

Calibration Report



Camera:	UltraCam Eagle, S/N UC-Eagle-1-60411397-f80
Manufacturer:	Vexcel Imaging GmbH, A-8010 Graz, Austria
Date of Calibration:	Jan-28-2016
Date of Report:	Feb-09-2016
Revision of Camera:	Rev04.00
Version of Report:	V01

Calibration Report

Geometric Calibration



Camera: UltraCam Eagle, S/N UC-Eagle-1-60411397-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-28-2016
Date of Report: Feb-09-2016
Revision of Camera: Rev04.00
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 (Level 2)	X_ppa	0.000 mm	± 0.002mm
	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 (Level 2)	X_ppa	0.000 mm	± 0.002mm
	Y_ppa	0.000 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

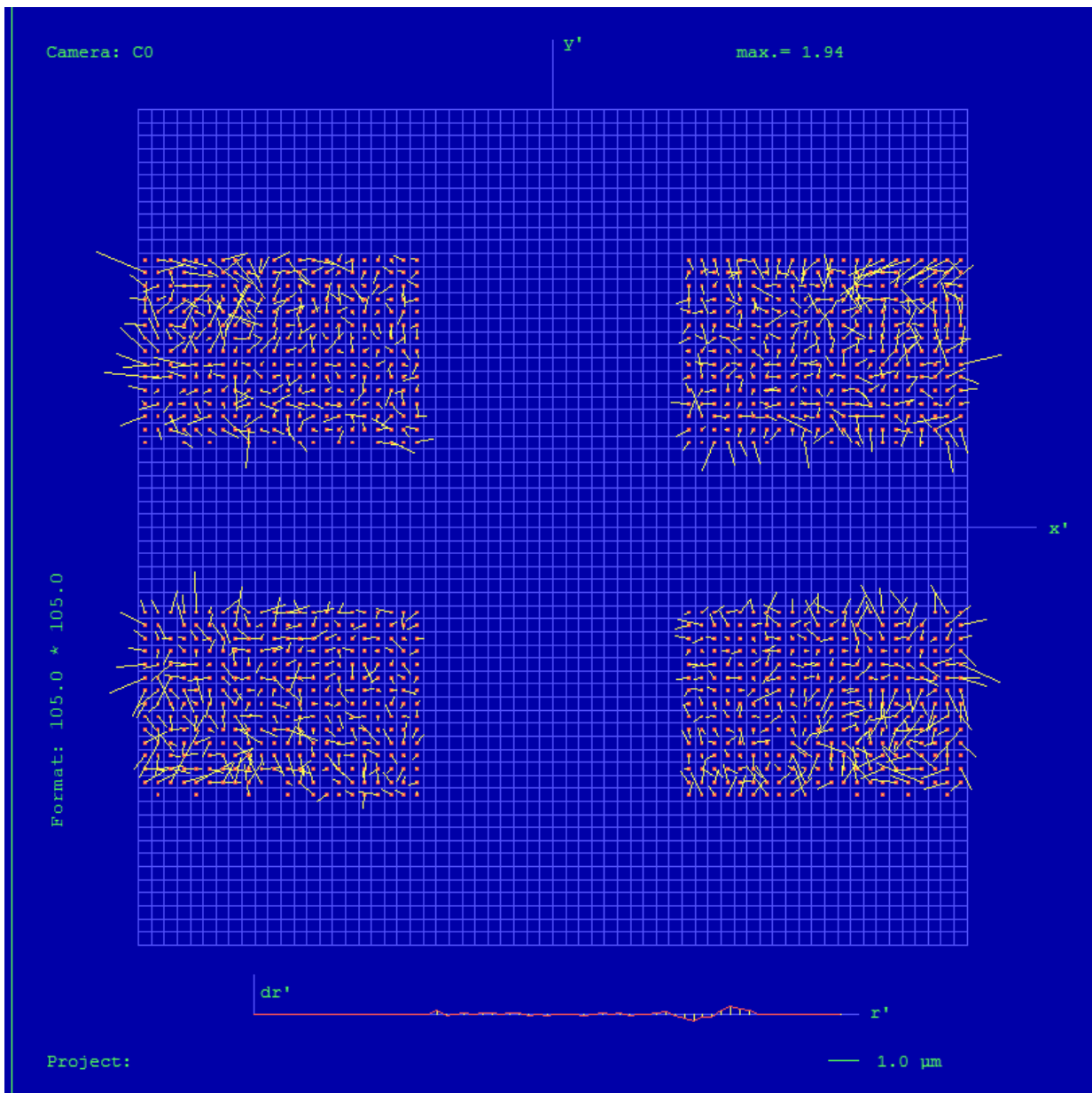
Individual Panchromatic Cone Data

Cone 0, Parametric Description, Not Effective in Output Image

Cone # C0													
Lens		Linios Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linios 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		-2.8437507E-02 mm ± 0.0008 mm			7.4720842E-02 mm ± 0.0012 mm			-1.1474050E-02 gon ± 0.0001 gon			1.0062967 ± 0.00005		
CCD1		7.5453441E-03 mm ± 0.0008 mm			-2.7628620E-02 mm ± 0.0012 mm			0.0000000 gon			1.0063407 ± 0.00005		
CCD2		-7.5089391E-02 mm ± 0.0008 mm			9.4521407E-02 mm ± 0.0012 mm			-5.0895199E-02 gon ± 0.0001 gon			1.0059713 ± 0.00005		
CCD3		-2.0356518E-02 mm ± 0.0008 mm			-1.6310275E-02 mm ± 0.0012 mm			-3.8567678E-02 gon ± 0.0001 gon			1.0062712 ± 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]	33.6	63.7	92.9	120.9	145.2	160.7	159.8	132.5	66.1	-54.3	-246.3	-529.9	-927.7

UltraCamEagle, Serial Number UC-Eagle-1-60411397-f80

Cone 0, Residual Error Diagram

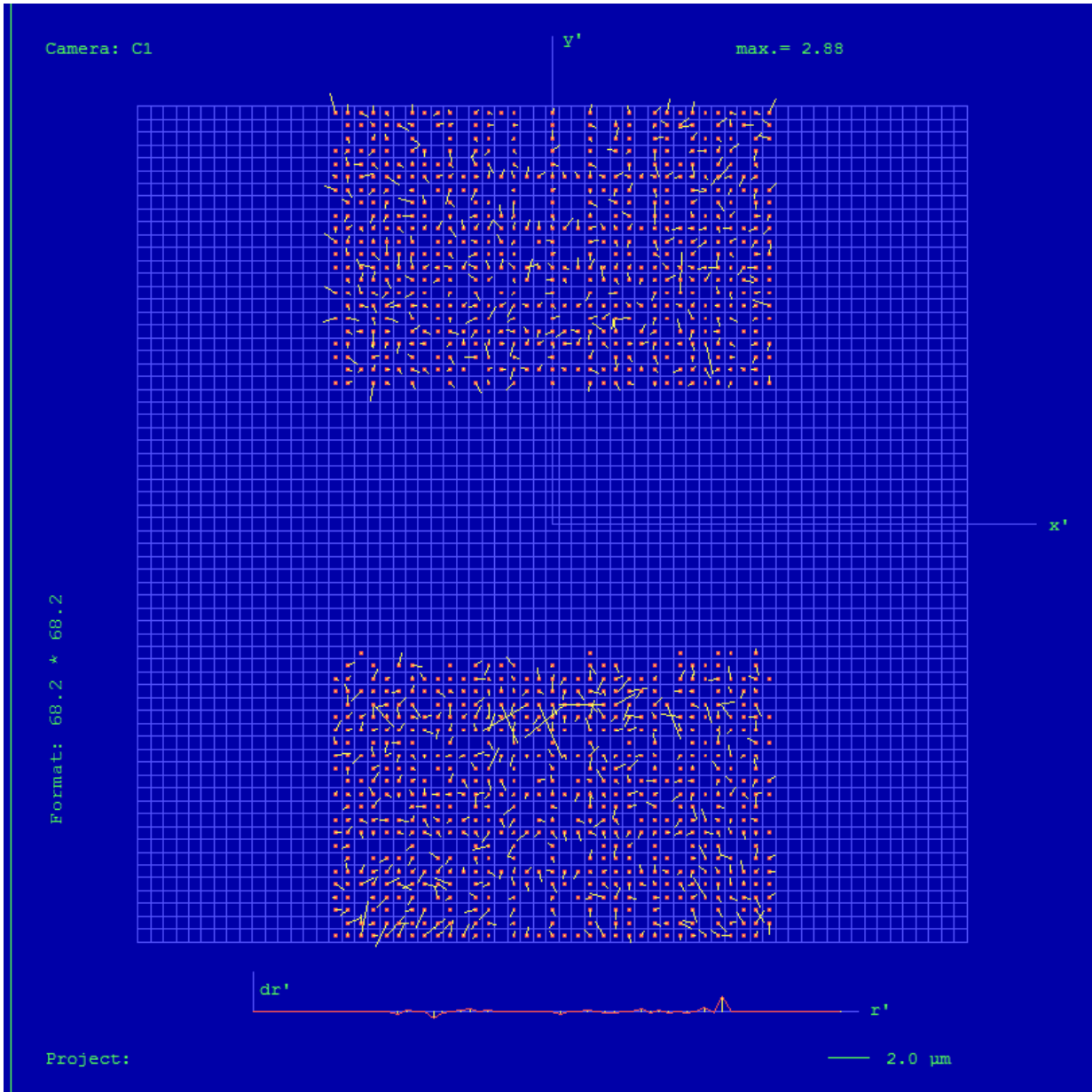


Residual Error (RMS): **1.47 μ m**

Cone 1, Parametric Description, Not Effective in Output Image

Cone # C1												
Lens		Linios Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linios 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		5.5088431E-02 mm ± 0.0012 mm			4.7840612E-02 mm ± 0.0009 mm			0.0000000 gon			1.0012209 ± 0.00005	
CCD1		-1.2878584E-02 mm ± 0.0012 mm			-9.2571536E-03 mm ± 0.0009 mm			1.4938572E-02 gon ± 0.0001 gon			1.0009975 ± 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]	13.4	25.6	37.7	48.6	55.3	52.7	33.8	-10.6	-91.5	-222.2	-417.7	-695.4

