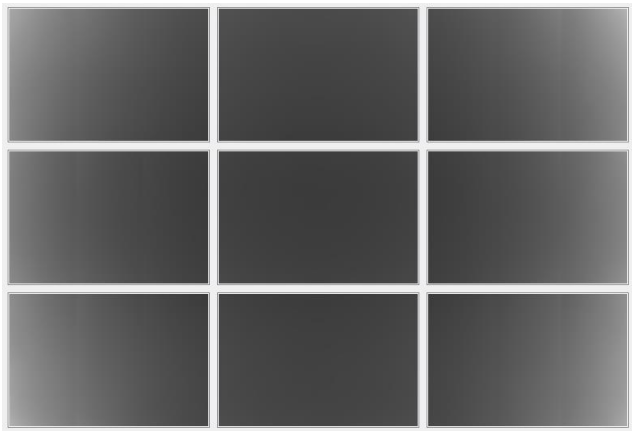
	PAN	R, G, NIR	B
Aperture	F13	F19	F13

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	4.00
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

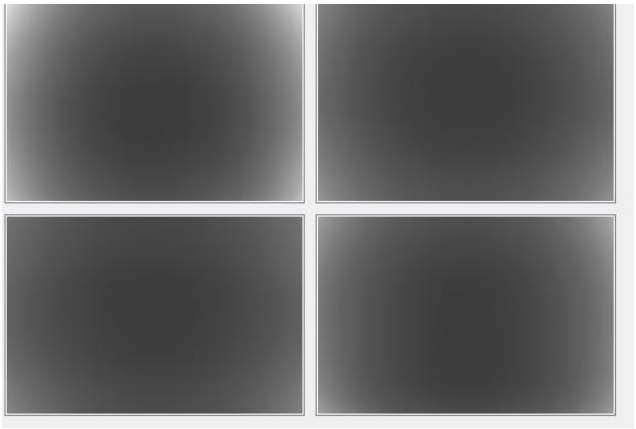
Calibration of Vignetting for Aperture Setting 6

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

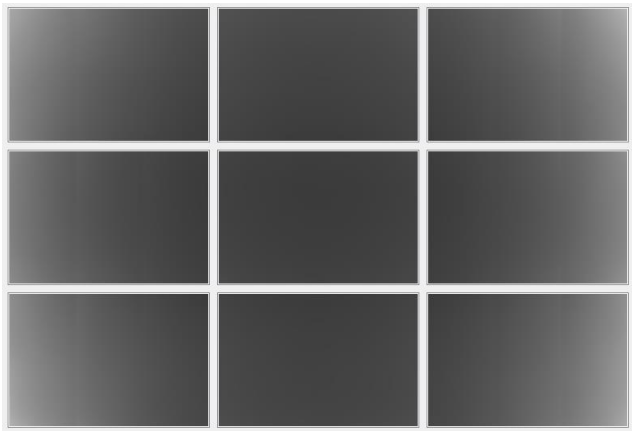
	PAN	R, G, NIR	B
Aperture	F16	F22	F16

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	4.00
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

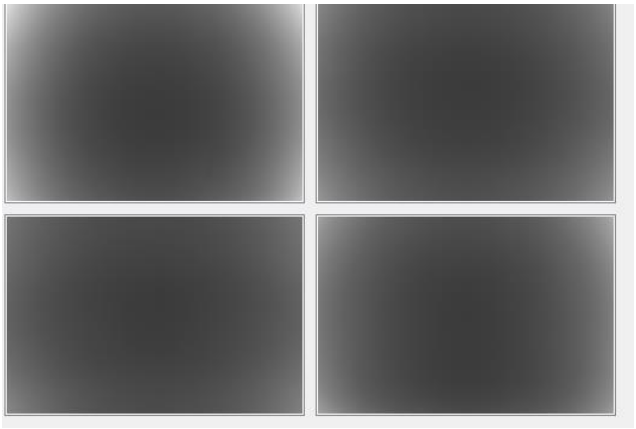
Calibration of Vignetting for Aperture Setting 7

