

Calibration Report



Camera:	UltraCam D, S/N UCD-SU-1-0039
Manufacturer:	Vexcel Imaging GmbH, A-8010 Graz, Austria
Date of Calibration:	Nov-28-2006
Date of Report:	Nov-28-2006
Camera Revision:	2.0
Revision of Report:	2.0

Calibration Report

Geometric Calibration



Camera:	UltraCam D, S/N UCD-SU-1-0039
Manufacturer:	Vexcel Imaging GmbH, A-8010 Graz, Austria
Panchromatic Camera:	ck = 105.200mm
Multispectral Camera:	ck = 105.200mm
Date of Calibration:	Nov-28-2006
Date of Report:	Nov-28-2006
Camera Revision:	2.0
Revision of Report:	2.0

Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track	67.5mm	7500 pixel
	cross track	103.5mm	11500 pixel
Image Extent		(-33.75, -51.75)mm	(33.75, 51.75)mm
Pixel Size		9.000µm*9.000µm	
Focal Length	ck	105.200mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000 mm	± 0.002mm
	Y_ppa	0.360 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Multispectral Camera

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

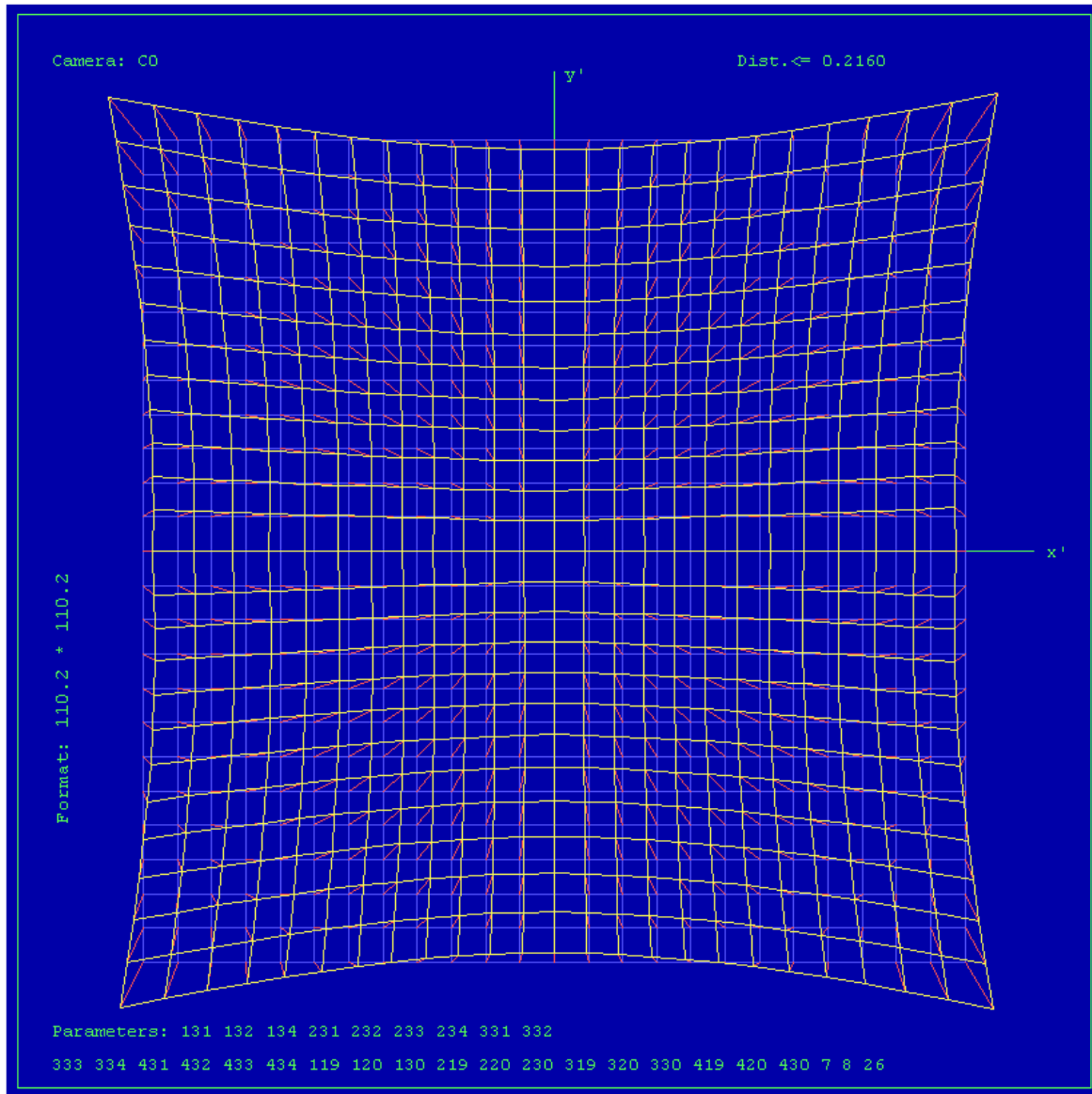
Image Format	long track	67.5mm	2400 pixel
	cross track	103.5mm	3680 pixel
Image Extent		(-33.75, -51.75)mm	(33.75, 51.75)mm
Pixel Size		28.125µm*28.125µm	
Focal Length	ck	105.200mm	
Principal Point (Level 2)	X_ppa	0.000 mm	± 0.002mm
	Y_ppa	0.360 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Individual Panchromatic Cone Data

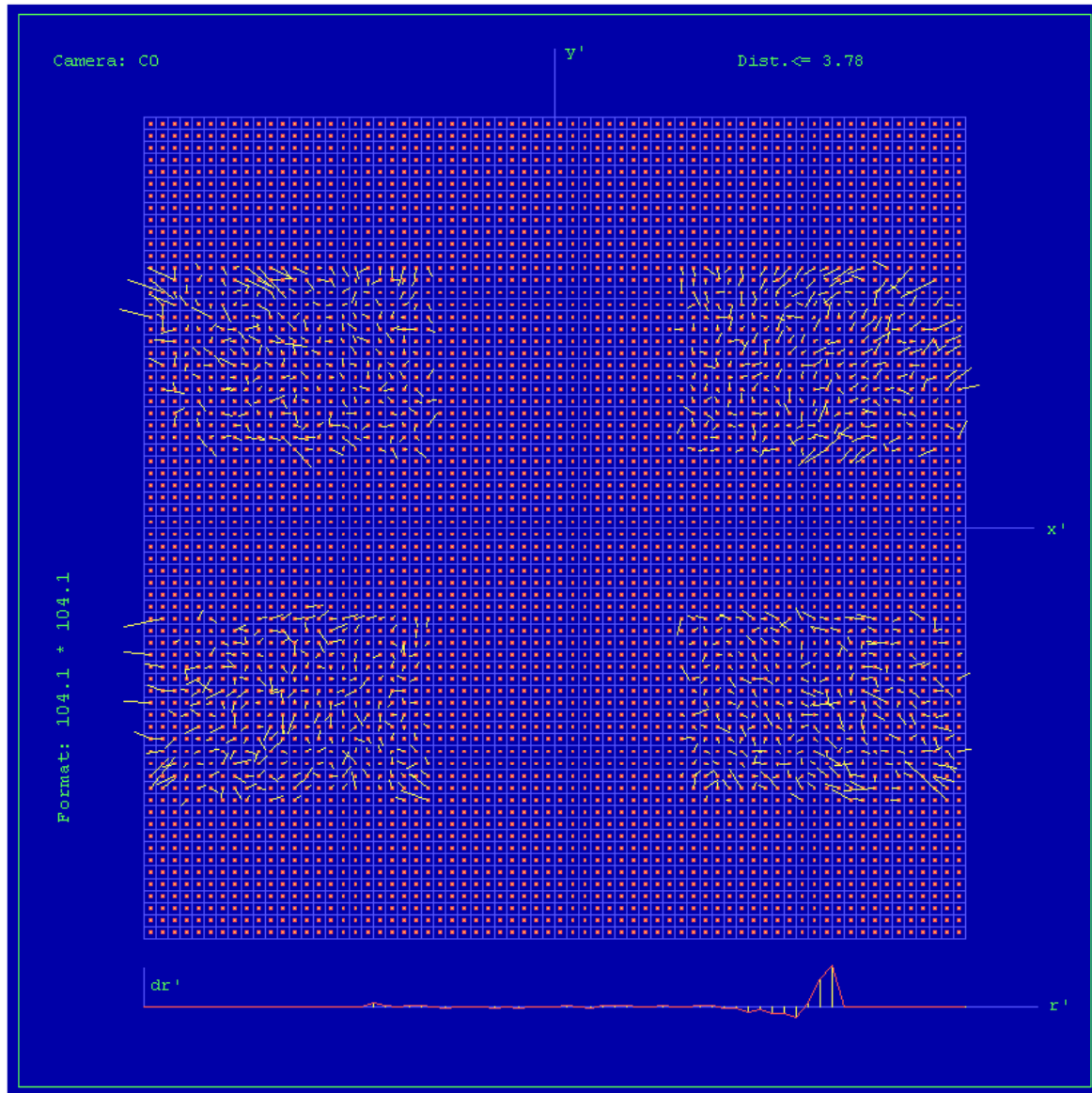
Cone 0, Parametric Description, Not Effective in Output Image

Cone # C0												
Lens	Rodenstock Apo-Sironar Digital 105mm Linos GmbH, Germany											
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH											
Image Extent (nominally)		(-33.75, -51.75)mm	(33.75, 51.75)mm									
Extent CCD 0		(-33.75, -51.75)mm	(-9.75, -15.75)mm									
Extent CCD 1		(-33.75, 15.75)mm	(-9.75, 51.75)mm									
Extent CCD 2		(9.75, -51.75)mm	(33.75, -15.75)mm									
Extent CCD 3		(9.75, 15.75)mm	(33.75, 51.75)mm									
Parameters	Shift X	ShiftY	Rotation	Scale								
CCD0	5.54587344E-02 mm ± 0.0016 mm	-2.95022115E-01 mm ± 0.0025 mm	9.70174425E-02 gon ± 0.0001 gon	1.00287242 ± 0.00005								
CCD1	1.03314563E-01 mm ± 0.0016 mm	-3.69209174E-01 mm ± 0.0025 mm	0.00000000 gon	1.00357441 ± 0.00005								
CCD2	1.08351767E-02 mm ± 0.0016 mm	-3.11077925E-01 mm ± 0.0025 mm	2.63778391E-02 gon ± 0.0001 gon	1.00353674 ± 0.00005								
CCD3	4.32910718E-02 mm ± 0.0016 mm	-3.26720202E-01 mm ± 0.0025 mm	8.58813481E-02 gon ± 0.0001 gon	1.00426246 ± 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]	-16.8	-34.3	-51.3	-66.7	-79.5	-88.4	-92.4	-90.3	-81.1	-63.6	-36.7	0.8