Cone 1, Residual Error Diagram

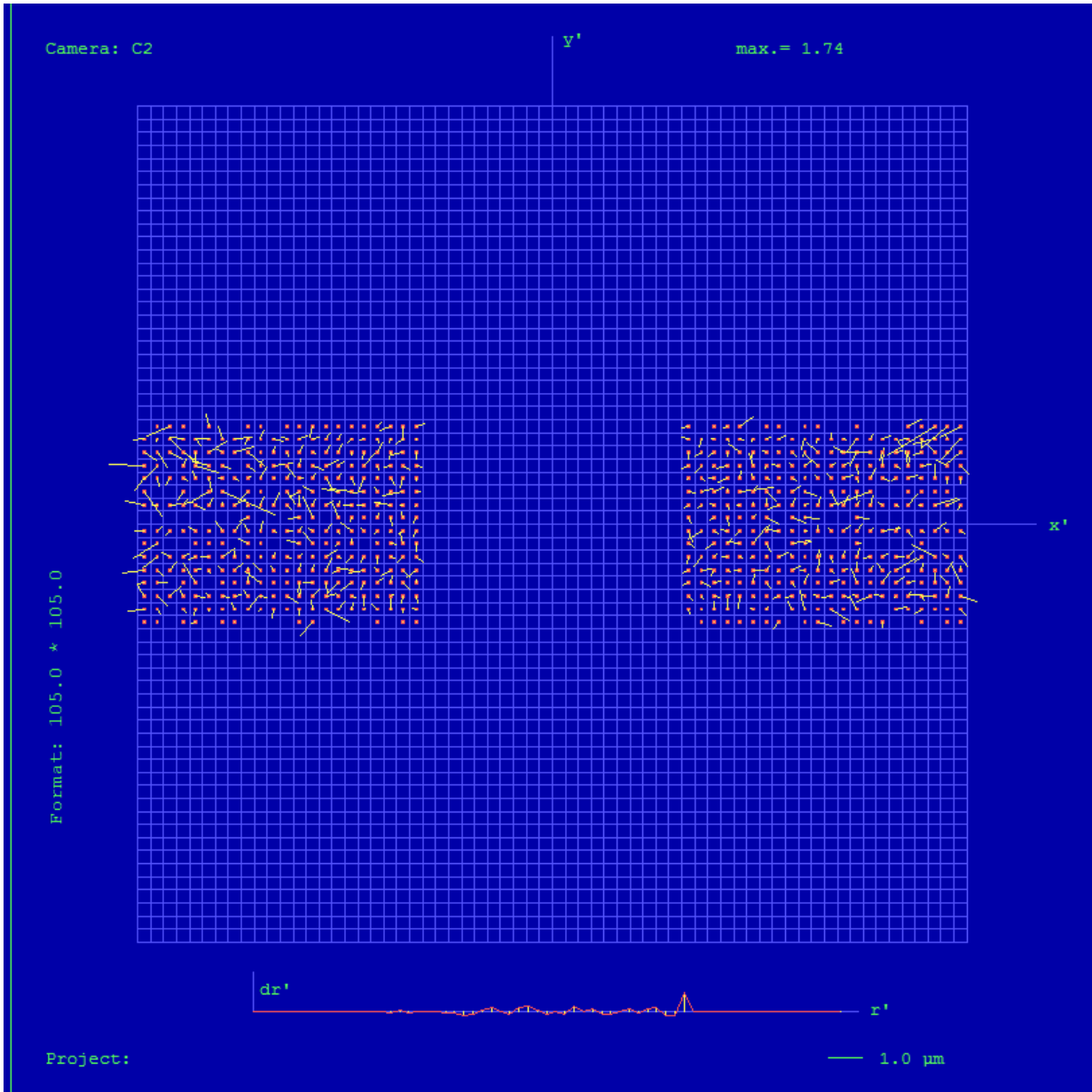


Residual Error (RMS): 1.23 μm

Cone 2, Parametric Description, Not Effective in Output Image

Cone # C2												
Lens		Linios Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linios 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	Shift Y	Rotation	Scale								
CCD0	5.0108390E-02 mm ± 0.0007 mm	1.5254219E-01 mm ± 0.0030 mm	-7.5665481E-02 gon ± 0.0001 gon	1.0066575 ± 0.00005								
CCD1	5.9107066E-02 mm ± 0.0007 mm	2.3705060E-02 mm ± 0.0030 mm	0.0000000 gon	1.0070564 ± 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]	35.1	67.0	97.9	127.6	153.3	169.9	169.6	142.3	75.3	-46.5	-240.7	-527.3

Cone 2, Residual Error Diagram



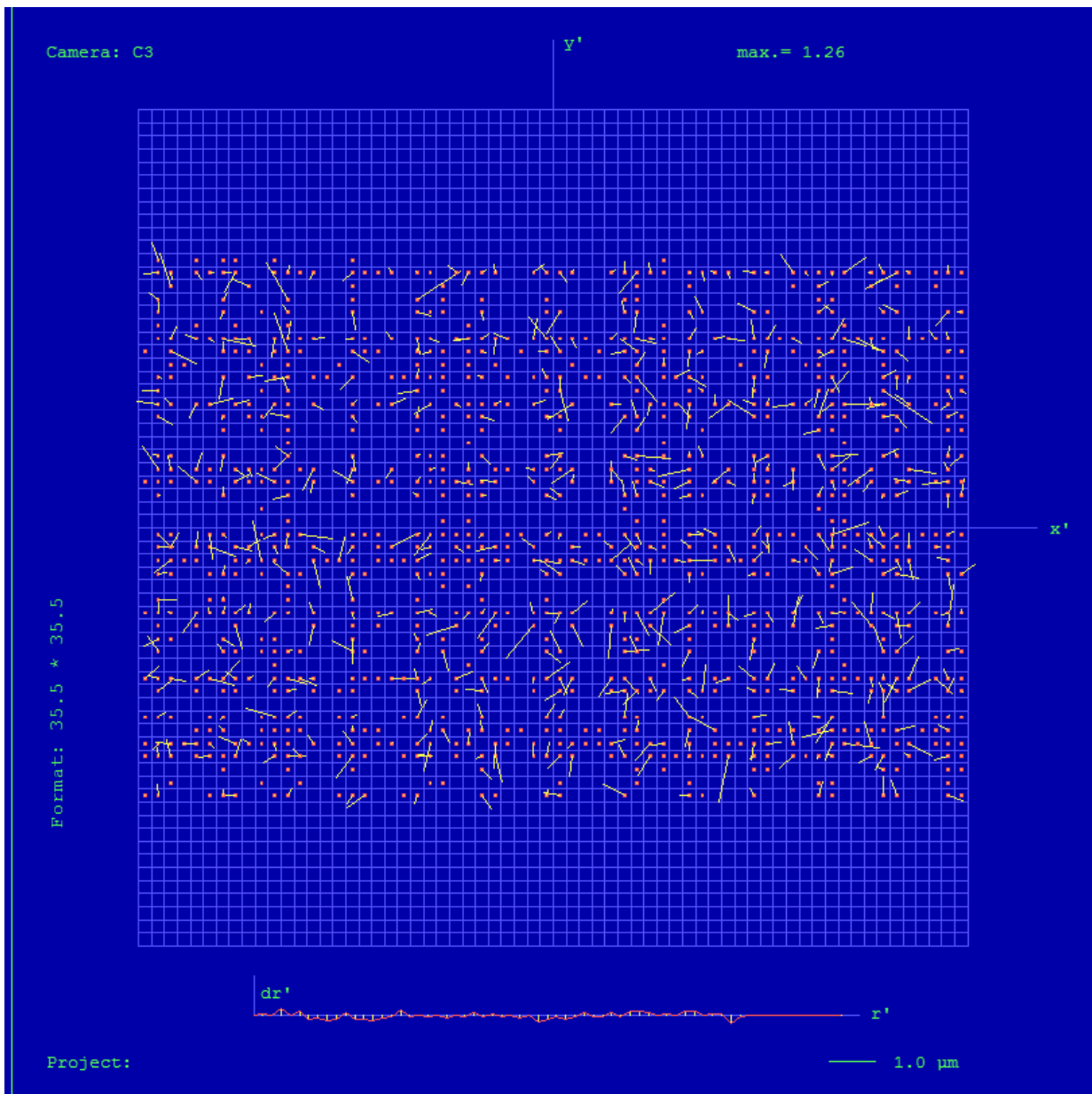
Residual Error (RMS): **1.12 μm**

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	6.8390382E-02 mm ± 0.0016 mm	4.5892954E-02 mm ± 0.0039 mm	0.0000000 gon	0.9992188 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	-0.8	-1.0	-1.0	-2.5	-7.9