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

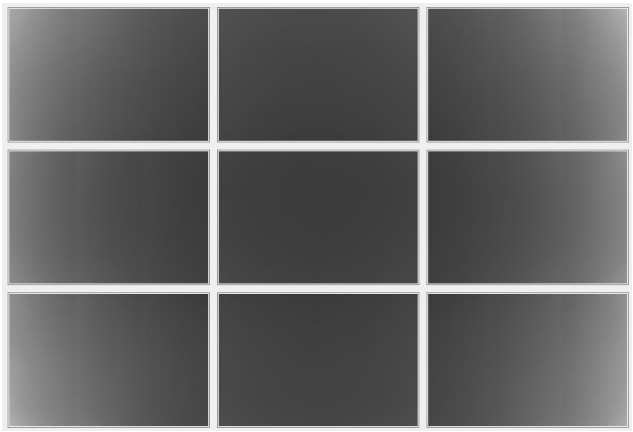
	PAN	R, G, NIR	B
Aperture	F22	F27	F22

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	4.00
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

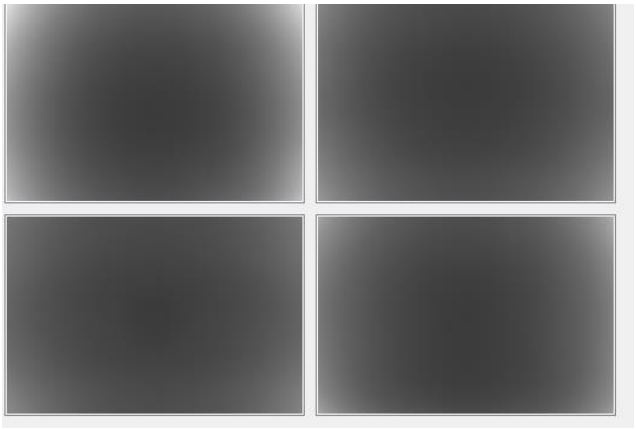
Calibration of Vignetting for Aperture Setting 8

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: 1900/ 230
PIXEL: 2418/4366
PIXEL: 2584/4404
PIXEL: 3998/ 969
PIXEL: 3020/3027
PIXEL: 3019/3027

C00-01

PIXEL: 127/2750
PIXEL: 309/2726
PIXEL: 389/3628
PIXEL: 468/1984
PIXEL: 1010/3129
PIXEL: 1051/2848
PIXEL: 1209/4418
PIXEL: 1339/3469
PIXEL: 2170/2546
PIXEL: 2358/2516
PIXEL: 2747/2079
PIXEL: 3317/2560
PIXEL: 3763/4388
PIXEL: 3813/1811
PIXEL: 4927/4129
PIXEL: 4930/1240
PIXEL: 5578/2657
PIXEL: 5690/3994
PIXEL: 6066/ 456
PIXEL: 6153/1880
PIXEL: 6415/1368
PIXEL: 4385/2988
PIXEL: 6658/1528
PIXEL: 6658/1529

C00-02

PIXEL: 2217/2661
PIXEL: 4815/ 305
PIXEL: 6093/ 57
PIXEL: 1598/1353
PIXEL: 5904/2099
PIXEL: 5902/2098

C00-03

PIXEL: 2071/1618
PIXEL: 4587/ 960
PIXEL: 5659/2385
PIXEL: 6002/3296
PIXEL: 6119/1282
PIXEL: 3387/4362

C01-00

```
PIXEL:  1595/3172
PIXEL:  2176/3304
PIXEL:  3494/3947
PIXEL:  3611/  83
PIXEL:  3957/4228
PIXEL:  4233/ 937
```