Cone 0, Distortion Diagram, Not Effective in Output Image



Cone 0, Residual Error Diagram



Residual Error (RMS): **0.92 μm**

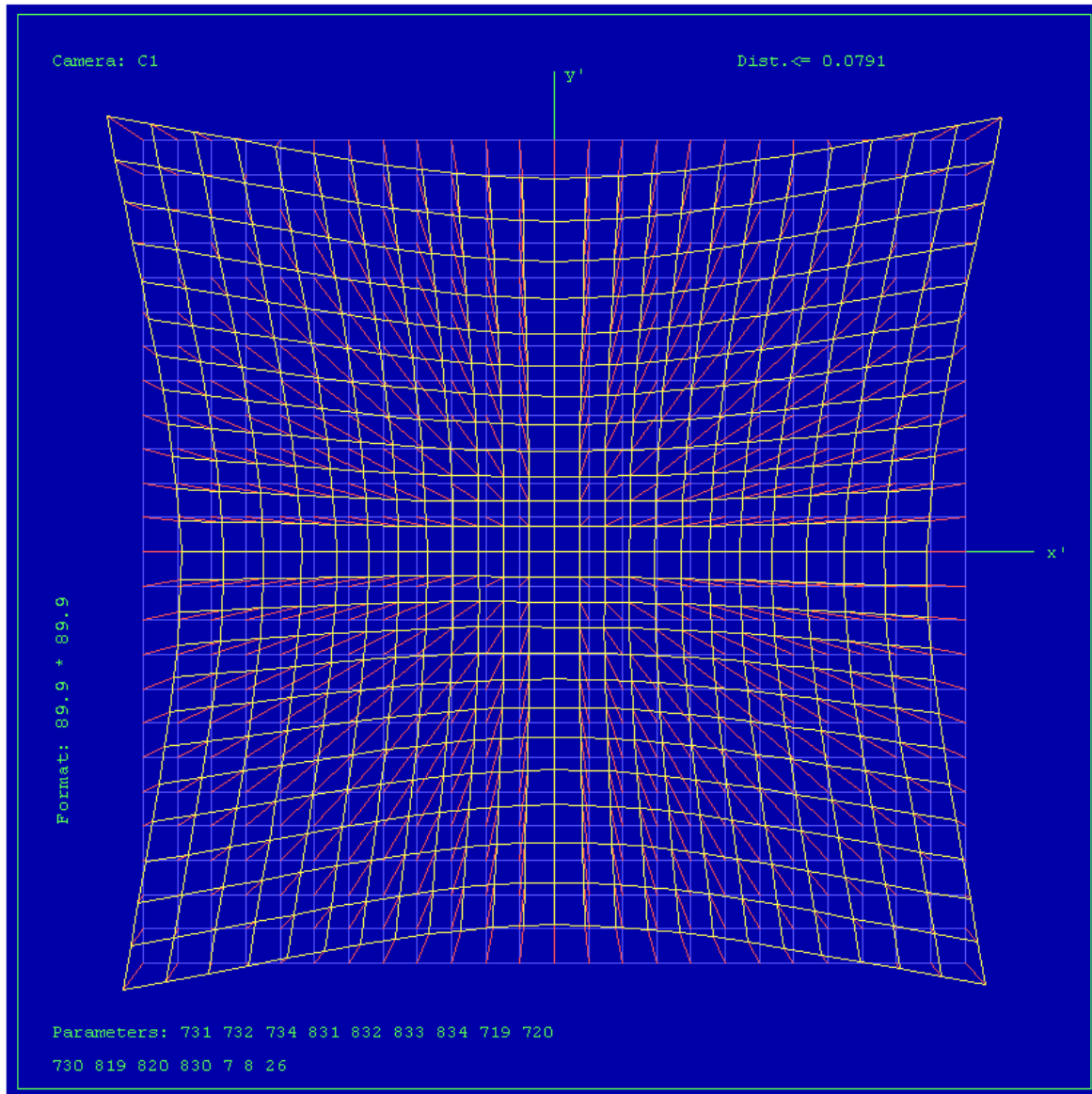


UltraCam D, Serial Number UCD-SU-1-0039

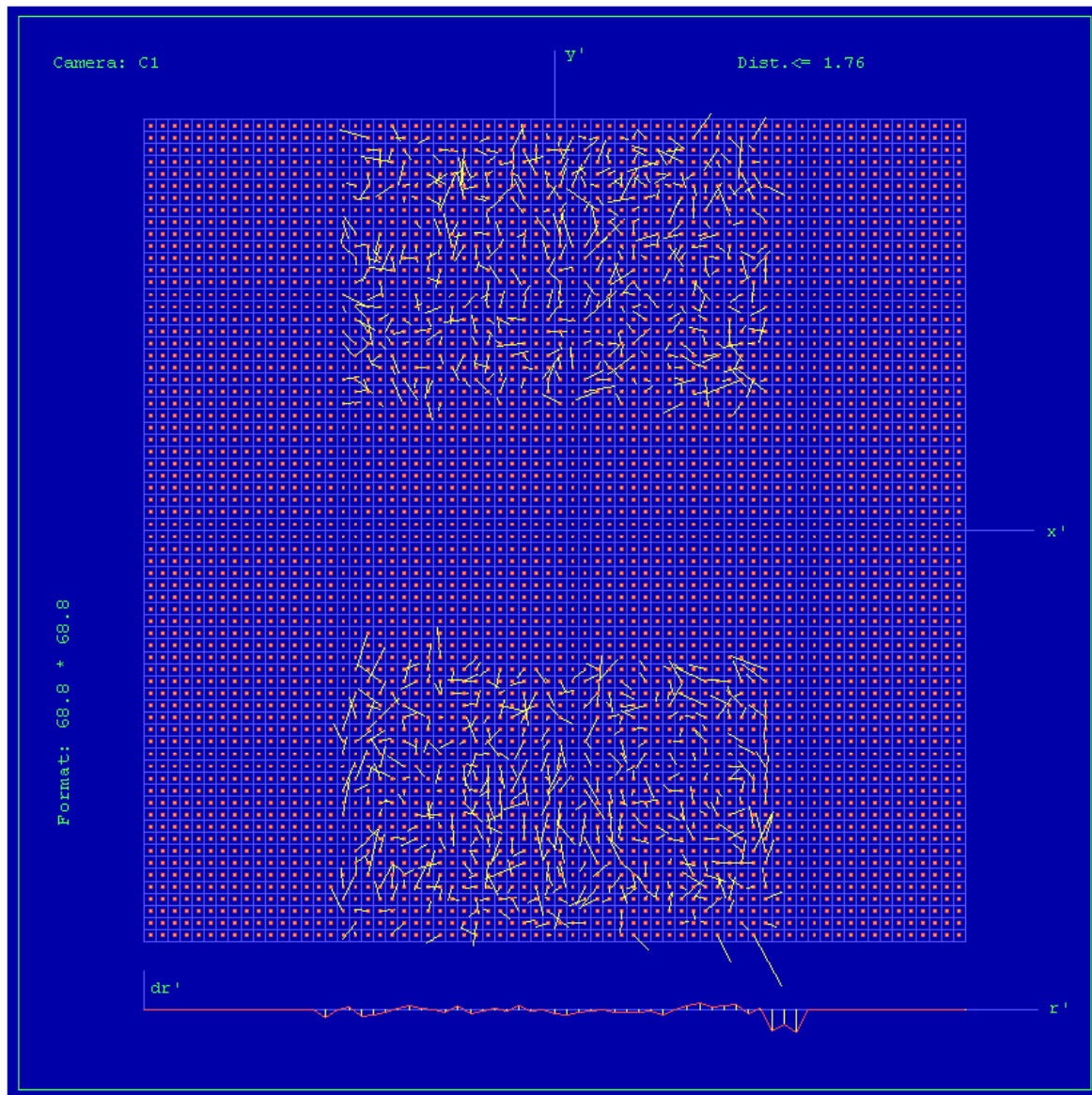
Cone 1, Parametric Description, Not Effective in Output Image

Cone # C1												
Lens	Rodenstock Apo-Sironar Digital 105mm Linos GmbH, Germany											
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH											
Image Extent (nominally)		(-33.75, -18.04)mm	(33.75, 18.04)mm									
Extent CCD 0		(-33.75, -18.04)mm	(-9.75, 18.04)mm									
Extent CCD 1		(9.75, -18.04)mm	(33.75, 18.04)mm									
Parameters	Shift X	Shift Y	Rotation	Scale								
CCD0	8.94679326E-02 mm ± 0.0026 mm	-2.48281814E-01 mm ± 0.0021 mm	0.00000000 gon	1.00478336 ± 0.00005								
CCD1	-9.11539360E-3 mm ± 0.0026 mm	-2.34079490E-01 mm ± 0.0021 mm	2.12334946E-02 gon ±0.0001 gon	1.00541895 ± 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]	-16.3	-33.9	-50.7	-64.6	-74.1	-78.2	-76.1	-67.5	-52.3	-31.0	-4.5	26.1

Cone 1, Distortion Diagram, Not Effective in Output Image



Cone 1, Residual Error Diagram



Residual Error (RMS): **0.93 μm**

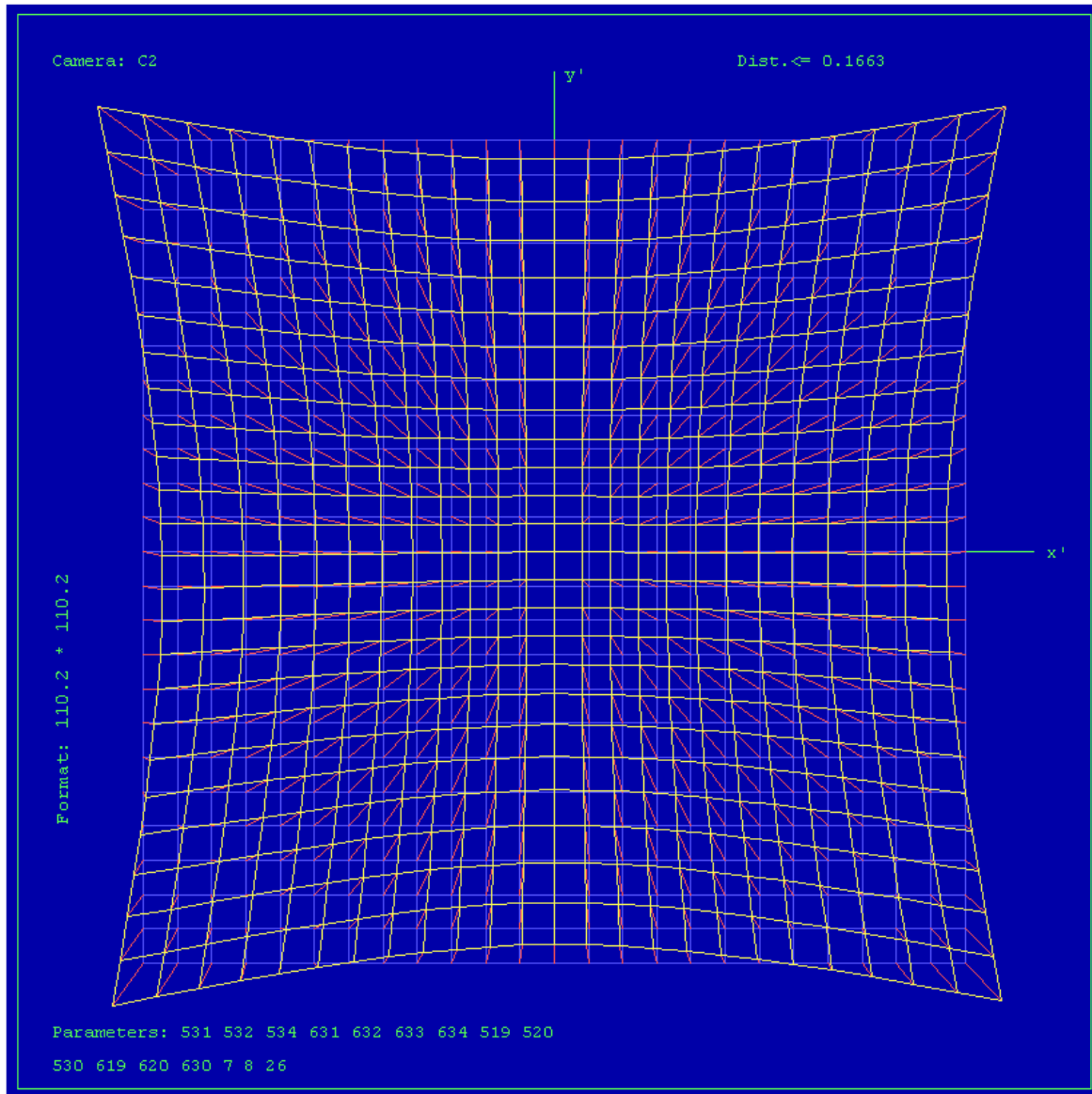


UltraCam D, Serial Number UCD-SU-1-0039

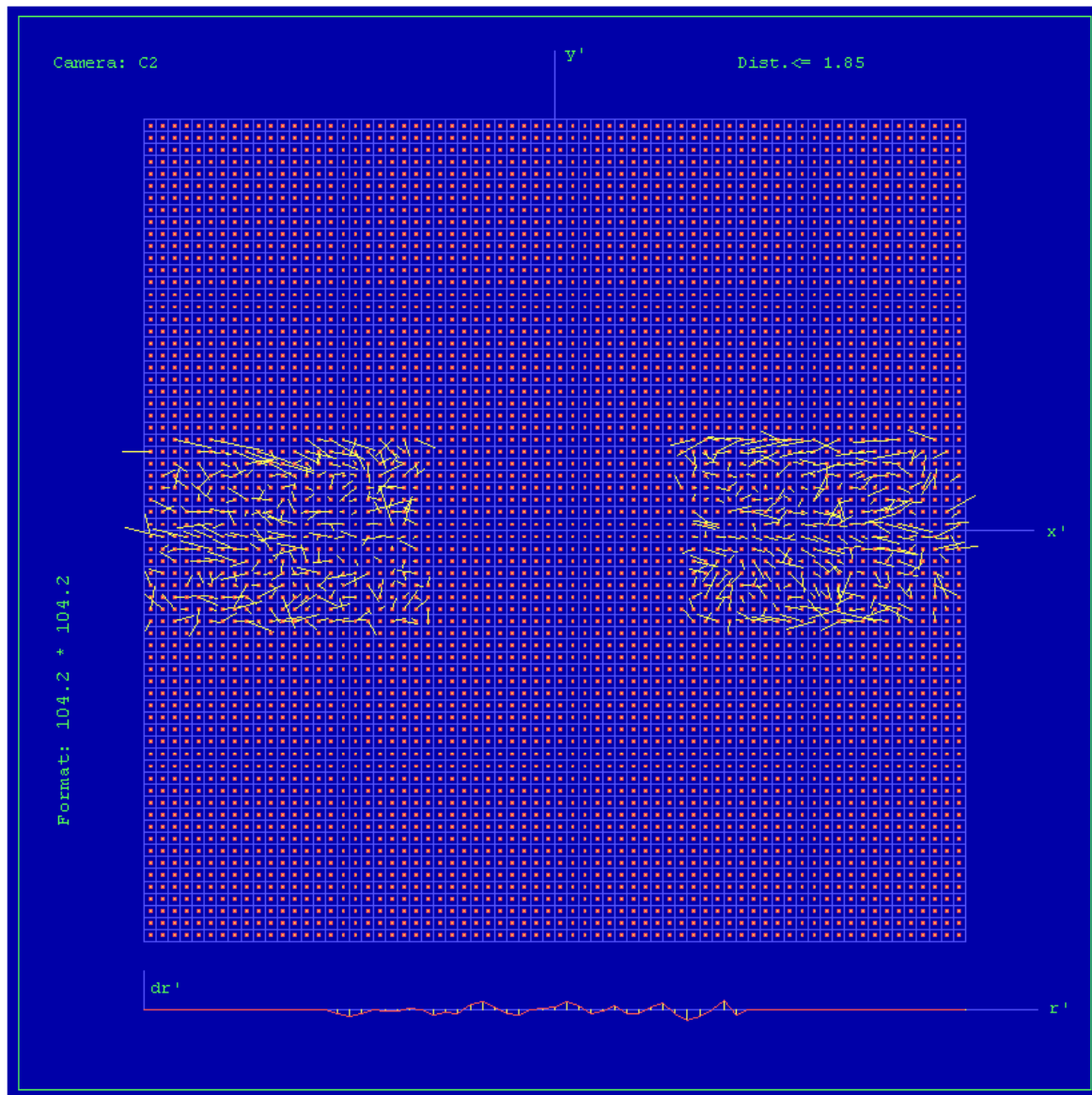
Cone 2, Parametric Description, Not Effective in Output Image

Cone # C2												
Lens	Rodenstock Apo-Sironar Digital 105mm Linos GmbH, Germany											
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH											
Image Extent (nominally)		(-12.01, -51.75)mm		(12.01, 51.75)mm								
Extent CCD 0		(-12.01, -51.75)mm		(12.01, -15.75)mm								
Extent CCD 1		(-12.01, 15.75)mm		(12.01, 51.75)mm								
Parameters	Shift X	ShiftY	Rotation	Scale								
CCD0	-1.69248301E-01 mm ± 0.0018 mm	-1.80208113E-01 mm ± 0.0064 mm	-3.65179306E-02 gon ± 0.0001 gon	1.00284841 ± 0.00005								
CCD1	2.09251432E-01 mm ± 0.0018 mm	-2.87335618E-01 mm ± 0.0064 mm	0.00000000 gon	1.00300488 ± 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]	-20.0	-40.5	-60.1	-77.6	-91.7	-101.4	-105.8	-104.1	-95.6	-79.7	-55.9	-23.9