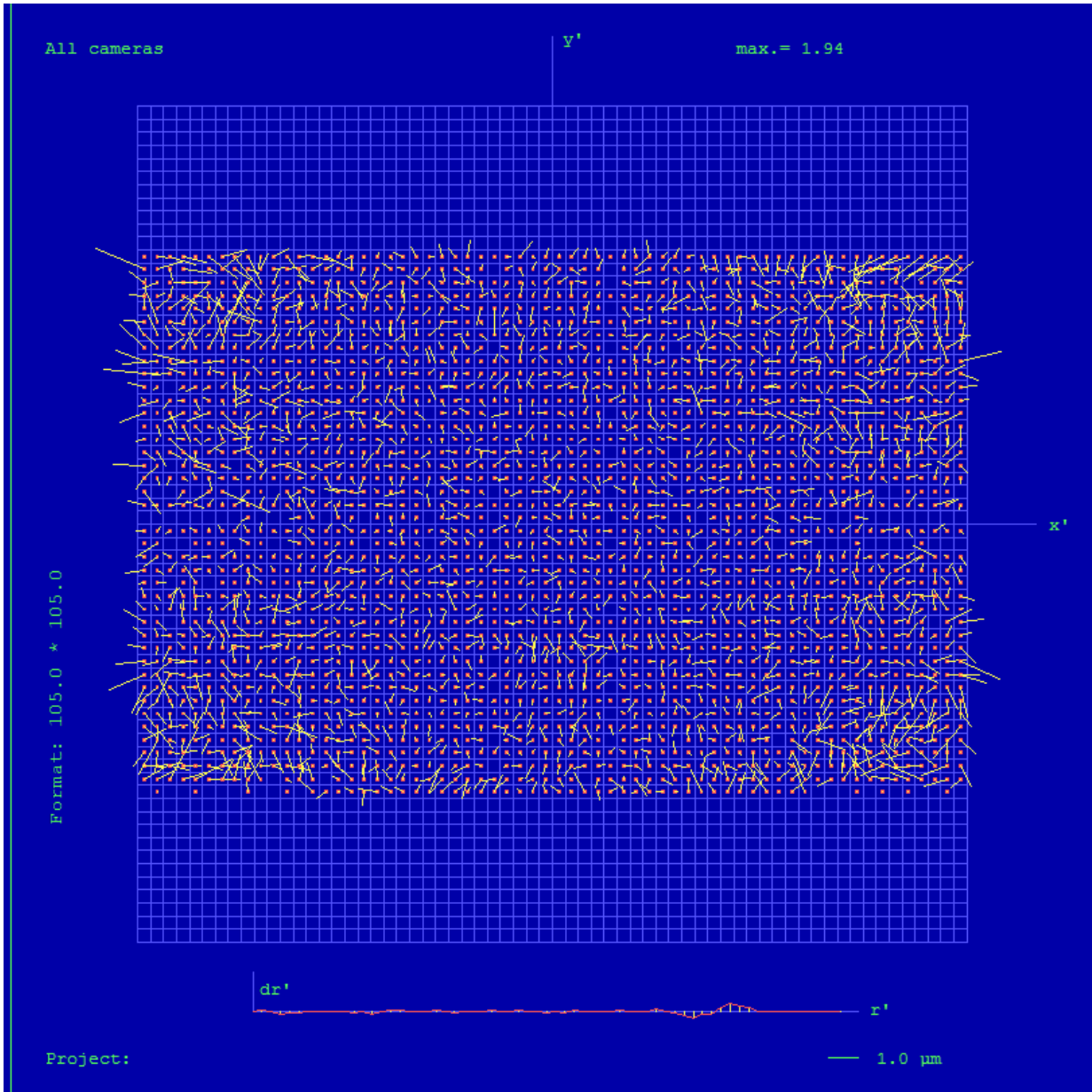
UltraCamEagle, Serial Number UC-Eagle-1-60411397-f80

Cone 3, Residual Error Diagram



Residual Error (RMS): **0.65 μm**

Full Pan Image, Residual Error Diagram



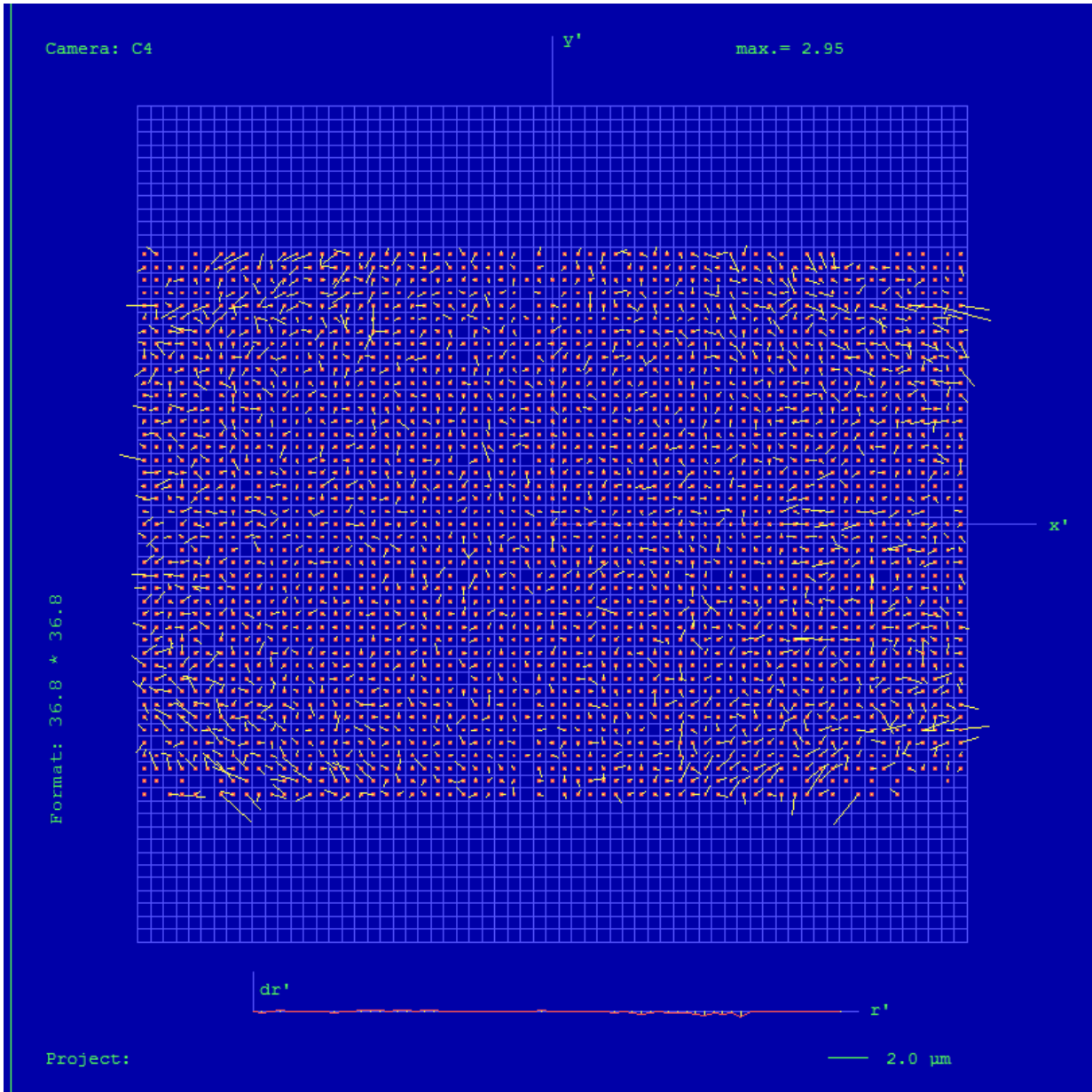
Residual Error (RMS): **1.06 μm**

Individual Multispectral Cone Data

Cone 4, Parametric Description, Not Effective in Output Image

Cone # C4 (red)					
Lens	Linios Vexcel HR Digaron 1:4/27mm Linios 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	1.8313985E-02 mm ± 0.0001 mm	-3.4261193E-02 mm ± 0.0001 mm	0.0000000 gon	1.0533669 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	116.6	179.6	167.6	111.9	111.3