C01-01

```
PIXEL:   569/ 686
PIXEL:  3864/ 111
PIXEL:  4472/2480
PIXEL:  4524/3446
PIXEL:  5991/2506
```

C02-00

```
PIXEL:   294/2116
PIXEL:   677/ 159
PIXEL:   680/1950
PIXEL:   891/ 915
PIXEL:  1386/4209
PIXEL:  2295/ 858
PIXEL:  2381/3898
PIXEL:  2587/1647
PIXEL:  2693/2006
PIXEL:  3115/1735
PIXEL:  3767/ 806
PIXEL:  4144/ 598
PIXEL:  4394/1873
PIXEL:  4503/2355
PIXEL:  4539/4611
PIXEL:  4553/3328
PIXEL:  4649/  32
PIXEL:  5275/ 491
PIXEL:  5332/1400
PIXEL:  5753/1035
PIXEL:  6362/ 590
PIXEL:  6685/2102
PIXEL:  6702/ 512
PIXEL:  3568/1810
PIXEL:  3569/1810
PIXEL:  3570/1810
```

C02-01

```
PIXEL:   123/1128
PIXEL:  1395/2384
PIXEL:  2031/2020
PIXEL:  2031/3022
PIXEL:  2057/2024
PIXEL:  3861/2286
PIXEL:  6446/4441
```

C03-00

```
PIXEL:    68/3924
PIXEL:    74/2775
PIXEL:   203/1911
PIXEL:   667/ 556
PIXEL:  1387/3138
PIXEL:  1808/1350
PIXEL:  1921/1902
```

```
PIXEL:  2625/3991
PIXEL:  3935/2280
PIXEL:  4148/1546
PIXEL:  4773/4049
PIXEL:  5620/  74
PIXEL:  6401/1726
PIXEL:  6425/2514
PIXEL:  6578/ 857
PIXEL:  6662/1294
PIXEL:  5217/1569
PIXEL:  5218/1569
PIXEL:  5218/1570
PIXEL:  5219/1569
PIXEL:  5219/1570
```

C04-00

```
PIXEL:  1631/3655
PIXEL:  1632/3649
PIXEL:  1758/ 315
PIXEL:  5012/3478
PIXEL:  5027/3558
PIXEL:  5035/3480
PIXEL:  5036/3422
PIXEL:  5043/3434
PIXEL:  5052/3368
PIXEL:  5083/3495
PIXEL:  5092/3410
PIXEL:  5095/3557
PIXEL:  5131/3530
PIXEL:  5135/3452
PIXEL:  5145/3318
PIXEL:  5146/3452
PIXEL:  5148/3548
PIXEL:  5159/3369
PIXEL:  5182/3452
PIXEL:  5182/3457
PIXEL:  5194/3440
PIXEL:  5206/3452
PIXEL:  5221/3452
PIXEL:  5223/3461
PIXEL:  5223/3474
PIXEL:  5237/3472
PIXEL:  5275/3557
PIXEL:  5298/3531
PIXEL:  5305/3504
PIXEL:  5329/3444
PIXEL:  5339/3556
PIXEL:  5361/3451
PIXEL:  5368/3463
PIXEL:  5417/1679
PIXEL:   111/4270
PIXEL:   111/4271
PIXEL:  5175/2110
PIXEL:   111/4269
PIXEL:   110/4271
```

C05-00

```
PIXEL:   479/ 630
PIXEL:   579/1375
PIXEL:  1186/1166
PIXEL:  1553/1406
PIXEL:  1635/3079
```

```
PIXEL:  1696/ 198
PIXEL:  2235/1009
PIXEL:  2634/ 368
PIXEL:  2736/4051
PIXEL:  2748/2190
PIXEL:  6041/ 309
PIXEL:  6116/ 670
PIXEL:  6889/2450
PIXEL:  6924/2932
PIXEL:  6927/1008
```

C06-00

```
PIXEL:  4474/ 662
PIXEL:  3707/4153
PIXEL:  4256/2813
PIXEL:  6673/3052
PIXEL:  6674/3052
PIXEL:  6675/3052
```