Cone 2, Distortion Diagram, Not Effective in Output Image



Cone 2, Residual Error Diagram



Residual Error (RMS): **0.97 μm**

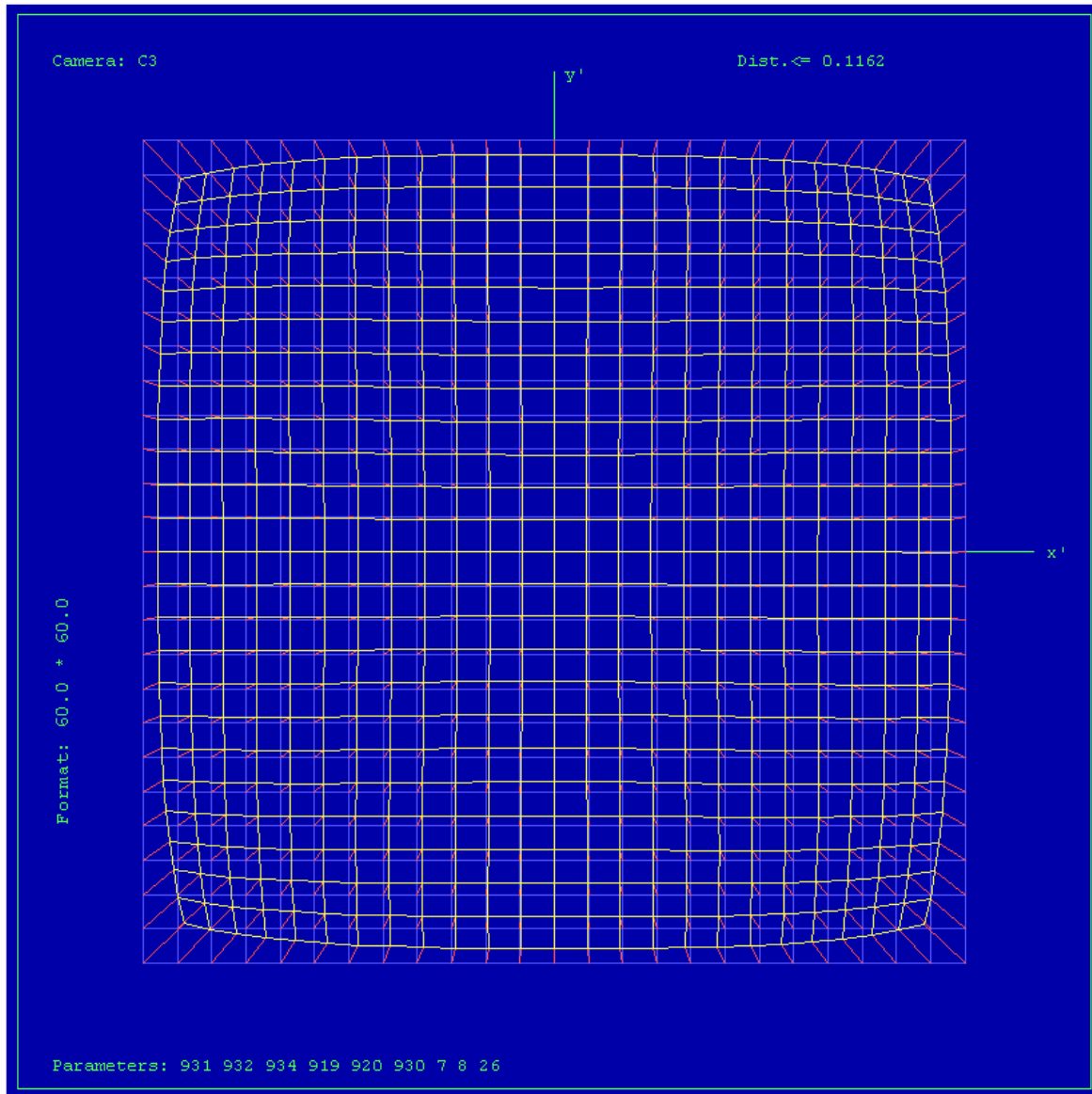


UltraCam D, Serial Number UCD-SU-1-0039

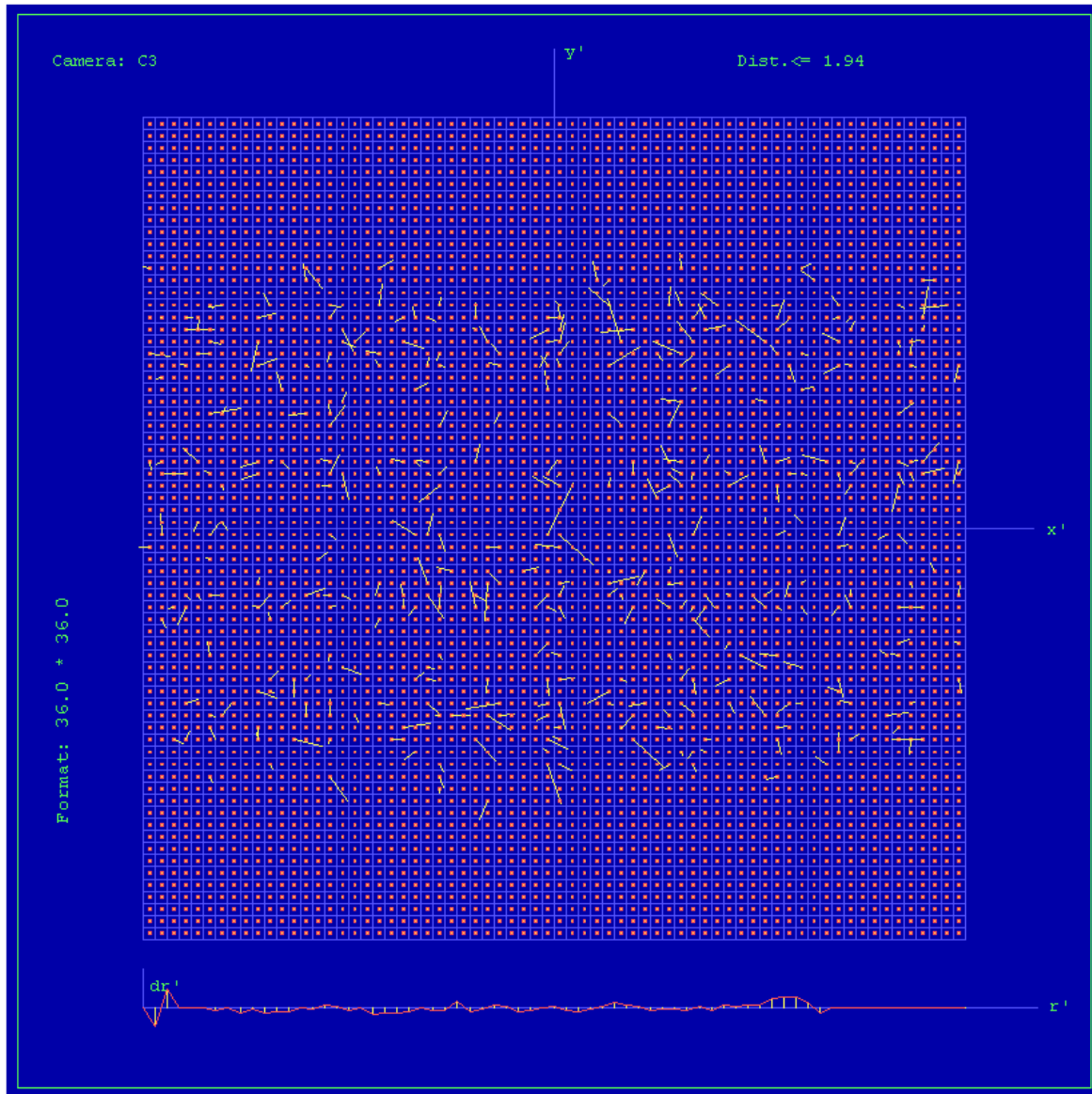
Cone 3, Parametric Description, Not Effective in Output Image

Cone # C3				
Lens	Rodenstock Apo-Sironar Digital 105mm Linos GmbH, Germany			
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH			
Image Extent (nominally)		(-12.01, -18.04)mm		(12.01, 18.04)mm
Extent CCD 0		(-12.01, -18.04)mm		(12.01 , 18.04)mm
Parameters	Shift X	ShiftY	Rotation	Scale
CCD0	1.72261480E-03 mm ± 0.0043 mm	-1.95389857E-01 mm ± 0.0099 mm	0.00000000 gon	1.00609607 ± 0.00005
Radial Distortion				
R [mm]	2.5	5.0	7.5	10.0 12.5 15.0 17.5 20.0 22.5 25.0
dr [µm]	-2.3	-4.5	-6.2	-7.3 -7.6 -7.1 -6.0 -4.5 -3.1 -2.2

Cone 3, Distortion Diagram, Not Effective in Output Image

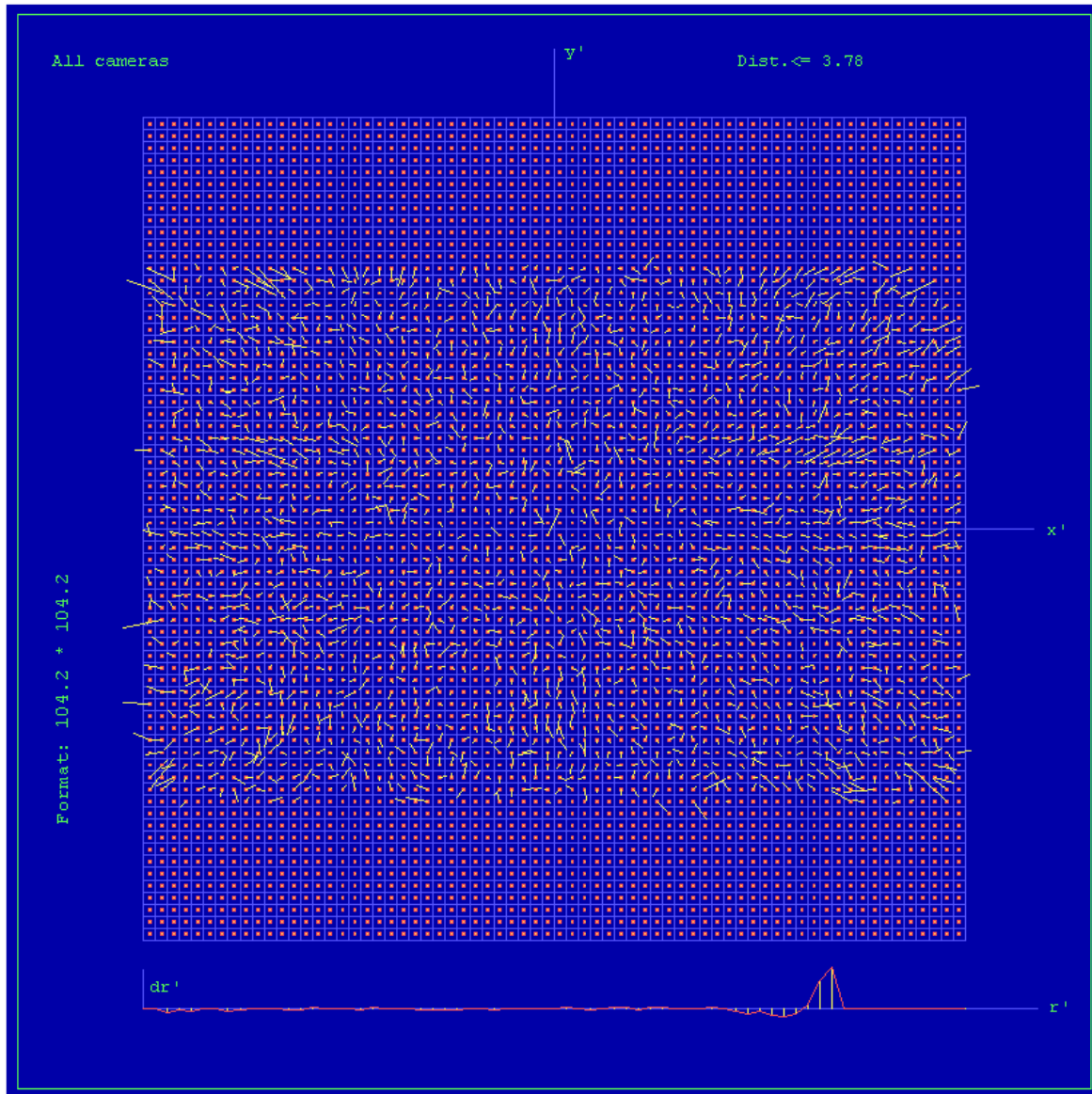


Cone 3, Residual Error Diagram



Residual Error (RMS): **0.82 μm**

Full Pan Image, Residual Error Diagram



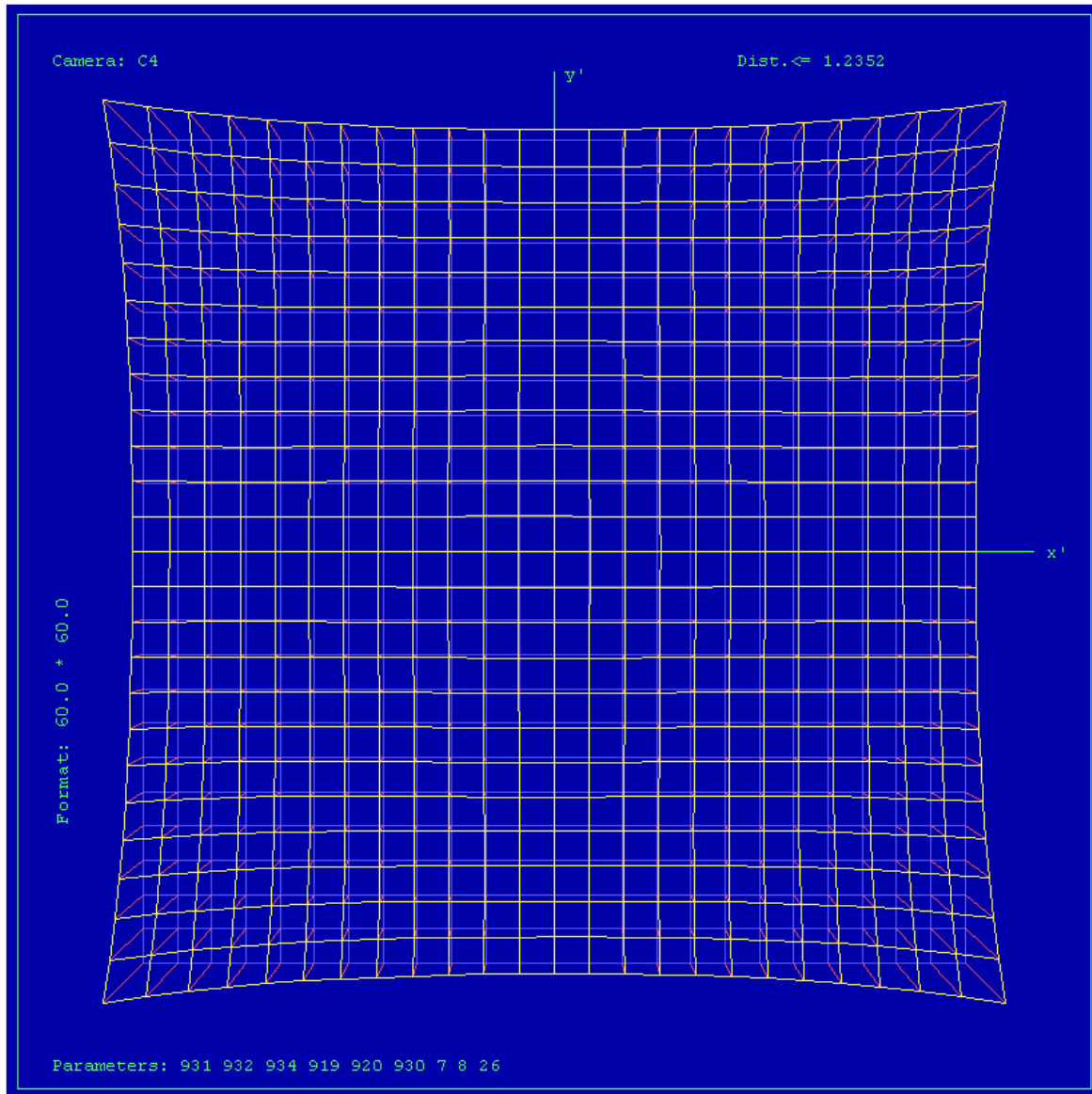
Residual Error (RMS): **0.81 μm**

Individual Multispectral Cone Data

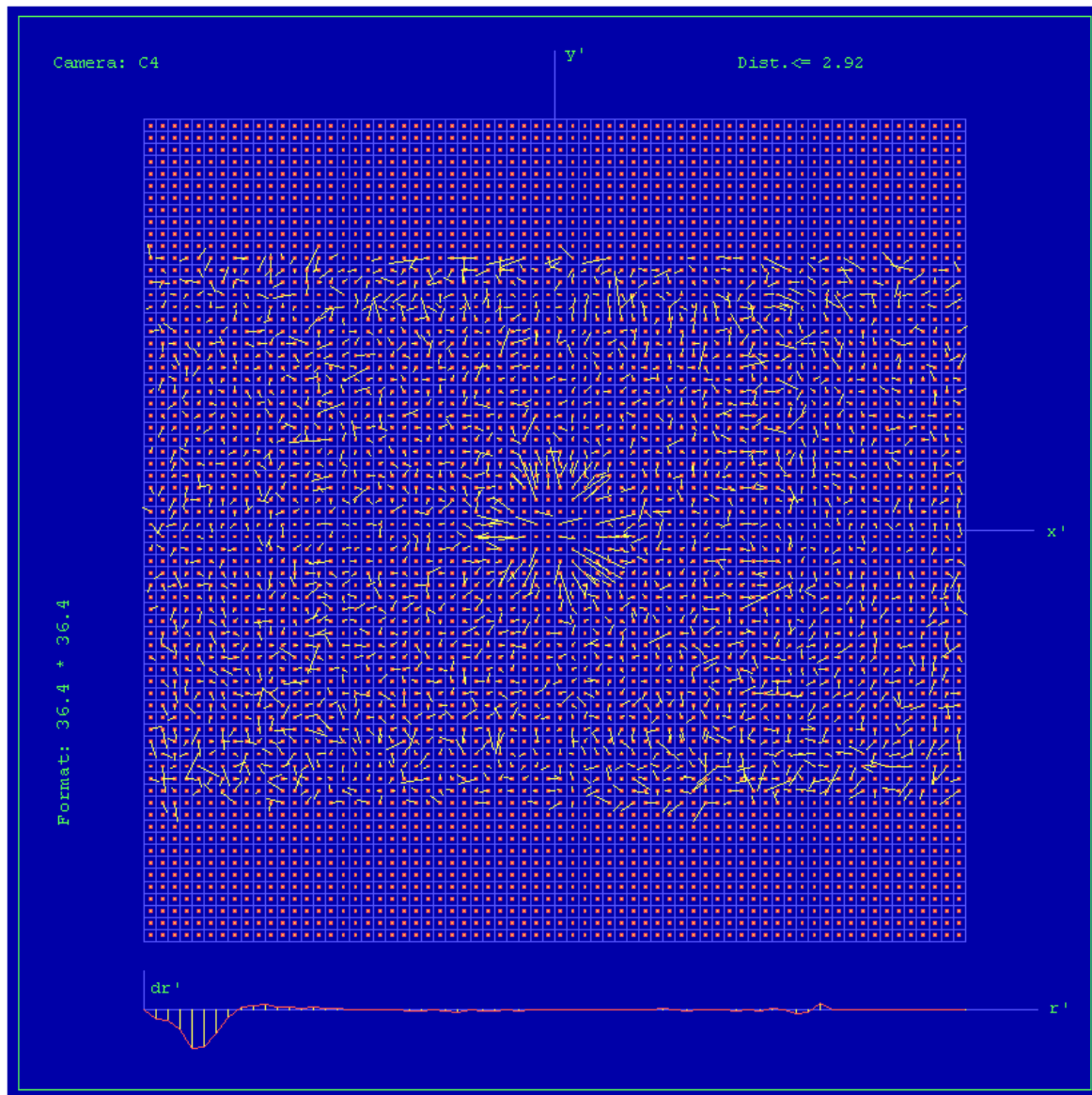
Cone 4, Parametric Description, Not Effective in Output Image