Cone 4, Residual Error Diagram

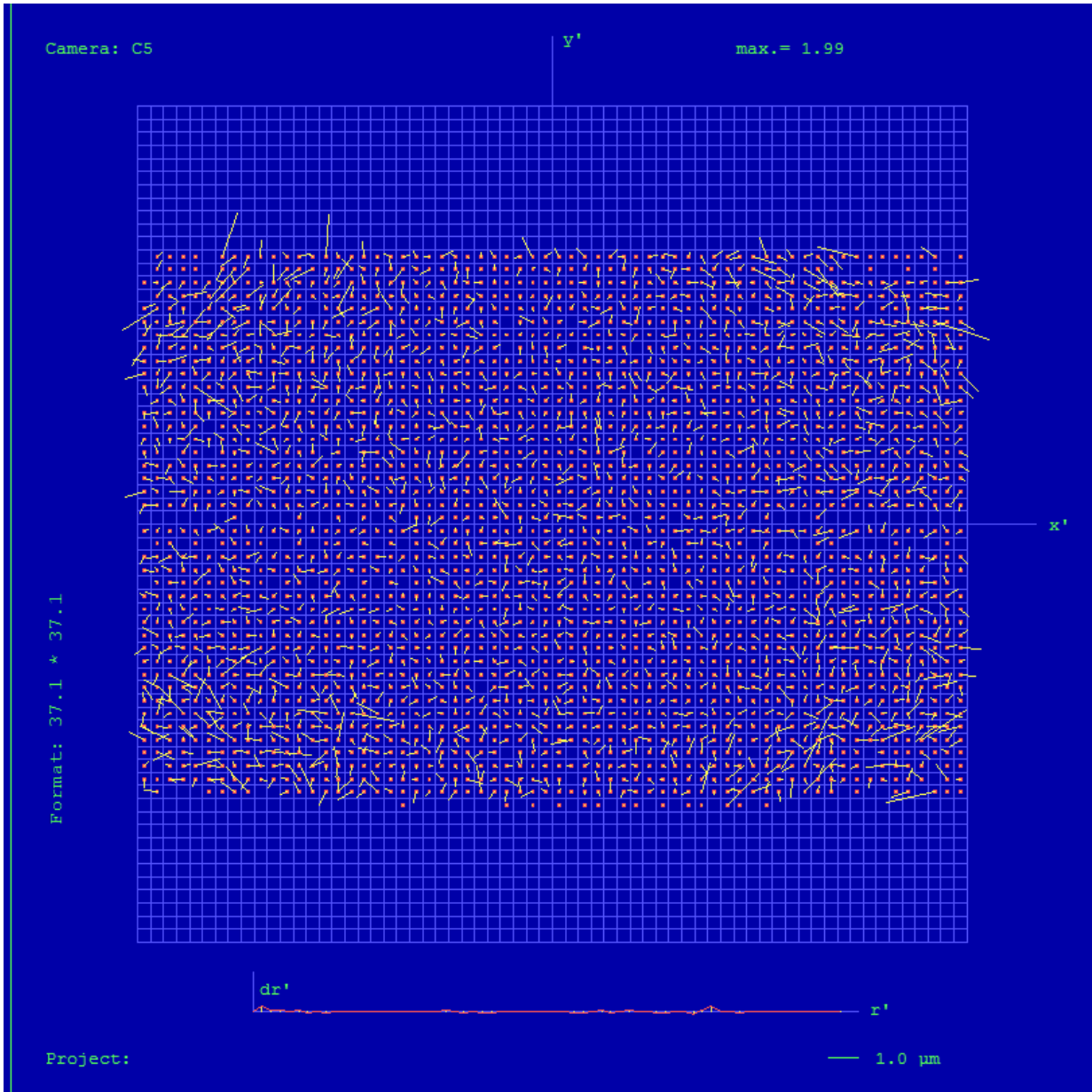


Residual Error (RMS): **0.92 μm**

Cone 5, Parametric Description, Not Effective in Output Image

Cone # C5 (green)					
Lens	Linios Vexcel HR Digaron 1:4/27mm Linios 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	-6.4351124E-02 mm ± 0.0001 mm	-5.8448127E-02 mm ± 0.0001 mm	0.0000000 gon	1.0574211 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	118.1	182.4	171.2	115.5	106.7

Cone 5, Residual Error Diagram



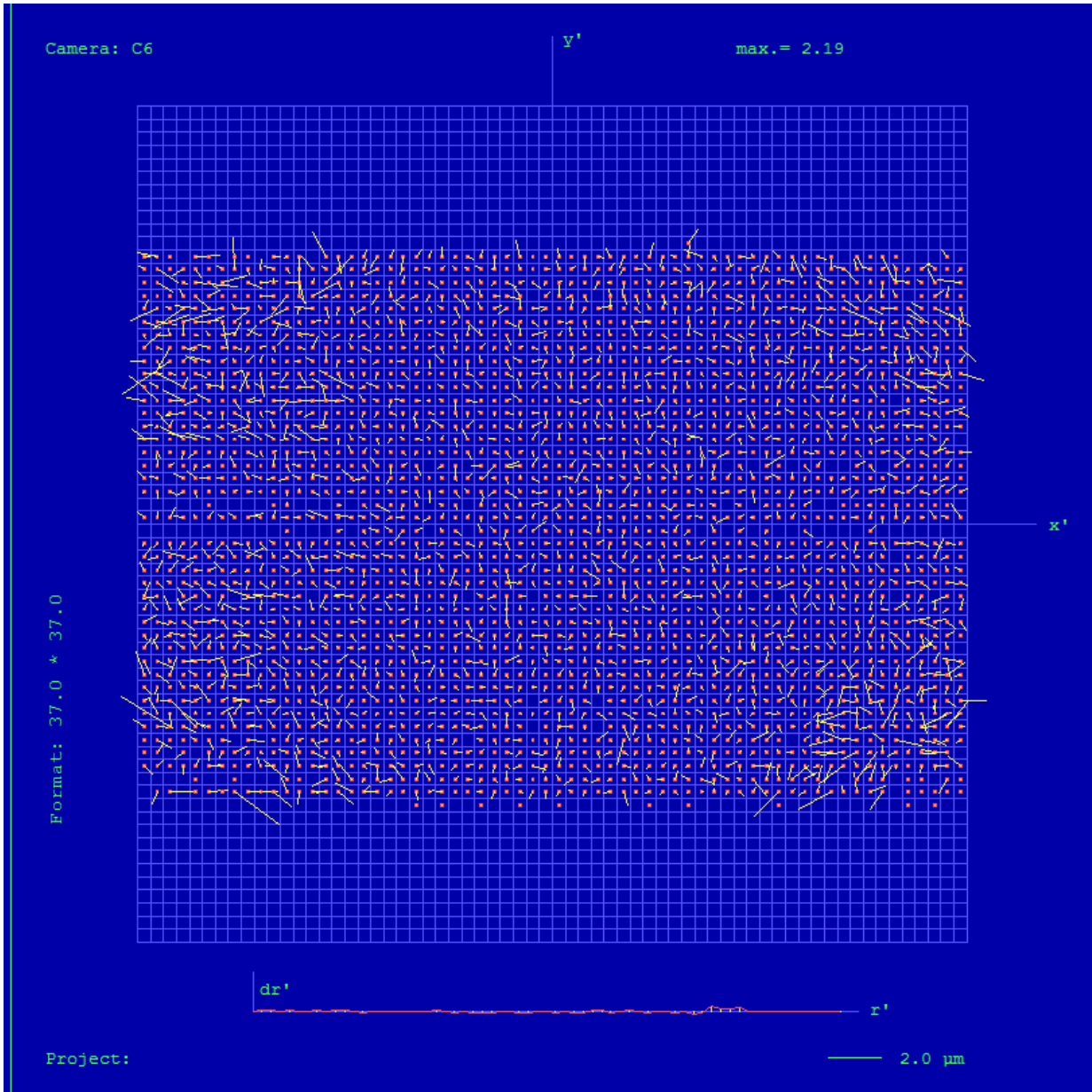
Residual Error (RMS): **0.92 μm**

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	-4.8822175E-02 mm ± 0.0001 mm	-8.5938564E-03 mm ± 0.0001 mm	0.0000000 gon	1.0545998 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	115.7	178.1	166.4	108.8	90.3

UltraCamEagle, Serial Number UC-Eagle-1-60411397-f80

Cone 6, Residual Error Diagram

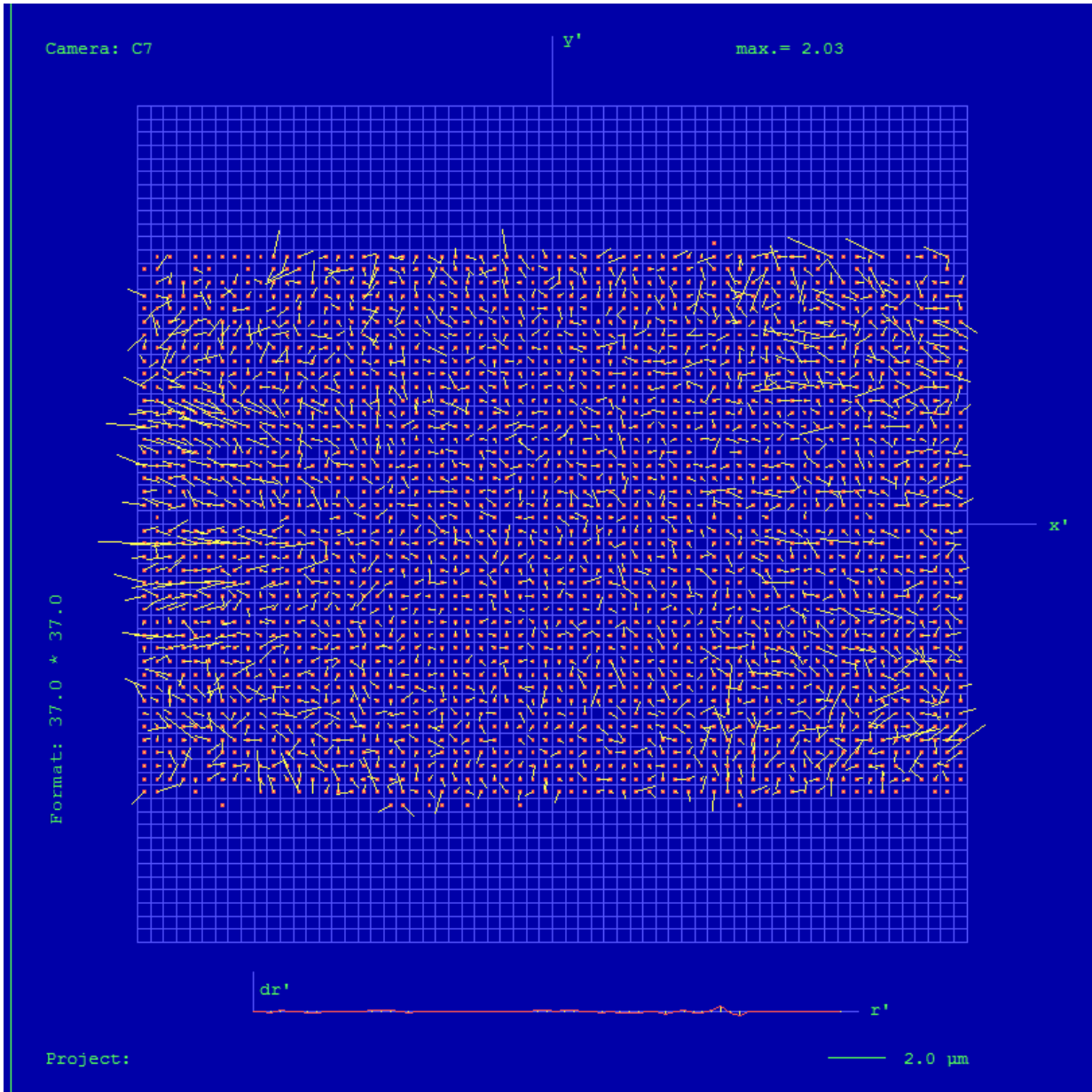


Residual Error (RMS): **0.92 μm**

Cone 7, Parametric Description, Not Effective in Output Image

Cone # C7 (NIR)					
Lens	Linios Vexcel HR Digaron 1:4/27mm Linios 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	1.6822426E-02 mm ± 0.0001 mm	-3.4042736E-02 mm ± 0.0001 mm	0.0000000 gon	1.0574443 ± 0.00005	
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	118.9	183.8	171.6	113.7	112.1