C07-00

```
PIXEL:   412/ 863
PIXEL:   794/1886
PIXEL:  1312/4126
PIXEL:  1440/2575
PIXEL:  1499/4419
PIXEL:  1865/2496
PIXEL:  2174/1481
PIXEL:  2404/2214
PIXEL:  2582/ 863
PIXEL:  3134/ 716
PIXEL:  3347/4234
PIXEL:  3599/1302
PIXEL:  3693/4300
PIXEL:  3760/4227
PIXEL:  3886/1161
PIXEL:  4488/ 976
PIXEL:  4490/2183
PIXEL:  6173/1391
PIXEL:  6326/  46
PIXEL:  6438/3355
PIXEL:  4807/  94
PIXEL:  4807/  95
PIXEL:  4808/  95
PIXEL:  4808/  96
```

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-1-00017501-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:	**Feb-11-2015**
Date of Report:	**Mar-20-2015**
Revision of Camera:	**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 4CCD)	12 12 20 08	6.64	6.86	7.17	7.37	7.58	7.76	7.79	8.00	+/- 0.2
C1 (Pan 2CCD V)	12 12 20 15	6.82	6.99	7.29	7.53	7.64	7.79	7.89	8.10	+/- 0.2
C2 (Pan 2CCD H)	12 12 20 21	6.67	6.83	7.11	7.23	7.47	7.58	7.68	7.84	+/- 0.2
C3 (Pan Central)	12 12 20 22	6.32	6.55	6.75	6.96	7.14	7.27	7.31	7.52	+/- 0.2
C4 (Red)	12 11 00 07	7.23	7.30	7.42	7.47	7.64	7.65	7.65	7.65	+/- 0.2
C5 (Green)	12 11 00 47	7.20	7.28	7.41	7.57	7.64	7.64	7.64	7.81	+/- 0.2
C6 (Blue)	12 11 00 46	7.68	7.74	7.74	7.79	7.90	8.06	8.18	8.27	+/- 0.2
C7 (NIR)	12 11 00 30	7.20	7.31	7.31	7.49	7.66	7.72	7.72	7.86	+/- 0.2

Calibration Report

Electronics and Sensor Calibration

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-00017501-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:	**Feb-11-2015**
Date of Report:	**Mar-20-2015**
Revision of Camera:	**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]
00_00	FTF7046-M	16 0474/146	24.20
00_01	FTF7046-M	16 0872/051	24.20
00_02	FTF7046-M	16 0474/133	24.20
00_03	FTF7046-M	16 0474/150	24.20
01_00	FTF7046-M	16 0474/149	24.00
01_01	FTF7046-M	16 0474/114	24.00
02_00	FTF7046-M	16 0872/066	24.00
02_01	FTF7046-M	16 0474/129	24.00
03_00	FTF7046-M	16 0872/052	24.00
04_00 (red)	FTF7046-M	16 0872/016	24.00
05_00 (green)	FTF7046-M	16 0872/056	24.00
06_00 (blue)	FTF7046-M	16 0872/002	24.00
07_00 (NIR)	FTF7046-M	16 0872/060	24.00

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	16 0474/146	13080
00_01	FTF7046-M	16 0872/051	13070
00_02	FTF7046-M	16 0474/133	13720
00_03	FTF7046-M	16 0474/150	12710
01_00	FTF7046-M	16 0474/149	13050
01_01	FTF7046-M	16 0474/114	12730
02_00	FTF7046-M	16 0872/066	13500
02_01	FTF7046-M	16 0474/129	13230
03_00	FTF7046-M	16 0872/052	12680
04_00 (red)	FTF7046-M	16 0872/016	13060
05_00 (green)	FTF7046-M	16 0872/056	12900
06_00 (blue)	FTF7046-M	16 0872/002	13590
07_00 (NIR)	FTF7046-M	16 0872/060	12760

Calibration Report

Summary

Camera:	**UltraCam Eagle, S/N UC-Eagle-1-00017501-f80**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Date of Calibration:	**Feb-11-2015**
Date of Report:	**Mar-20-2015**
Revision of Camera:	**Rev01.00**
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.

Dr. Michael Gruber
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Vexcel Imaging GmbH

Ing. Peter Prassl
Senior Calibration Engineer
Vexcel Imaging GmbH