Cone # C4 (red)					
Lens	Rodenstock Apo-Sironar Digital HR 35mm Linios GmbH, Germany				
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH				
Image Extent (nominally)		(-10.08, -16.56)mm	(10.08, 16.56)mm		
Extent CCD 0		(-12.08, -18.04)mm	(12.08, 18.04)mm		
Parameters		Shift X	ShiftY	Rotation	Scale
CCD0		-2.65265672E-02 mm ± 0.0002 mm	2.28599691E-02 mm ± 0.0003 mm	0.00000000 gon	1.02972214 ± 0.00005
Radial Distortion					
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	37.9	59.5	58.2	48.0	63.2

Cone 4, Distortion Diagram, Not Effective in Output Image



Cone 4, Residual Error Diagram

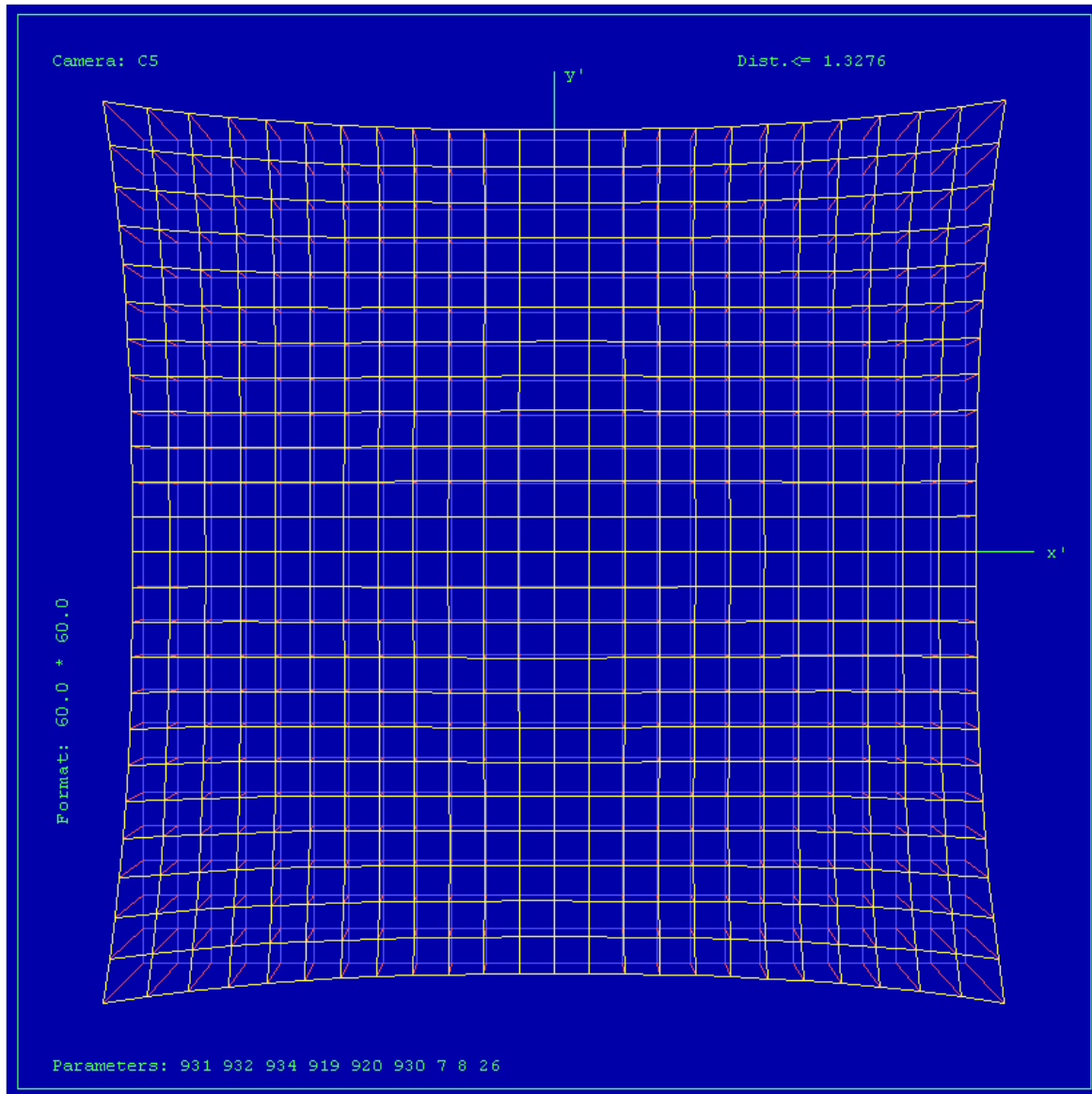


Residual Error (RMS): **0.96 μm**

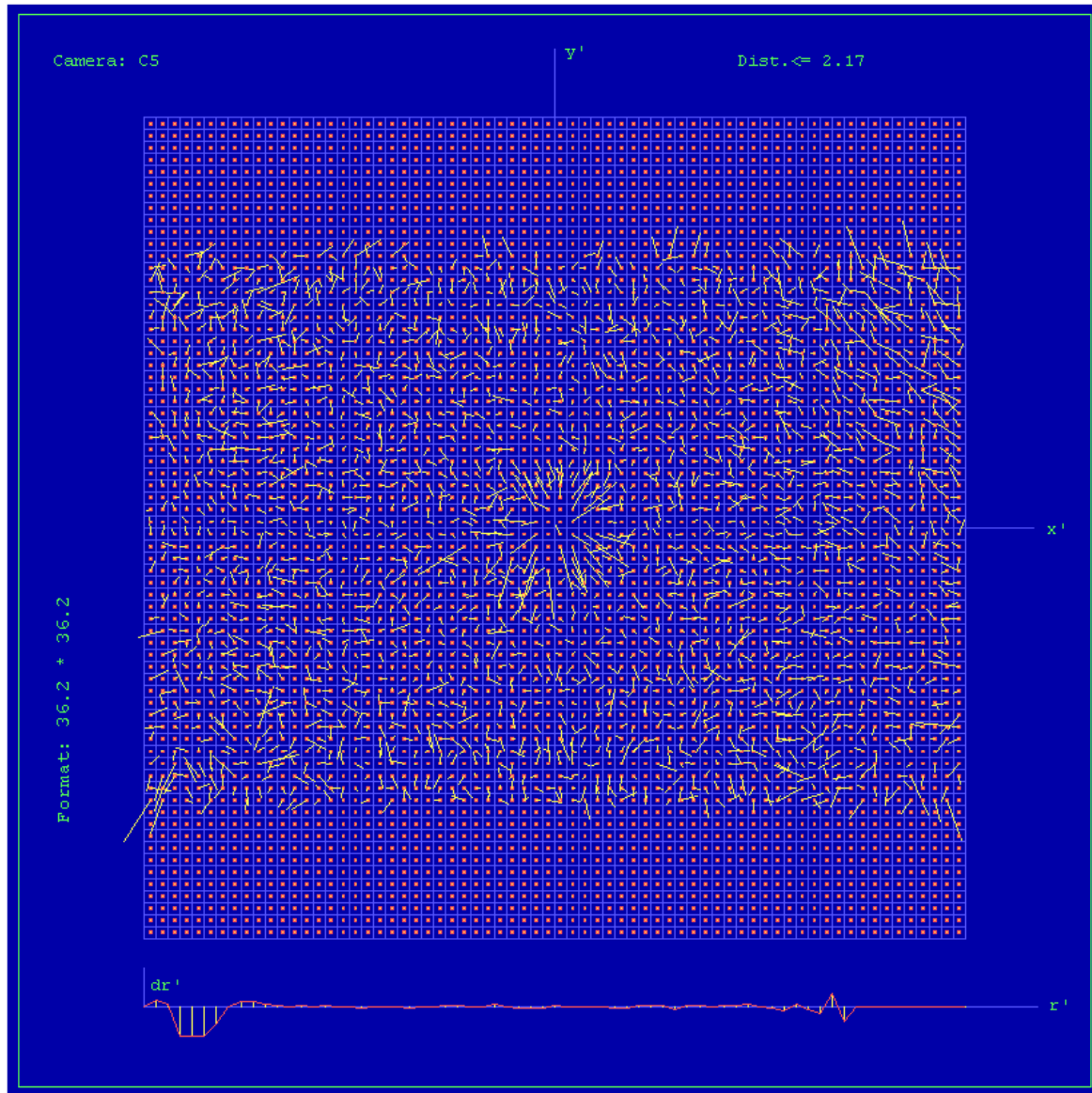
Cone 5, Parametric Description, Not Effective in Output Image

Cone # C5 (green)					
Lens	Rodenstock Apo-Sironar Digital HR 35mm Linos GmbH, Germany				
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH				
Image Extent (nominally)		(-10.08, -16.56)mm		(10.08, 16.56)mm	
Extent CCD 0		(-12.08, -18.04)mm		(12.08, 18.04)mm	
Parameters	Shift X	Shift Y	Rotation	Scale	
CCD0	5.31395995E-02 mm ± 0.0002 mm	5.36831503E-03 mm ± 0.0003 mm	0.00000000 gon	1.02563782 ± 0.00005	
Radial Distortion	Not effective in Production Image				
R [mm]	5.0	10.0	15.0	20.0	25.0
dr [µm]	39.0	61.4	60.4	50.3	66.7