Cone 7, Residual Error Diagram



Residual Error (RMS): 0.95 μm

Explanations:

1) Calibration Method:

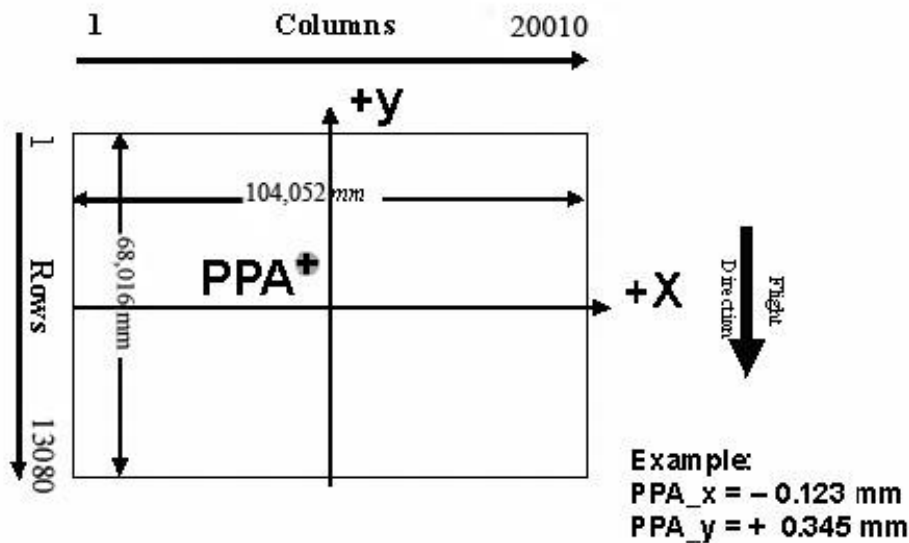
The geometric calibration is based on a set of 84 images of a defined geometry target with 394 GCPs.

Number of point measurements for the panchromatic camera : 20001
 Number of point measurements for the multispectral camera : 75081

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

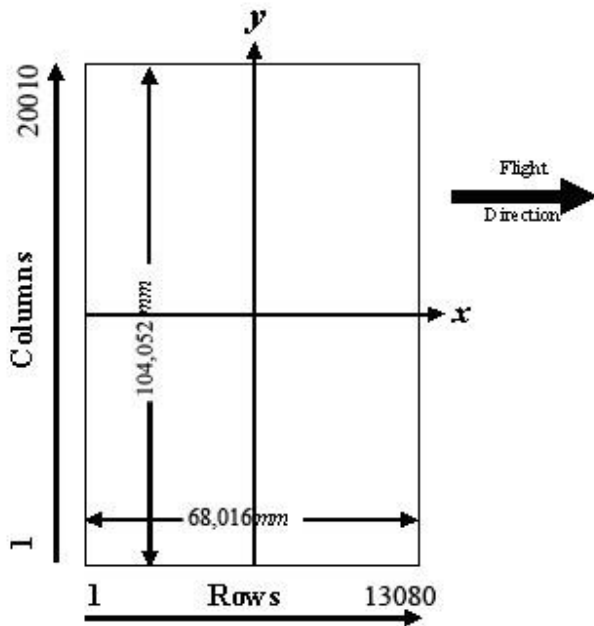
Lvl2, Camera prop. Orientation



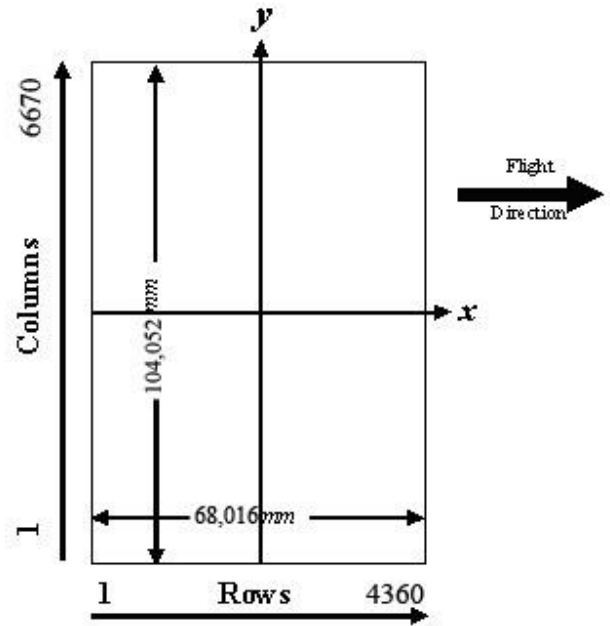
The image coordinate system of the Level 2 images is shown in the above figure. The level 2 image consists of 20010 columns and 13080 rows, which leads to a total image format of 104.052 x 68.016 mm. The coordinate of the principal point in the level 2 image is given on page 3 of this report. The above 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

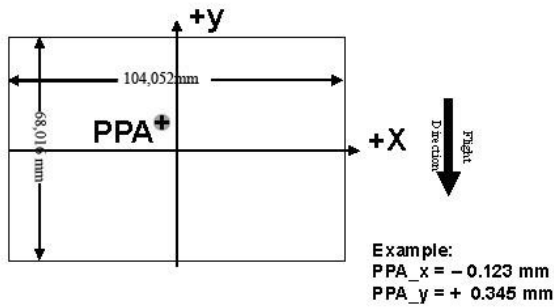
4) Position of Principal Point in Level 3 Image

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.

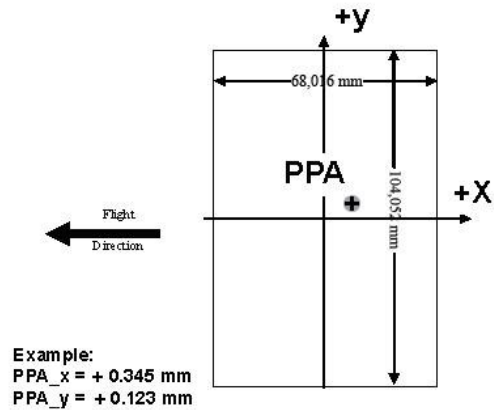
Image Format	Clockwise Rotation (Degree)	PPA	
		X	Y
Level 2	-	0.000	0.000
Level 3	0	0.000	0.000
Level 3	90	0.000	0.000
Level 3	180	0.000	0.000
Level 3	270	0.000	0.000

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.

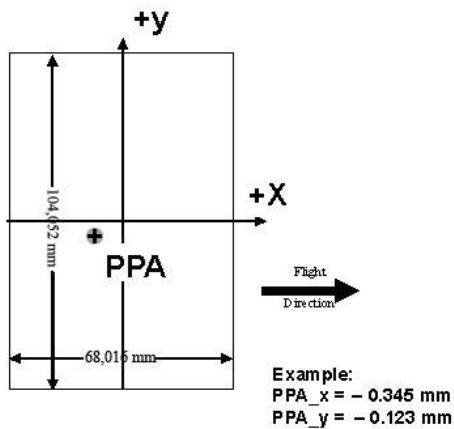
Lvl3, Rotation 0 deg clockwise



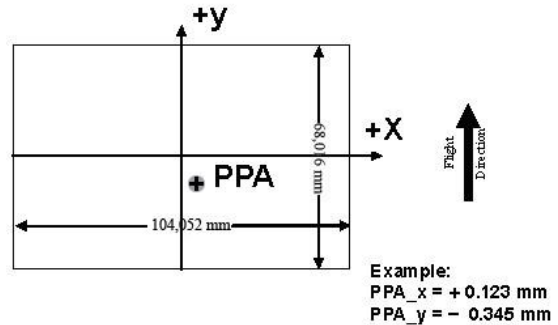
Lvl3, Rotation 90 deg clockwise



Lvl3, Rotation 270 deg clockwise



Lvl3, Rotation 180 deg clockwise



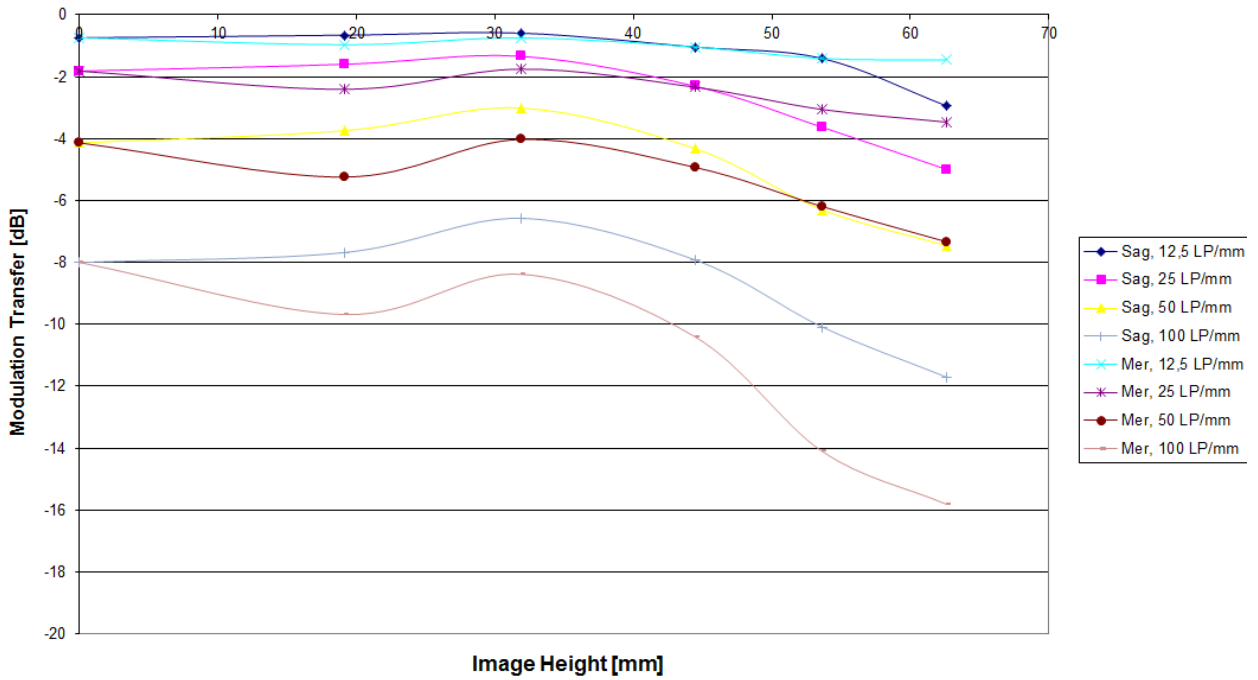
Lens Resolving Power

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).