Cone 5, Distortion Diagram, Not Effective in Output Image



Cone 5, Residual Error Diagram

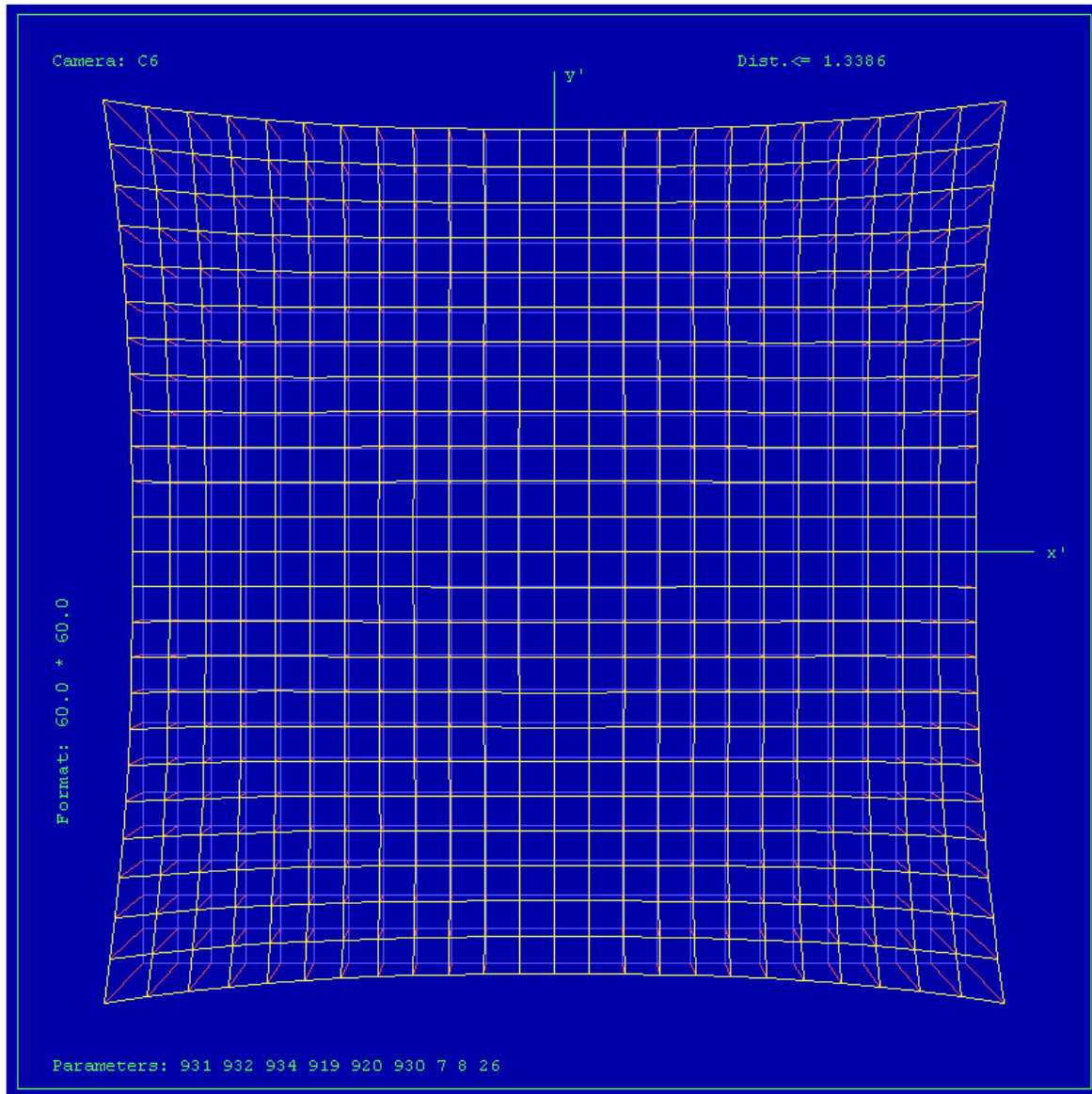


Residual Error (RMS): **0.81 μm**

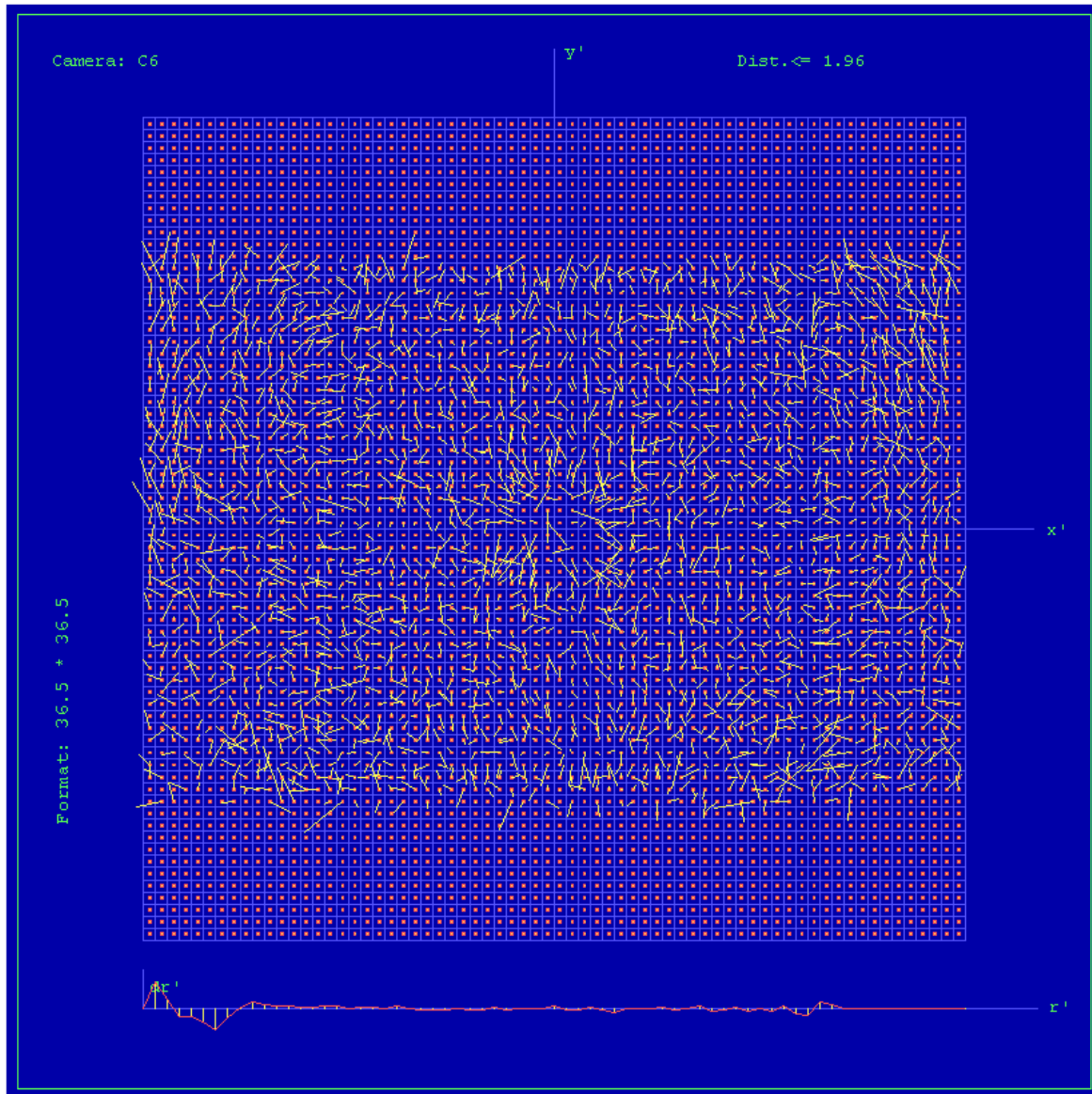
Cone 6, Parametric Description, Not Effective in Output Image

Cone # C6 (blue)				
Lens	Rodenstock Apo-Sironar Digital HR 35mm Linos GmbH, Germany			
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH			
Image Extent (nominally)		(-10.08, -16.56)mm	(10.08, 16.56)mm	
Extent CCD 0		(-12.08, -18.04)mm	(12.08, 18.04)mm	
Parameters	Shift X	ShiftY	Rotation	Scale
CCD0	2.23275447E-02 mm ± 0.0002 mm	-4.39776506E-02 mm ± 0.0003 mm	0.00000000 gon	1.02839515 ± 0.00005
Radial Distortion	Not effective in Production Image			
R [mm]	5.0	10.0	15.0	20.0 25.0
dr [µm]	37.5	59.5	59.2	51.4 72.4

Cone 6, Distortion Diagram, Not Effective in Output Image



Cone 6, Residual Error Diagram

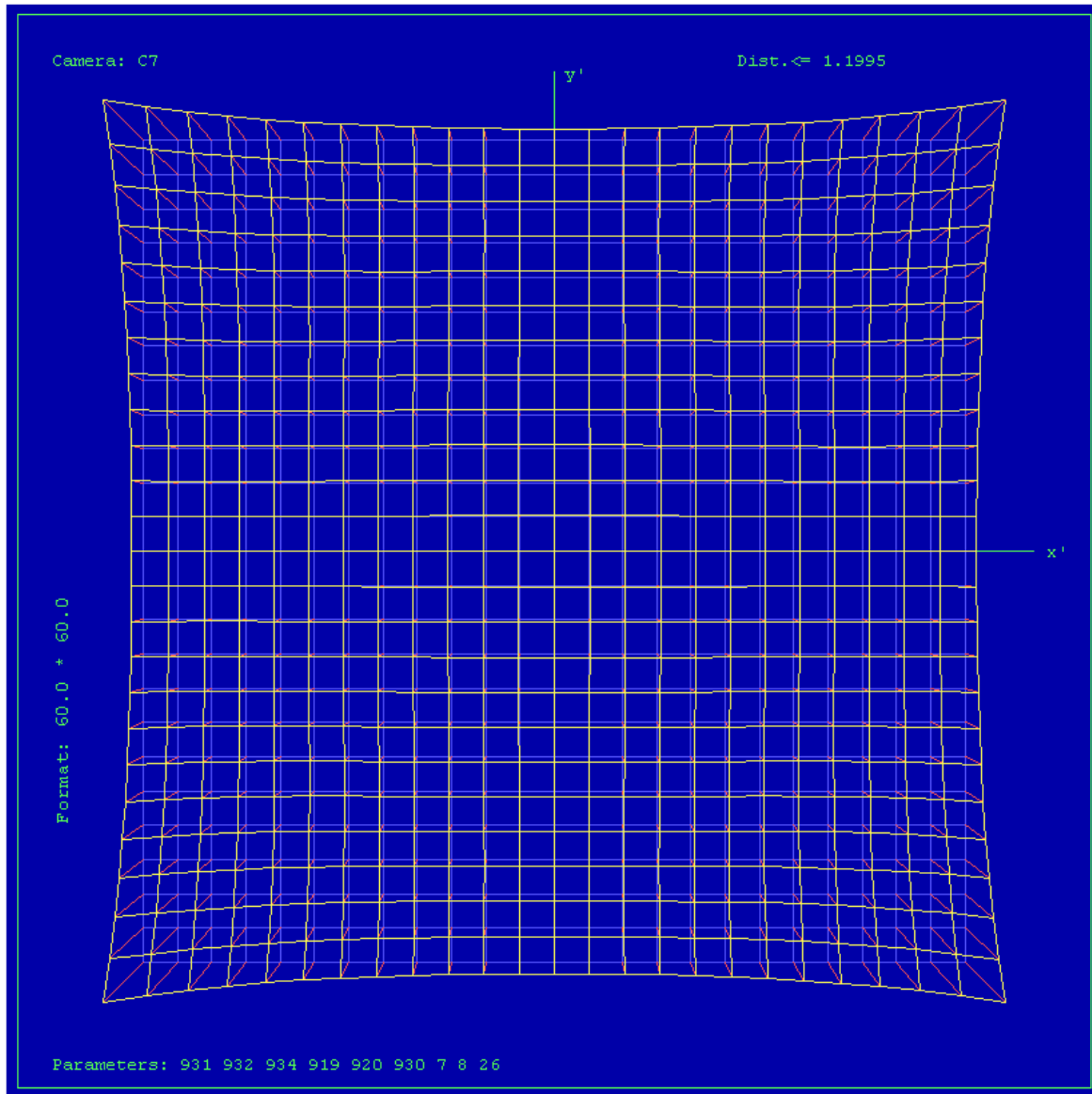


Residual Error (RMS): **0.84 μm**

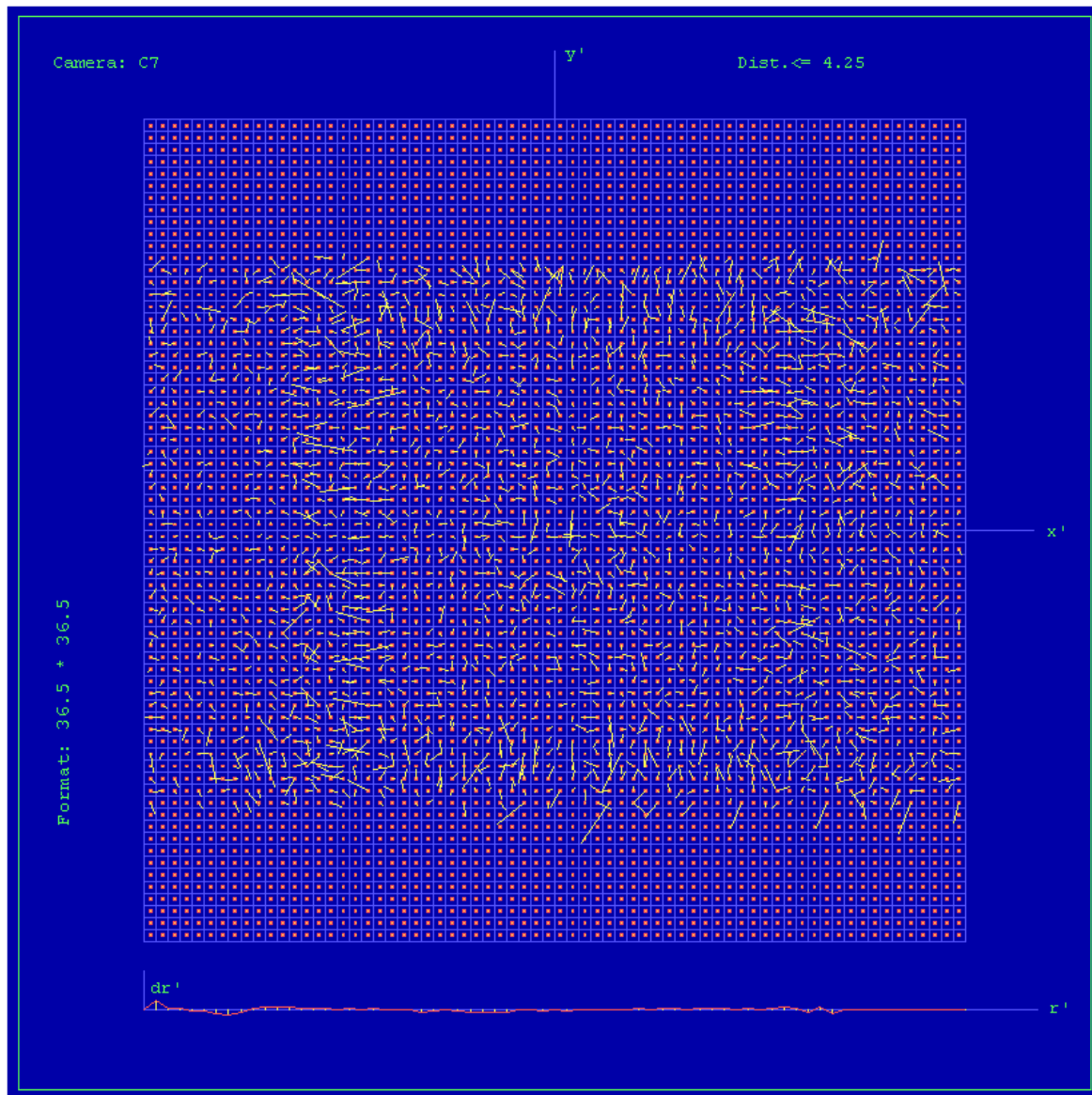
Cone 7, Parametric Description, Not Effective in Output Image

Cone # C7 (NIR)				
Lens	Rodenstock Apo-Sironar Digital HR 35mm Linos GmbH, Germany			
Shutter	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH			
Image Extent (nominally)		(-10.08, -16.56)mm		(10.08, 16.56)mm
Extent CCD 0		(-12.08, -18.04)mm		(12.08, 18.04)mm
Parameters	Shift X	ShiftY	Rotation	Scale
CCD0	3.06721109E-02 mm ± 0.0002 mm	-5.48097386E-03 mm ± 0.0003 mm	0.00000000 gon	1.03092754 ± 0.00005
Radial Distortion	Not effective in Production Image			
R [mm]	5.0	10.0	15.0	20.0 25.0
dr [µm]	39.3	61.9	60.5	48.1 58.5

Cone 7, Distortion Diagram, Not Effective in Output Image



Cone 7, Residual Error Diagram



Residual Error (RMS): **1.18 μm**

Explanations:

1) Calibration Method:

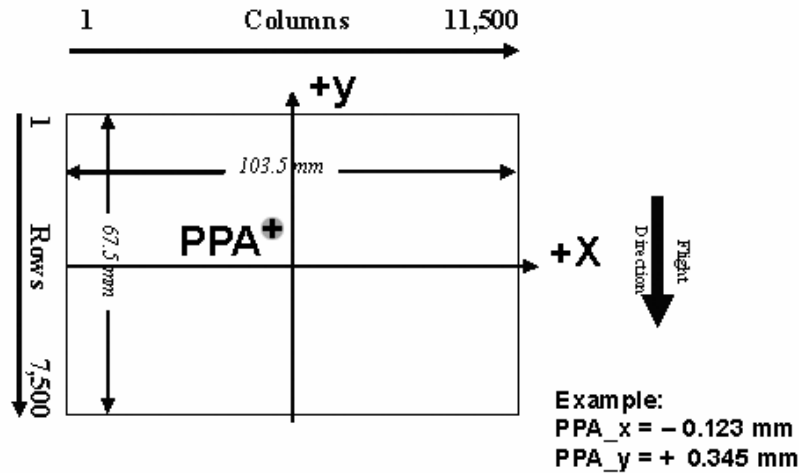
The geometric calibration is based on a set of 84 images of a defined geometry target with 240 GCPs.

Number of point measurements for the panchromatic camera : 12936
 Number of point measurements for the multispectral camera : 52132

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 11500 pixel by 7500 pixel
 MS 3680 pixel by 2400 pixel

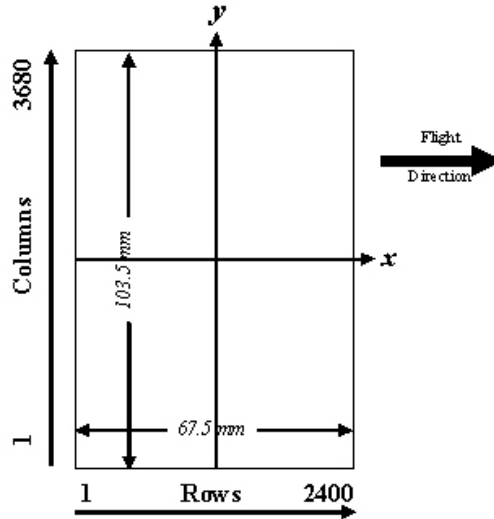
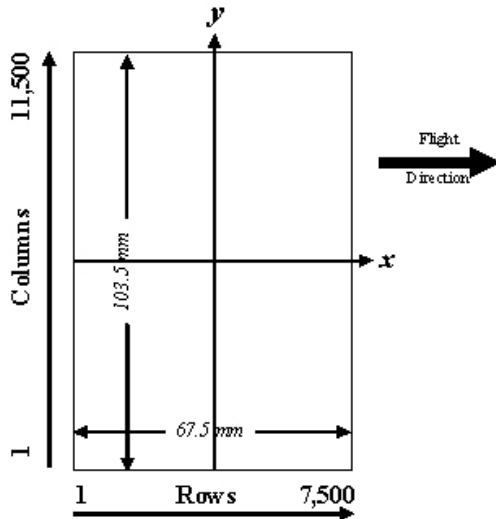
Lvl2, Camera prop. Orientation



The image coordinate system of the Level 2 images is shown in the above figure. The level 2 image consists of 11500 columns and 7500 rows, which leads to a total image format of 103.5 * 67.5 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 7500 pixel by 11500 pixel
MS 2400 pixel by 3680 pixel



Panchromatic Image Format

Multispectral Image Format

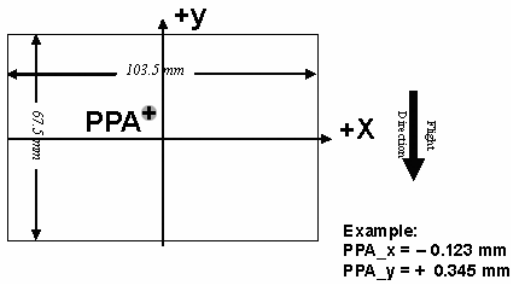
4) Position of Principal Point in Level 3 Image

The position of the principal point in the level 3 image depends on the “rotation” setting used in the OPC 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 the OPC. 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.

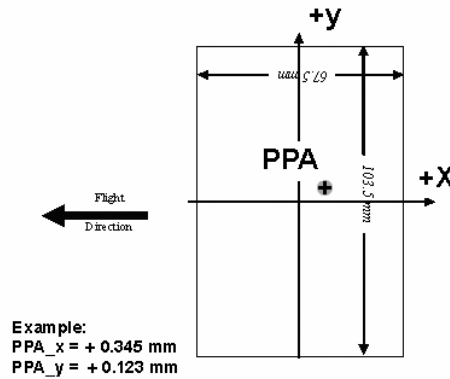
Image Format	Clockwise Rotation (Degree)	PPA	
		X	Y
Level 2	-	0.000	0.360
Level 3	0	0.000	0.360
Level 3	90	0.360	0.000
Level 3	180	0.000	-0.360
Level 3	270	-0.360	0.000

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.

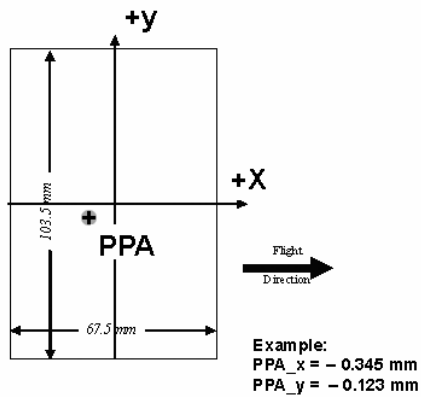
Lvl3, Rotation 0 deg clockwise



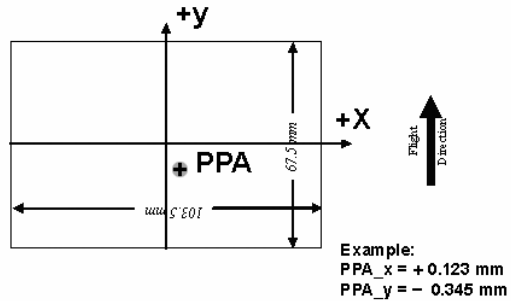
Lvl3, Rotation 90 deg clockwise



Lvl3, Rotation 270 deg clockwise



Lvl3, Rotation 180 deg clockwise



Lens Resolving Power

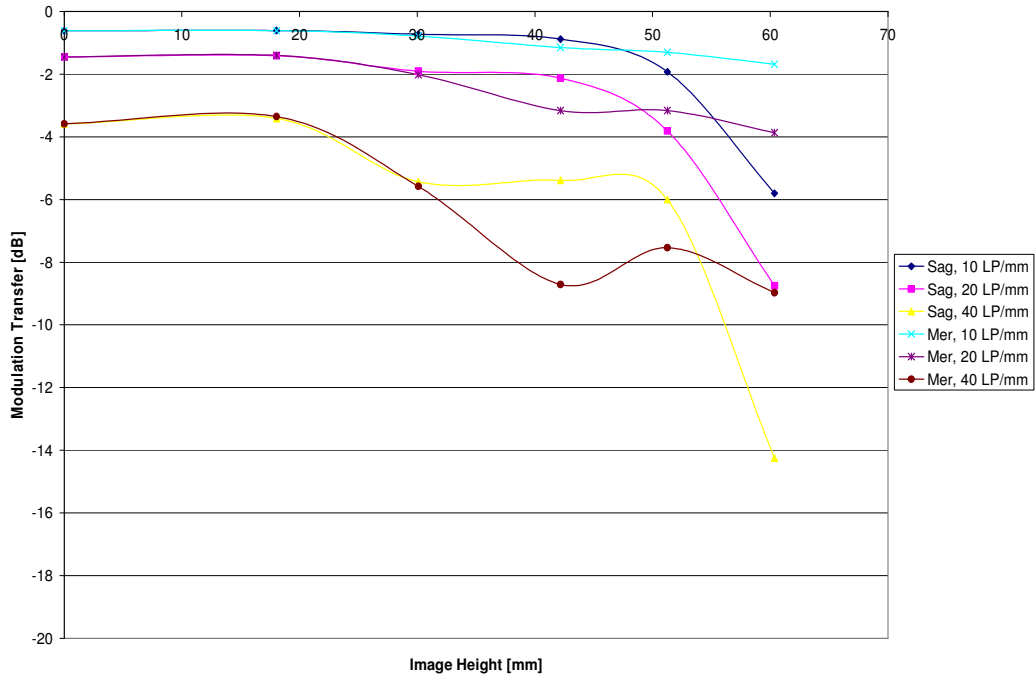
The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones.

The curves are given for the meridional (tangential) and sagittal (radial) component of signals at frequencies of 10, 20 and 40 line pairs per millimeter.

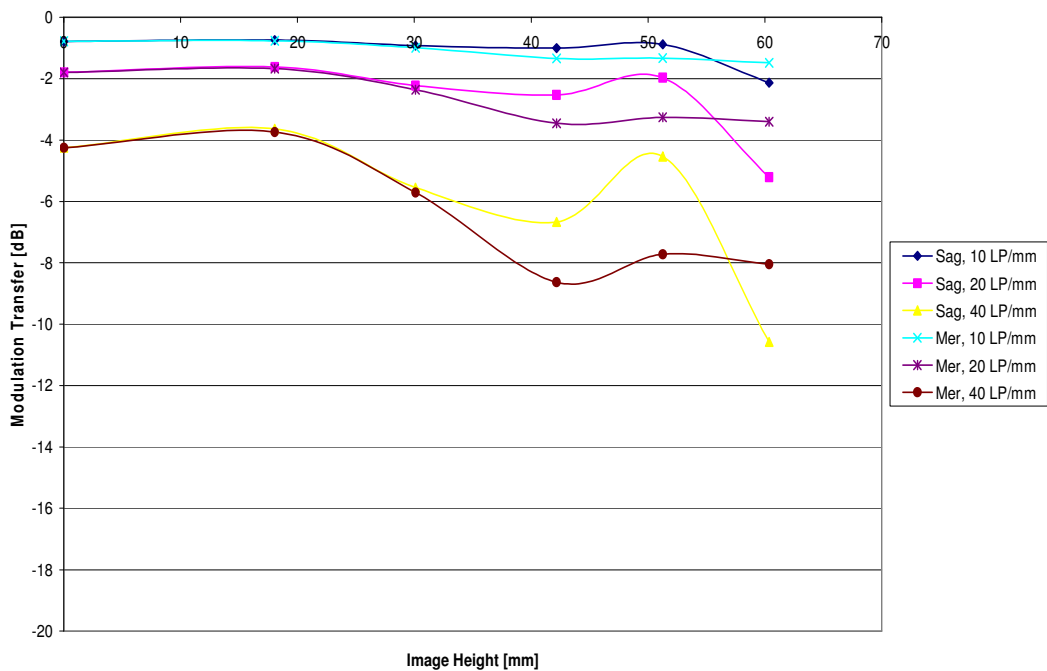
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.



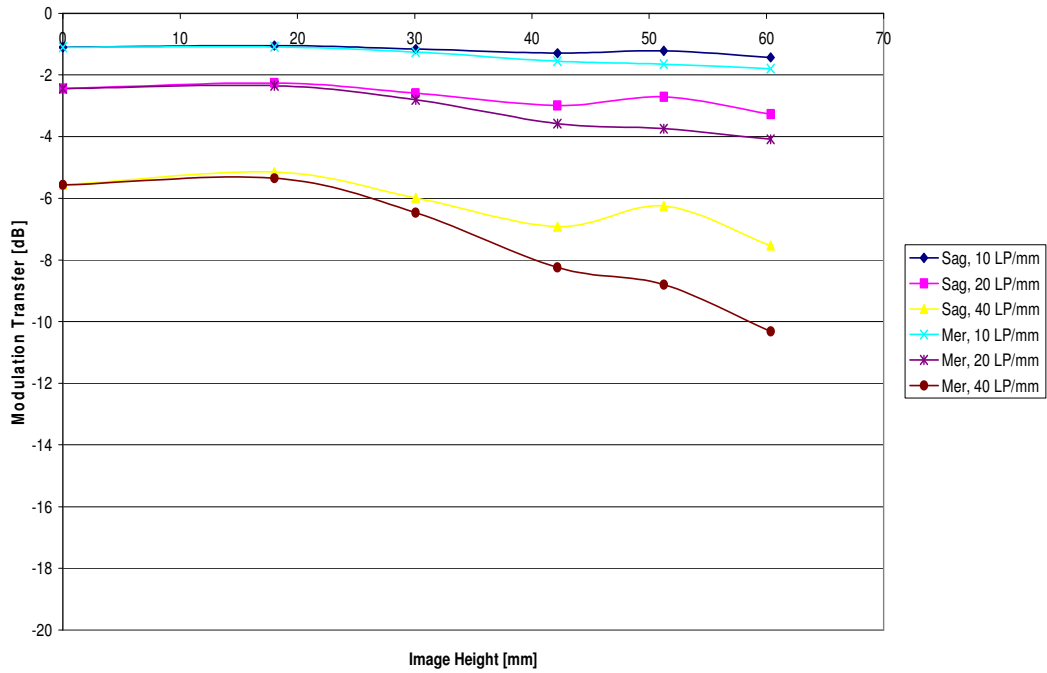
Modulation versus Image Height - Aperture f / 8



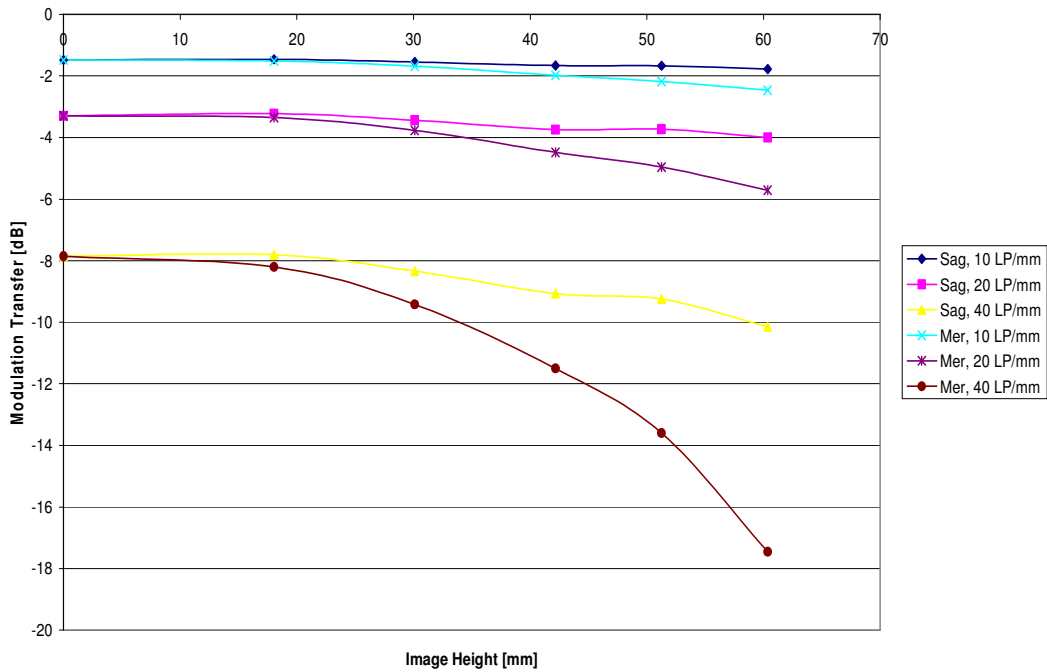
Modulation versus Image Height - Aperture f / 11



Modulation versus Image Height - Aperture f / 16



Modulation versus Image Height - Aperture f / 22



Calibration Report

Radiometric Calibration



Camera:	UltraCam D, S/N UCD-SU-1-0039
Manufacturer:	Vexcel Imaging GmbH, A-8010 Graz, Austria
Panchromatic Camera:	Apertures: f/5.6, f/8, f/11, f/16, f/22 (All Pan)
Multispectral Camera:	Apertures: f/4, f/5.6, f/8, f/11, f/16 (Red, Green) f/4, f/4, f/5.6, f/8, f/11 (Blue, NIR)
Date of Calibration:	Nov-28-2006
Date of Report:	Nov-28-2006
Camera Revision:	2.0
Revision of Report:	2.0

Calibration of Vignetting for Aperture Setting 1

Panchromatic: **f / 5.6**
Red Channel: **f / 4**
Green Channel: **f / 4**
Blue Channel: **f / 4**
NIR Channel: **f / 4**

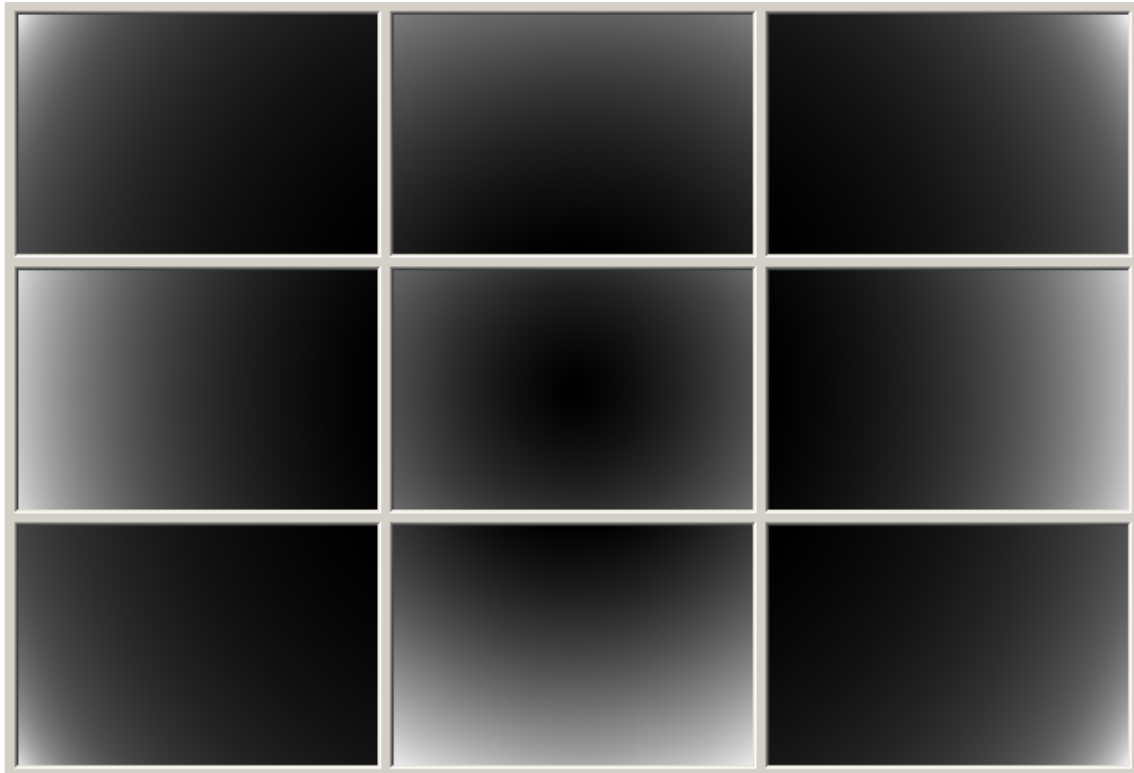
Stepper Motor Position: **1000h**

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain ≥	Maximum Gain ≤
00_00	f / 5.6	1.00	8.00
00_01	f / 5.6	1.00	8.00
00_02	f / 5.6	1.00	9.00
00_03	f / 5.6	1.00	8.00
01_00	f / 5.6	1.00	3.00
01_01	f / 5.6	1.00	2.00
02_00	f / 5.6	1.00	4.00
02_01	f / 5.6	1.00	4.00
03_00	f / 5.6	1.00	2.00
04_00 (red)	f / 4	1.00	3.00
05_00 (green)	f / 4	1.00	2.00
06_00 (blue)	f / 4	1.00	2.00
07_00 (NIR)	f / 4	1.00	3.00