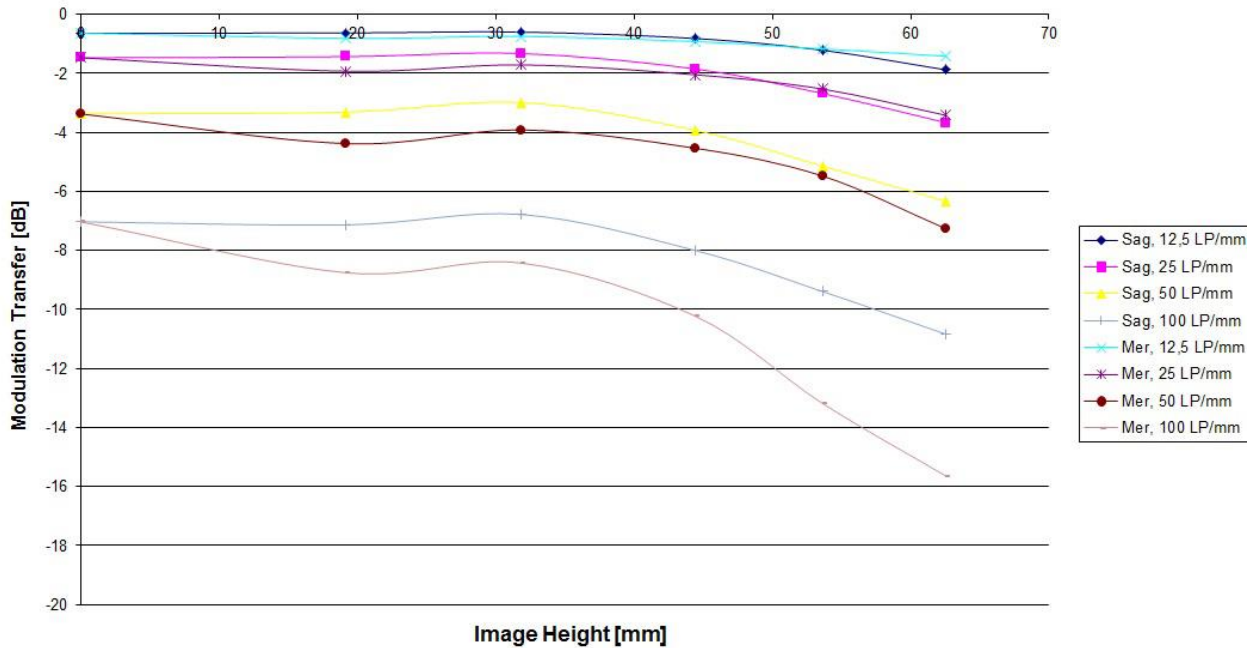
The curves are given for the meridional (tangential) and sagittal (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

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

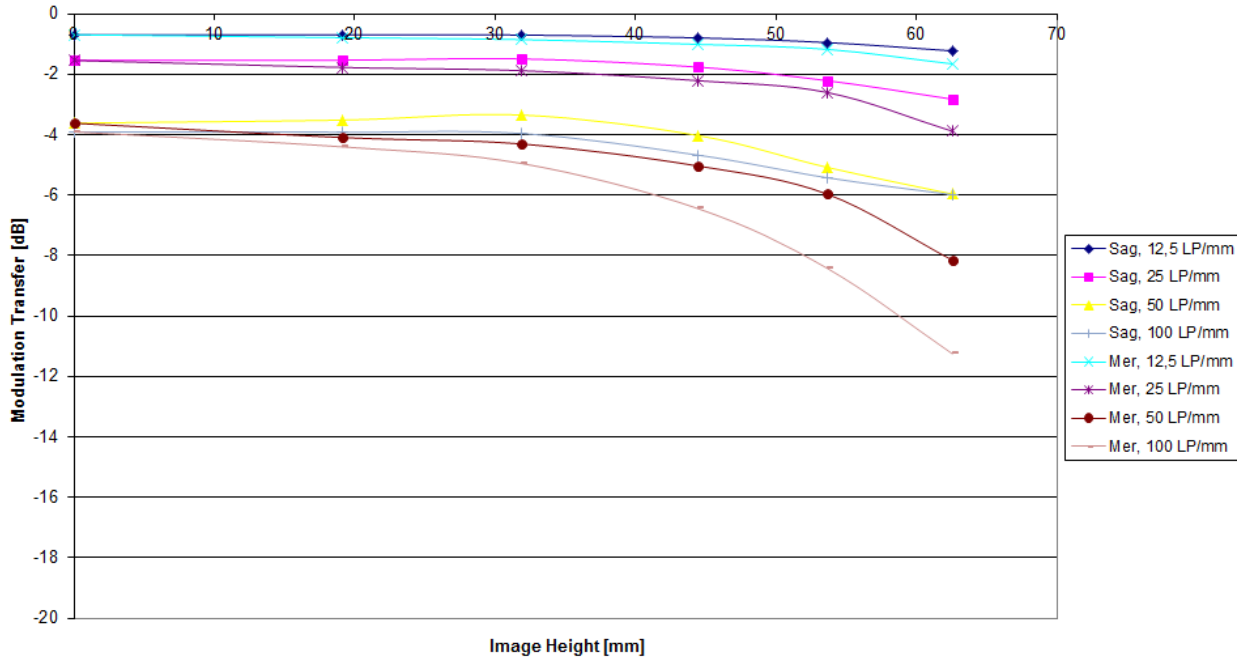
Modulation versus Image Height - Aperture f / 5.6



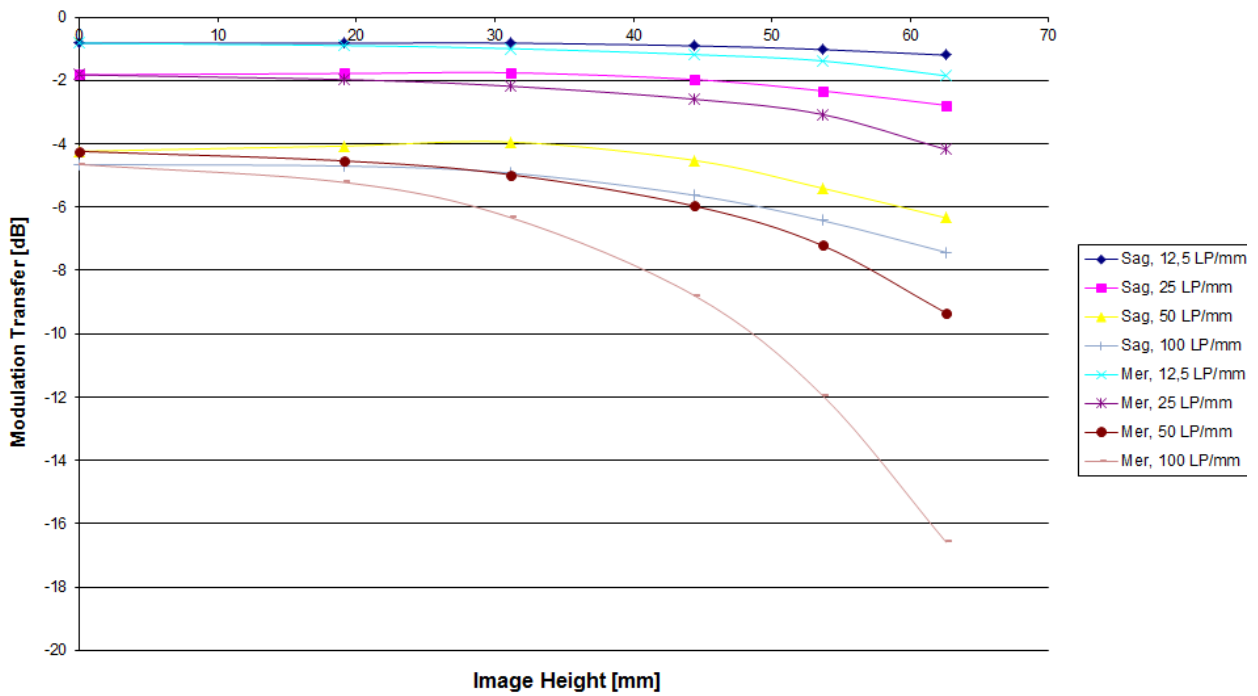
Modulation versus Image Height - Aperture f / 6.7



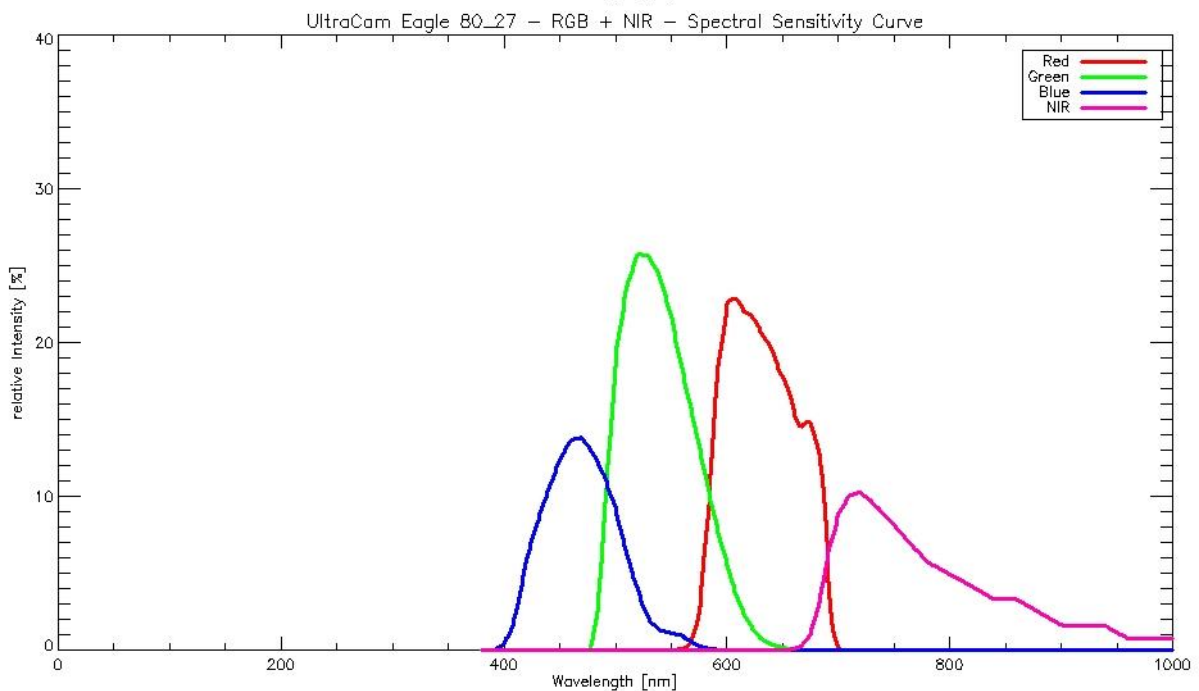
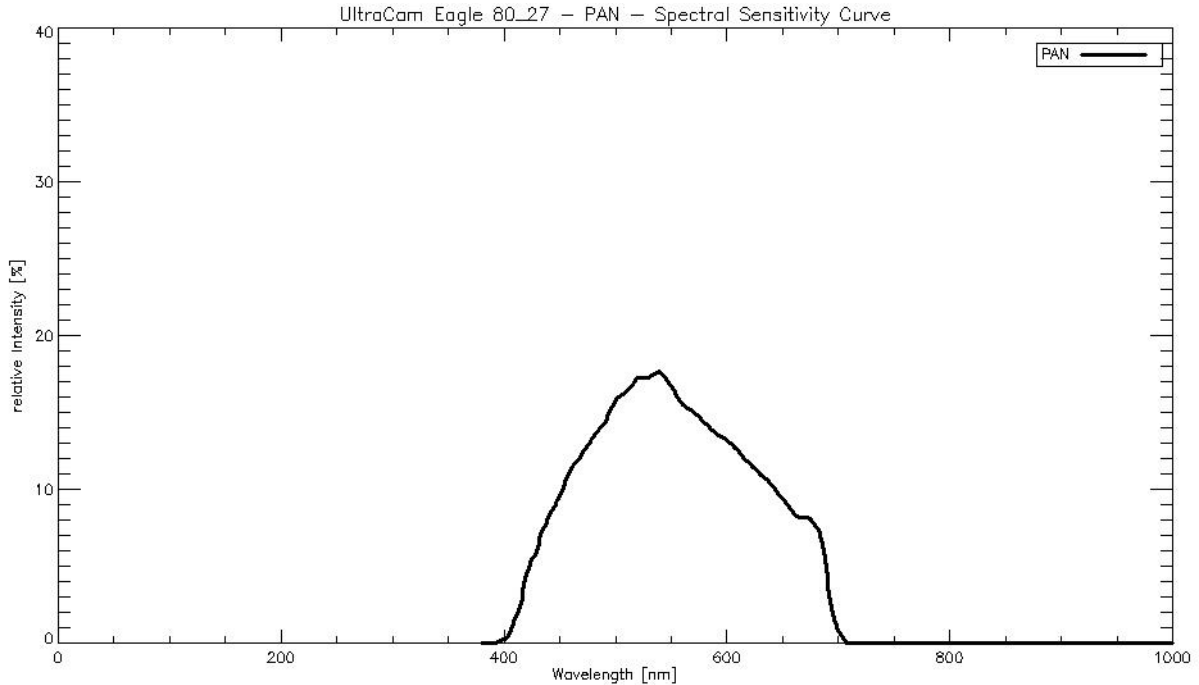
Modulation versus Image Height - Aperture f / 8



Modulation versus Image Height - Aperture f / 9.5



Spectral Sensitivity



Calibration Report

Radiometric Calibration



Camera:

UltraCam Eagle, S/N UC-Eagle-1-60411397-f80

Manufacturer:

Vexcel Imaging GmbH, A-8010 Graz,
Austria

	PAN	R, G, NIR	B
Aperture	F5.6	F4.8	F4.8
	F6.5	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

Date of Calibration:

Jan-28-2016

Date of Report:

Feb-09-2016

Revision of Camera:

Rev04.00

Version of Report:

V01

Calibration of Vignetting for Aperture Setting 1


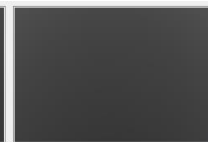

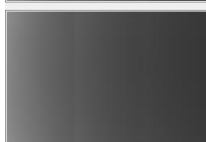
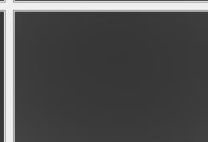
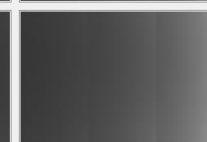



	PAN	R, G, NIR	B
Aperture	F5.6	F4.8	F4.8

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain \geq	Maximum Gain \leq
00_00	f / 5.6	1.00	3.00
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 / 4.8	1.00	5.00
05_00 (green)	f / 4.8	1.00	3.00
06_00 (blue)	f / 4.8	1.00	3.00
07_00 (NIR)	f / 4.8	1.00	4.00

Calibration of Vignetting for Aperture Setting 1

Graphical Overview of Pan Sensor Gain Values:

Graphical Overview of Multispectral Sensor Gain Values:

Calibration of Vignetting for Aperture Setting 2


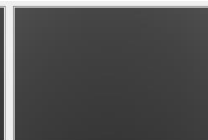

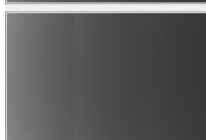
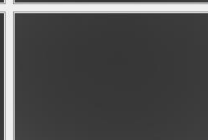
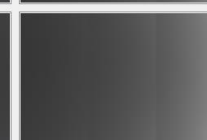
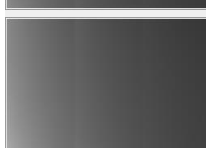
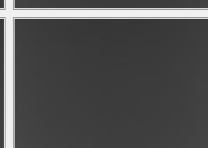
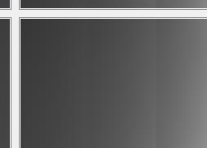
	PAN	R, G, NIR	B
Aperture	F6.5	F5.4	F4.8

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain \geq	Maximum Gain \leq
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 / 5.4	1.00	5.00
05_00 (green)	f / 5.4	1.00	3.00
06_00 (blue)	f / 4.8	1.00	3.00
07_00 (NIR)	f / 5.4	1.00	3.00

Calibration of Vignetting for Aperture Setting 2

Graphical Overview of Pan Sensor Gain Values:

Graphical Overview of Multispectral Sensor Gain Values:

Calibration of Vignetting for Aperture Setting 3

	PAN	R, G, NIR	B
Aperture	F8	F6.7	F4.8

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 / 6.7	1.00	4.00
05_00 (green)	f / 6.7	1.00	3.00
06_00 (blue)	f / 4.8	1.00	3.00
07_00 (NIR)	f / 6.7	1.00	3.00

Calibration of Vignetting for Aperture Setting 3

Graphical Overview of Pan Sensor Gain Values:

Graphical Overview of Multispectral Sensor Gain Values:

Calibration of Vignetting for Aperture Setting 4


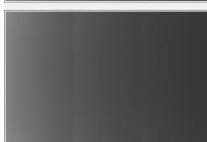
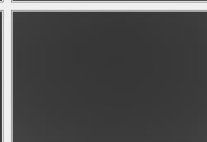
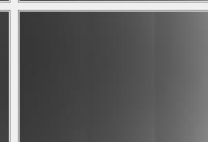

	PAN	R, G, NIR	B
Aperture	F9.5	F8	F5.6

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain \geq	Maximum Gain \leq
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 / 8	1.00	4.00
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	3.00

Calibration of Vignetting for Aperture Setting 4

Graphical Overview of Pan Sensor Gain Values:

Graphical Overview of Multispectral Sensor Gain Values:

Calibration of Vignetting for Aperture Setting 5


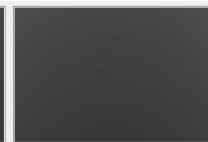

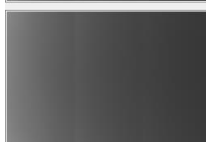
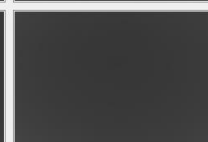
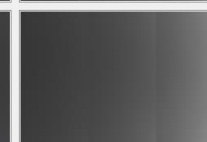



	PAN	R, G, NIR	B
Aperture	F11	F9.5	F6.7

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 / 9.5	1.00	4.00
05_00 (green)	f / 9.5	1.00	3.00
06_00 (blue)	f / 6.7	1.00	3.00
07_00 (NIR)	f / 9.5	1.00	3.00

Calibration of Vignetting for Aperture Setting 5

Graphical Overview of Pan Sensor Gain Values:

Graphical Overview of Multispectral Sensor Gain Values:

Calibration of Vignetting for Aperture Setting 6


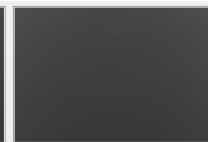

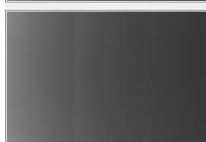
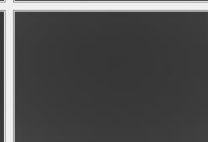
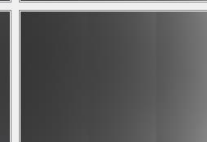



	PAN	R, G, NIR	B
Aperture	F13	F11	F8

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 / 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 6

Graphical Overview of Pan Sensor Gain Values:

Graphical Overview of Multispectral Sensor Gain Values:

Calibration of Vignetting for Aperture Setting 7



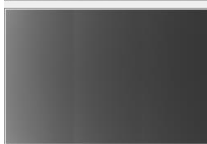
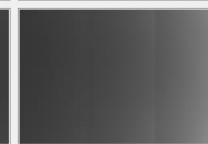

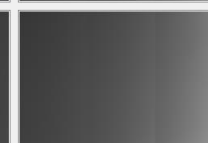
	PAN	R, G, NIR	B
Aperture	F16	F13	F8

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain \geq	Maximum Gain \leq
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 / 13	1.00	4.00
05_00 (green)	f / 13	1.00	3.00
06_00 (blue)	f / 8	1.00	3.00
07_00 (NIR)	f / 13	1.00	3.00

Calibration of Vignetting for Aperture Setting 7

Graphical Overview of Pan Sensor Gain Values:

Graphical Overview of Multispectral Sensor Gain Values:

Calibration of Vignetting for Aperture Setting 8


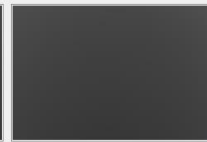

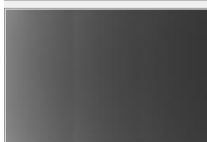
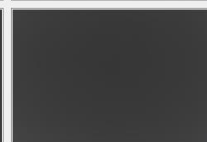
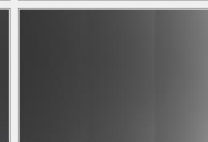


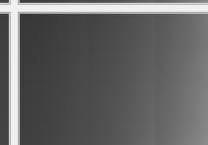
	PAN	R, G, NIR	B
Aperture	F22	F19	F13

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 / 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 8

Graphical Overview of Pan Sensor Gain Values:

Graphical Overview of Multispectral Sensor Gain Values:

Defective Pixel Report:

Sensor		
Anomaly Type	X	Y

C00-00

PIXEL: 66/4595
 PIXEL: 673/2831
 PIXEL: 1116/2375
 PIXEL: 2360/ 245
 PIXEL: 2941/1176
 PIXEL: 3588/1799
 PIXEL: 4162/4066
 PIXEL: 5939/1645
 PIXEL: 6919/ 900

C00-01

PIXEL: 2586/ 792
 PIXEL: 330/ 40
 PIXEL: 6289/1007
 PIXEL: 6359/2219
 PIXEL: 6392/4235
 PIXEL: 6614/4204
 PIXEL: 330/ 39
 PIXEL: 6289/1006
 PIXEL: 6359/2220
 PIXEL: 6589/4189

C00-02

PIXEL: 1702/ 29
 PIXEL: 4869/3057
 PIXEL: 5000/2642
 PIXEL: 463/3681
 PIXEL: 3767/3466
 PIXEL: 5536/3169
 PIXEL: 5679/3583
 PIXEL: 5679/3584
 PIXEL: 5680/3583

C00-03

PIXEL: 1051/4097
 PIXEL: 2465/ 86
 PIXEL: 3020/ 273
 PIXEL: 3092/2911
 PIXEL: 3213/2260
 PIXEL: 3215/2262
 PIXEL: 3397/4387
 PIXEL: 3493/1613
 PIXEL: 6418/3667
 PIXEL: 3642/4495
 PIXEL: 3642/4496
 PIXEL: 5550/3180
 PIXEL: 5551/3180

UltraCamEagle, Serial Number UC-Eagle-1-60411397-f80

C01-00

PIXEL: 4235/1725
PIXEL: 2290/3373
PIXEL: 2290/3374
PIXEL: 2291/3374
PIXEL: 2291/3375
PIXEL: 2769/ 919
PIXEL: 2770/ 919

C01-01

PIXEL: 1768/2658
PIXEL: 4237/ 887
PIXEL: 6149/3534

C02-00

PIXEL: 516/4263
PIXEL: 706/4285
PIXEL: 760/ 591
PIXEL: 1919/1003
PIXEL: 5539/3795
PIXEL: 5937/3571
PIXEL: 1806/3219
PIXEL: 2606/3260
PIXEL: 3839/3192
PIXEL: 4827/1229
PIXEL: 6872/ 103
PIXEL: 4828/1229
PIXEL: 4827/1228
PIXEL: 4827/1230
PIXEL: 6872/ 102

C02-01

PIXEL: 461/1903
PIXEL: 624/1793
PIXEL: 2001/2197
PIXEL: 3210/2792
PIXEL: 4469/ 56
PIXEL: 5254/2958
PIXEL: 5631/4516
PIXEL: 4398/ 183
PIXEL: 5682/3336
PIXEL: 5868/2237
PIXEL: 5869/2237
PIXEL: 5682/3335
PIXEL: 5868/2236

C03-00

PIXEL: 379/2387
PIXEL: 2396/ 640
PIXEL: 3461/1592
PIXEL: 4343/3290
PIXEL: 5362/1314
PIXEL: 5791/3256
PIXEL: 6251/3176
PIXEL: 2174/1143

UltraCamEagle, Serial Number UC-Eagle-1-60411397-f80

C04-00

PIXEL: 1134/1850
PIXEL: 2733/3469
PIXEL: 5500/ 921
PIXEL: 5500/ 920

C05-00

PIXEL: 3655/4421
PIXEL: 4082/3825

C06-00

PIXEL: 1327/ 210
PIXEL: 4757/1855
PIXEL: 6325/2398
PIXEL: 824/4616
PIXEL: 4287/4627

C07-00

PIXEL: 5066/3453
PIXEL: 5726/4265
PIXEL: 288/1821
PIXEL: 289/1820
PIXEL: 331/3188
PIXEL: 332/3187
PIXEL: 332/3188
PIXEL: 6280/ 952
PIXEL: 288/1820
PIXEL: 6279/ 952

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-1-60411397-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-28-2016

Date of Report: Feb-09-2016

Revision of Camera: Rev04.00

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 16 05 78	11.71	11.89	12.63	13.19	13.48	13.57	14.03	14.81	+/- 0.2
C1 (Pan 2CCD V)	12 16 05 84	10.84	11.13	11.69	12.05	12.49	12.63	12.90	13.32	+/- 0.2
C2 (Pan 2CCD H)	12 15 42 91	11.45	11.88	12.38	12.80	13.16	13.50	13.68	14.20	+/- 0.2
C3 (Pan Central)	12 16 05 88	11.11	11.52	12.05	12.46	12.68	12.90	13.10	13.61	+/- 0.2
C4 (Red)	12 11 00 37	12.53	12.70	12.94	13.13	13.30	13.35	13.51	13.59	+/- 0.2
C5 (Green)	12 11 00 62	12.37	12.50	12.76	13.01	13.15	13.29	13.44	13.66	+/- 0.2
C6 (Blue)	12 12 06 28	12.61	12.63	12.65	12.77	13.05	13.27	13.45	13.72	+/- 0.2
C7 (NIR)	12 15 32 05	12.05	12.21	12.41	12.69	12.79	12.87	12.93	13.06	+/- 0.2

Calibration Report

Electronics and Sensor Calibration



Camera:	UltraCam Eagle, S/N UC-Eagle-1-60411397-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-28-2016
Date of Report:	Feb-09-2016
Revision of Camera:	Rev04.00
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	15 7349/038	24.00
00_01	FTF7046-M	15 7349/022	23.80
00_02	FTF7046-M	15 7349/059	24.40
00_03	FTF7046-M	15 7349/073	24.40
01_00	FTF7046-M	15 7349/056	24.60
01_01	FTF7046-M	15 7349/060	24.60
02_00	FTF7046-M	15 7349/040	24.40
02_01	FTF7046-M	15 7349/046	23.80
03_00	FTF7046-M	15 0541/065	24.20
04_00 (red)	FTF7046-M	15 7349/069	24.60
05_00 (green)	FTF7046-M	15 7349/037	24.20
06_00 (blue)	FTF7046-M	15 7349/036	24.00
07_00 (NIR)	FTF7046-M	15 7349/063	24.60

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 7349/038	13380
00_01	FTF7046-M	15 7349/022	13770
00_02	FTF7046-M	15 7349/059	14160
00_03	FTF7046-M	15 7349/073	13870
01_00	FTF7046-M	15 7349/056	13520
01_01	FTF7046-M	15 7349/060	14010
02_00	FTF7046-M	15 7349/040	14050
02_01	FTF7046-M	15 7349/046	13500
03_00	FTF7046-M	15 0541/065	13860
04_00 (red)	FTF7046-M	15 7349/069	13580
05_00 (green)	FTF7046-M	15 7349/037	13890
06_00 (blue)	FTF7046-M	15 7349/036	14270
07_00 (NIR)	FTF7046-M	15 7349/063	13940

Calibration Report

Summary



Camera: UltraCam Eagle, S/N UC-Eagle-1-60411397-f80

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


Date of Calibration: Jan-28-2016
Date of Report: Feb-09-2016
Revision of Camera: Rev04.00
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
Chief Scientist, Photogrammetry
Vexcel Imaging GmbH


Ing. Peter Prassl
Senior Calibration Engineer
Vexcel Imaging GmbH