Calibration of Vignetting for Aperture Setting 1

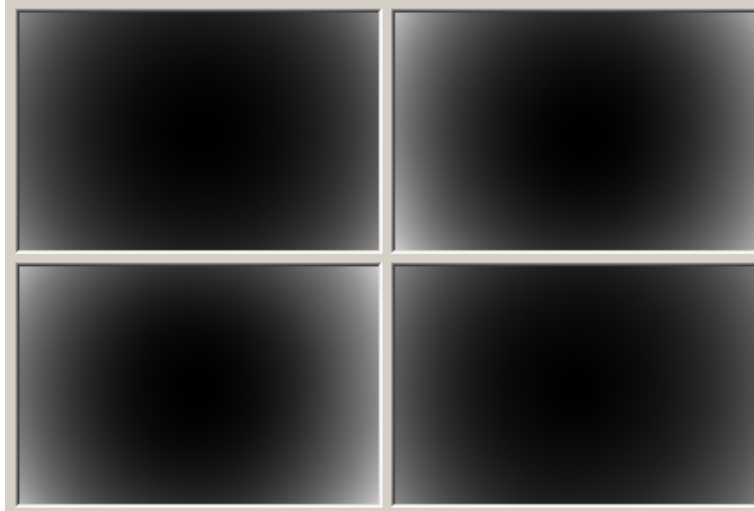
Graphical Overview of Pan Sensor Gain Values:



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

Calibration of Vignetting for Aperture Setting 1

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

Panchromatic: f / 8
Red Channel: f / 5.6
Green Channel: f / 5.6
Blue Channel: f / 4
NIR Channel: f / 4

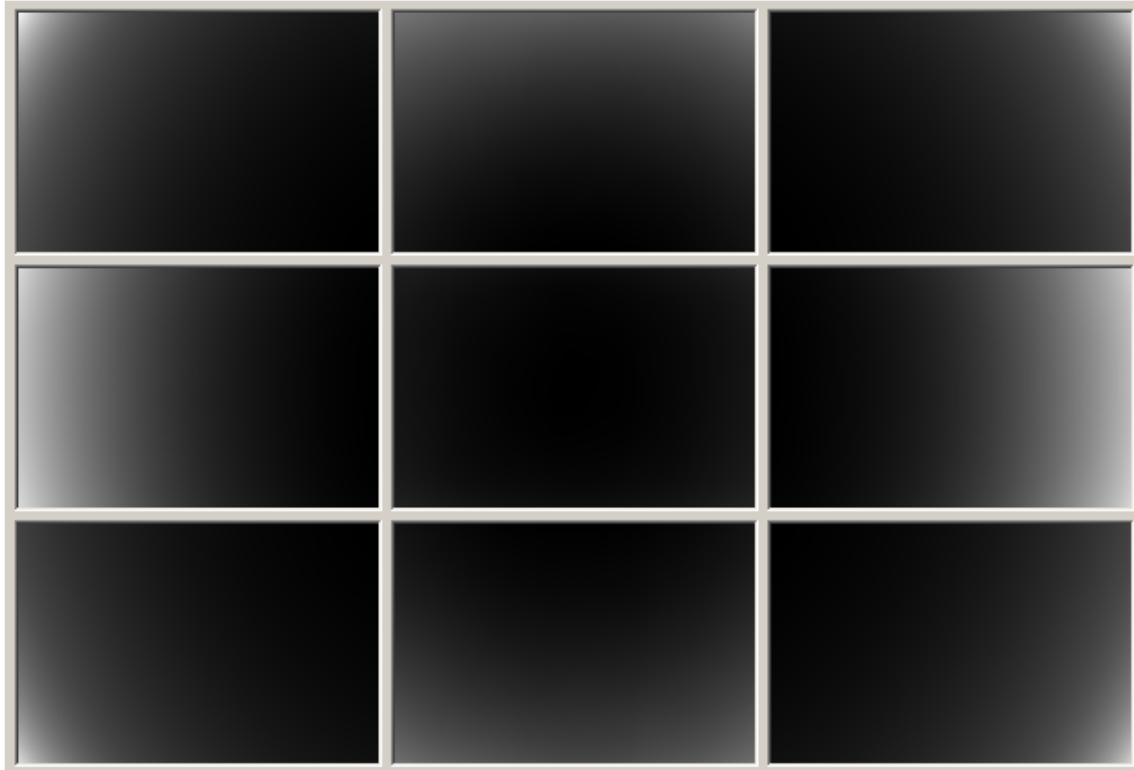
Stepper Motor Position: 1022h

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain \geq	Maximum Gain \leq
00_00	f / 8	1.00	6.00
00_01	f / 8	1.00	7.00
00_02	f / 8	1.00	7.00
00_03	f / 8	1.00	7.00
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 / 5.6	1.00	3.00
05_00 (green)	f / 5.6	1.00	2.00
06_00 (blue)	f / 4	1.00	2.00
07_00 (NIR)	f / 4	1.00	3.00

Calibration of Vignetting for Aperture Setting 2

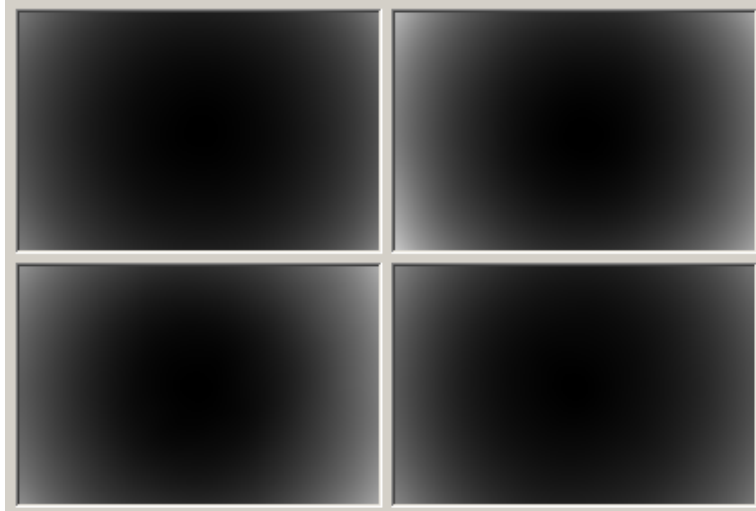
Graphical Overview of Pan Sensor Gain Values:



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

Calibration of Vignetting for Aperture Setting 2

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

Panchromatic: f / 11
Red Channel: f / 8
Green Channel: f / 8
Blue Channel: f / 5.6
NIR Channel: f / 5.6

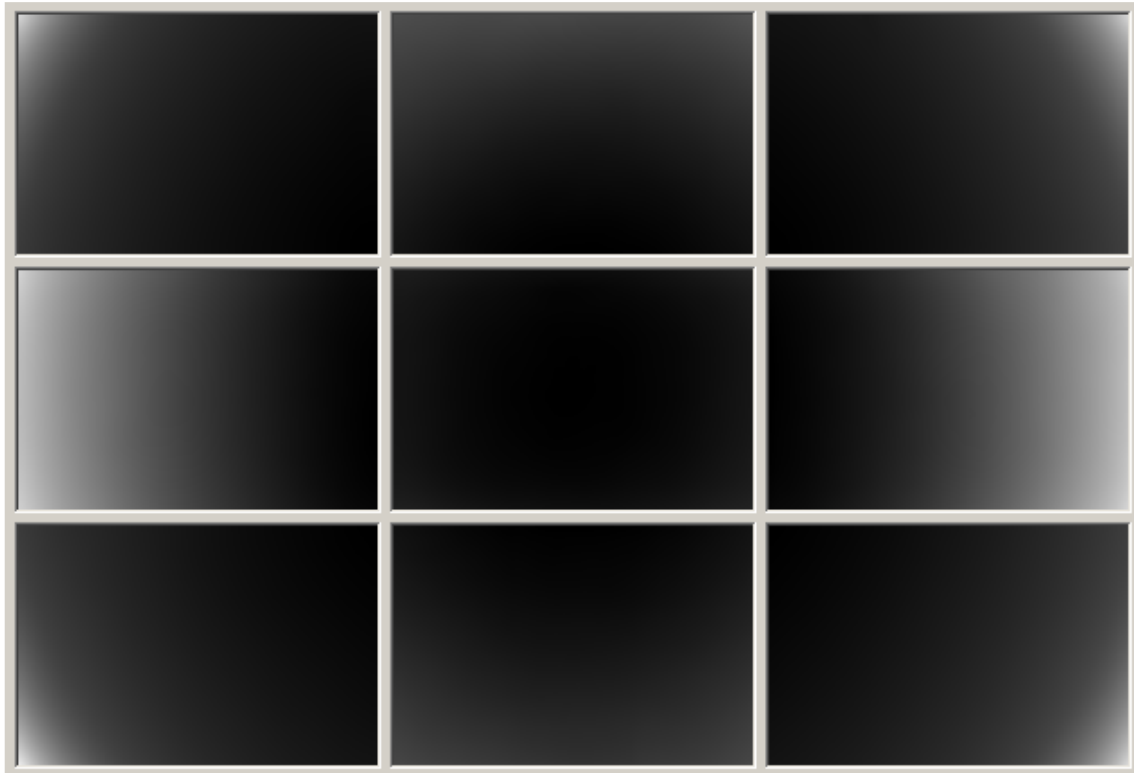
Stepper Motor Position: 1044h

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain \geq	Maximum Gain \leq
00_00	f / 11	1.00	4.00
00_01	f / 11	1.00	4.00
00_02	f / 11	1.00	4.00
00_03	f / 11	1.00	4.00
01_00	f / 11	1.00	2.00
01_01	f / 11	1.00	2.00
02_00	f / 11	1.00	2.00
02_01	f / 11	1.00	2.00
03_00	f / 11	1.00	2.00
04_00 (red)	f / 8	1.00	3.00
05_00 (green)	f / 8	1.00	2.00
06_00 (blue)	f / 5.6	1.00	2.00
07_00 (NIR)	f / 5.6	1.00	2.00

Calibration of Vignetting for Aperture Setting 3

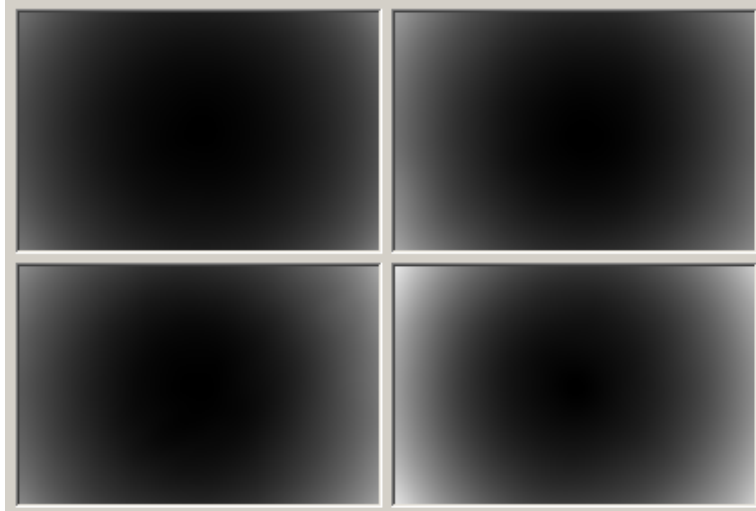
Graphical Overview of Pan Sensor Gain Values:



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

Calibration of Vignetting for Aperture Setting 3

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

Panchromatic: f / 16
Red Channel: f / 11
Green Channel: f / 11
Blue Channel: f / 8
NIR Channel: f / 8

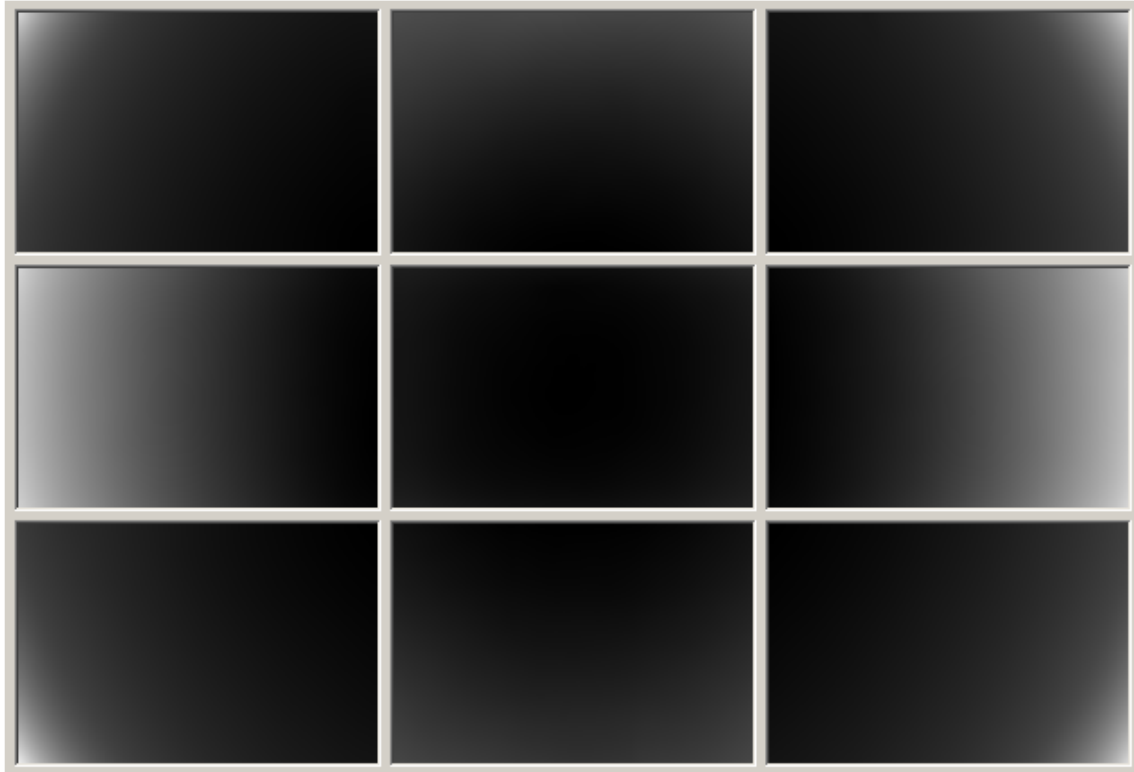
Stepper Motor Position: 1066h

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain \geq	Maximum Gain \leq
00_00	f / 16	1.00	4.00
00_01	f / 16	1.00	4.00
00_02	f / 16	1.00	4.00
00_03	f / 16	1.00	4.00
01_00	f / 16	1.00	2.00
01_01	f / 16	1.00	2.00
02_00	f / 16	1.00	2.00
02_01	f / 16	1.00	2.00
03_00	f / 16	1.00	2.00
04_00 (red)	f / 11	1.00	3.00
05_00 (green)	f / 11	1.00	2.00
06_00 (blue)	f / 8	1.00	2.00
07_00 (NIR)	f / 8	1.00	2.00

Calibration of Vignetting for Aperture Setting 4

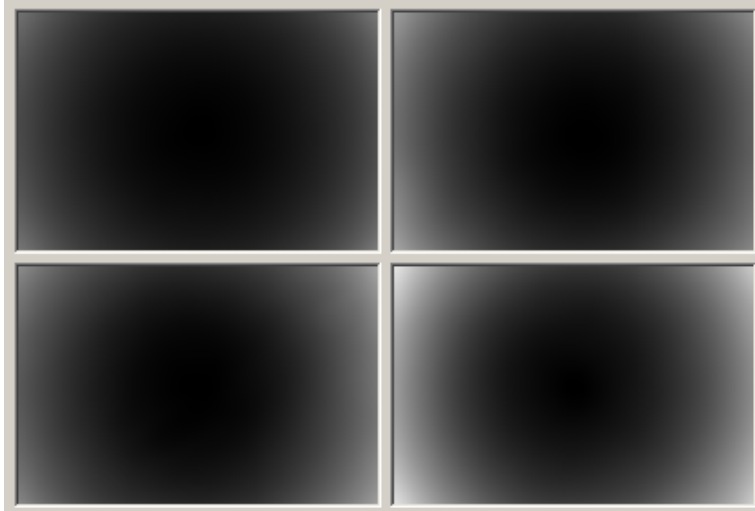
Graphical Overview of Pan Sensor Gain Values:



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

Calibration of Vignetting for Aperture Setting 4

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

Panchromatic: f / 22
Red Channel: f / 16
Green Channel: f / 16
Blue Channel: f / 11
NIR Channel: f / 11

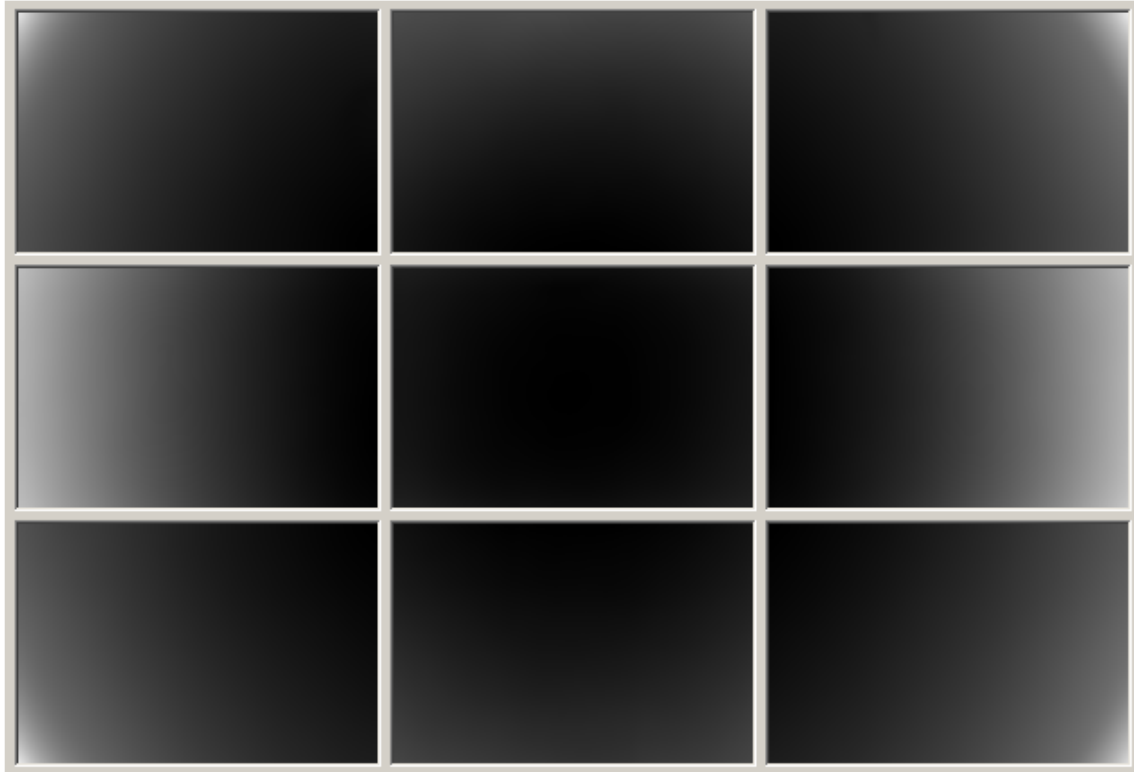
Stepper Motor Position: 1088h

Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain \geq	Maximum Gain \leq
00_00	f / 22	1.00	3.00
00_01	f / 22	1.00	3.00
00_02	f / 22	1.00	3.00
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	2.00
02_01	f / 22	1.00	2.00
03_00	f / 22	1.00	2.00
04_00 (red)	f / 16	1.00	3.00
05_00 (green)	f / 16	1.00	2.00
06_00 (blue)	f / 11	1.00	2.00
07_00 (NIR)	f / 11	1.00	2.00

Calibration of Vignetting for Aperture Setting 5

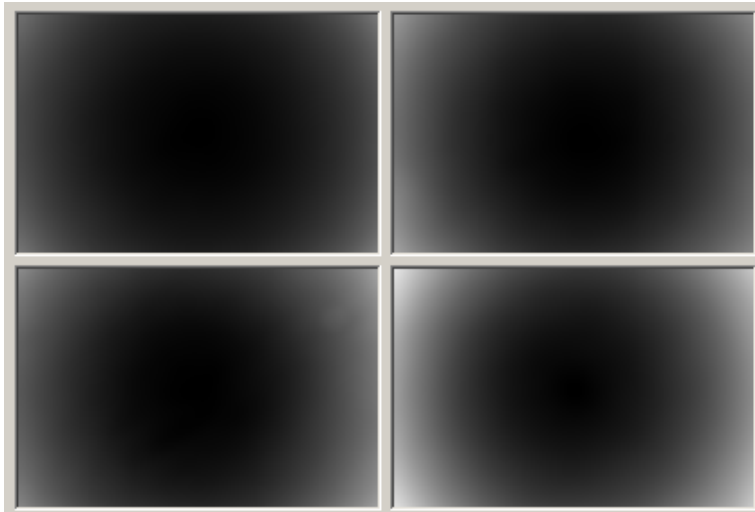
Graphical Overview of Pan Sensor Gain Values:



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

Calibration of Vignetting for Aperture Setting 5

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

00_00

PIXEL	58	1644	0
PIXEL	565	464	0
PIXEL	926	1319	0
PIXEL	2764	1199	0
PIXEL	3707	1774	0
PIXEL	28	2296	0
PIXEL	694	17	0
PIXEL	1359	163	0
PIXEL	2056	1348	0
PIXEL	3551	790	0
PIXEL	3915	1316	0
PIXEL	3920	357	0

00_01

PIXEL	1176	1181	0
PIXEL	1527	1354	0
PIXEL	3694	490	0
PIXEL	3719	2082	0
PIXEL	54	51	0
PIXEL	216	2544	0
PIXEL	424	1309	0
PIXEL	424	1310	0
PIXEL	425	1309	0
PIXEL	425	1310	0
PIXEL	442	1216	0
PIXEL	442	1217	0
PIXEL	443	1217	0
PIXEL	455	1253	0
PIXEL	473	991	0
PIXEL	473	992	0
PIXEL	473	993	0
PIXEL	474	992	0
PIXEL	474	993	0
PIXEL	504	868	0
PIXEL	504	869	0
PIXEL	505	868	0
PIXEL	505	869	0
PIXEL	531	710	0
PIXEL	532	710	0
PIXEL	543	1805	0
PIXEL	977	1519	0
PIXEL	977	1520	0
PIXEL	978	1519	0
PIXEL	979	1519	0
PIXEL	1772	2331	0



UltraCam D, Serial Number UCD-SU-1-0039

PIXEL	1773	2332	0
PIXEL	2773	1274	0
PIXEL	2774	1275	0
PIXEL	2886	2641	0

00_02

COLUMN	724	135	0
COLUMN	1279	1904	0
COLUMN	2363	2177	0
PIXEL	537	2012	0
PIXEL	585	1407	0
PIXEL	1064	2600	0
PIXEL	1620	496	0
PIXEL	1665	78	0
PIXEL	2762	1315	0
PIXEL	2770	495	0
PIXEL	3505	924	0
PIXEL	3763	2552	0
PIXEL	724	133	0
PIXEL	1279	1904	0
PIXEL	1580	671	0
PIXEL	2363	2177	0

00_03

COLUMN	3713	2462	0
PIXEL	78	1108	0
PIXEL	125	1254	0
PIXEL	159	1282	0
PIXEL	360	1253	0
PIXEL	619	1097	0
PIXEL	1856	2356	0
PIXEL	1920	1171	0
PIXEL	2004	720	0
PIXEL	2828	1724	0
PIXEL	2981	1834	0
PIXEL	3275	503	0
PIXEL	3412	1373	0
PIXEL	3602	2599	0
PIXEL	3636	638	0
PIXEL	547	569	0
PIXEL	548	570	0
PIXEL	1225	1618	0
PIXEL	1226	1618	0
PIXEL	1476	2549	0
PIXEL	1476	2550	0
PIXEL	1902	1460	0
PIXEL	1902	1461	0
PIXEL	1903	1461	0
PIXEL	3378	2363	0
PIXEL	3378	2364	0
PIXEL	3379	2362	0
PIXEL	3379	2363	0
PIXEL	3606	766	0
PIXEL	3710	1375	0

01_00

PIXEL	482	2132	0
PIXEL	1476	2296	0
PIXEL	1882	1954	0



UltraCam D, Serial Number UCD-SU-1-0039

PIXEL	2134	1289	0
PIXEL	2298	1888	0
PIXEL	2415	112	0
PIXEL	2631	528	0
PIXEL	3617	2516	0
PIXEL	72	42	0
PIXEL	102	716	0
PIXEL	223	1899	0
PIXEL	580	417	0
PIXEL	625	750	0
PIXEL	1404	800	0
PIXEL	1868	2619	0
PIXEL	3329	2510	0
PIXEL	3586	1681	0
PIXEL	3613	90	0
PIXEL	3963	1877	0

01_01

PIXEL	165	2612	0
PIXEL	550	1343	0
PIXEL	566	673	0
PIXEL	919	2200	0
PIXEL	926	622	0
PIXEL	1396	2205	0
PIXEL	1431	1681	0
PIXEL	1654	608	0
PIXEL	1922	208	0
PIXEL	2064	258	0
PIXEL	2243	2227	0
PIXEL	2431	2025	0
PIXEL	2512	1461	0
PIXEL	3173	1935	0
PIXEL	3780	2342	0
PIXEL	54	52	0
PIXEL	55	52	0
PIXEL	113	162	0
PIXEL	431	162	0
PIXEL	1462	844	0
PIXEL	3233	878	0
PIXEL	3748	1896	0

02_00

PIXEL	380	2042	0
PIXEL	454	1151	0
PIXEL	733	1072	0
PIXEL	1031	1415	0
PIXEL	1248	1039	0
PIXEL	1446	2324	0
PIXEL	2559	2406	0
PIXEL	2681	1491	0
PIXEL	2686	613	0
PIXEL	3173	1269	0
PIXEL	3337	2217	0
PIXEL	48	2665	0
PIXEL	419	2440	0
PIXEL	455	2216	0
PIXEL	456	2215	0
PIXEL	456	2216	0
PIXEL	457	2215	0

(53 of 64)



UltraCam D, Serial Number UCD-SU-1-0039

PIXEL	457	2216	0
PIXEL	599	1427	0
PIXEL	2121	1876	0
PIXEL	2563	2131	0
PIXEL	2640	1844	0
PIXEL	2838	1542	0
PIXEL	2932	1393	0
PIXEL	2987	1390	0
PIXEL	3173	275	0
PIXEL	3645	274	0
PIXEL	3645	275	0
PIXEL	3841	179	0

02_01

PIXEL	116	344	0
PIXEL	302	949	0
PIXEL	632	2384	0
PIXEL	708	914	0
PIXEL	920	2311	0
PIXEL	2041	65	0
PIXEL	2478	45	0
PIXEL	2775	1381	0
PIXEL	2776	1263	0
PIXEL	3928	1385	0
PIXEL	498	2514	0
PIXEL	499	2514	0
PIXEL	508	1285	0
PIXEL	508	1286	0
PIXEL	509	1285	0
PIXEL	509	1286	0
PIXEL	640	1048	0
PIXEL	905	2666	0
PIXEL	1449	1038	0
PIXEL	1449	1039	0
PIXEL	1477	1969	0
PIXEL	1558	931	0
PIXEL	2192	2580	0
PIXEL	2334	1546	0
PIXEL	2611	750	0
PIXEL	2621	763	0
PIXEL	2907	951	0
PIXEL	3410	2111	0
PIXEL	3535	2189	0
PIXEL	3536	2189	0
PIXEL	3577	1688	0
PIXEL	3578	1688	0
PIXEL	3578	1689	0
PIXEL	3579	1689	0
PIXEL	3580	1689	0
PIXEL	3649	2251	0
PIXEL	3946	568	0

03_00

COLUMN	3301	2253	0
PIXEL	361	851	0
PIXEL	841	812	0
PIXEL	933	2446	0
PIXEL	984	178	0
PIXEL	1495	2665	0

(54 of 64)



UltraCam D, Serial Number UCD-SU-1-0039

PIXEL	3972	72	0
PIXEL	740	492	0
PIXEL	1051	2217	0
PIXEL	1973	1337	0
PIXEL	1974	1329	0
PIXEL	1988	1327	0
PIXEL	1989	1383	0
PIXEL	1996	1333	0
PIXEL	1996	1339	0
PIXEL	1999	1393	0
PIXEL	2003	1406	0
PIXEL	2005	1367	0
PIXEL	2060	1360	0
PIXEL	2151	2628	0
PIXEL	2218	2612	0
PIXEL	2557	2647	0
PIXEL	2558	2647	0
PIXEL	3066	2154	0
PIXEL	3117	1667	0
PIXEL	3140	2271	0
PIXEL	3152	2403	0
PIXEL	3448	1786	0
PIXEL	3512	1683	0
PIXEL	3670	2147	0
PIXEL	3670	2148	0
PIXEL	3904	2561	0
PIXEL	3911	2448	0
PIXEL	4002	2350	0
PIXEL	4006	2148	0
PIXEL	4007	2662	0
PIXEL	4009	2369	0
PIXEL	4010	2370	0
PIXEL	4028	2445	0

04_00

PIXEL	609	897	0
PIXEL	1117	1626	0
PIXEL	1181	880	0
PIXEL	1350	2344	0
PIXEL	1444	2651	0
PIXEL	2289	1794	0
PIXEL	2579	773	0
PIXEL	3038	577	0
PIXEL	3040	2671	0
PIXEL	3133	1439	0
PIXEL	3539	917	0
PIXEL	3714	773	0
PIXEL	121	50	0
PIXEL	122	49	0
PIXEL	629	318	0
PIXEL	660	370	0
PIXEL	660	371	0
PIXEL	721	1972	0
PIXEL	721	1973	0
PIXEL	1043	971	0
PIXEL	1250	759	0
PIXEL	1420	2562	0
PIXEL	1421	2562	0



UltraCam D, Serial Number UCD-SU-1-0039

PIXEL	1422	2562	0
PIXEL	2560	47	0
PIXEL	2560	48	0
PIXEL	3059	2501	0
PIXEL	4026	2669	0

05_00

COLUMN	261	1737	0
PIXEL	768	1033	0
PIXEL	2050	1169	0
PIXEL	2050	1170	0
PIXEL	2683	126	0
PIXEL	3877	2628	0
PIXEL	196	2445	0
PIXEL	197	2445	0
PIXEL	197	2446	0
PIXEL	198	2445	0
PIXEL	198	2446	0
PIXEL	231	2280	0
PIXEL	261	1737	0
PIXEL	353	665	0
PIXEL	1049	42	0
PIXEL	1401	891	0
PIXEL	1402	891	0
PIXEL	2079	1753	0
PIXEL	2463	1130	0
PIXEL	3615	1666	0

06_00

COLUMN	2623	1604	0
PIXEL	650	861	0
PIXEL	3520	2426	0
PIXEL	3715	2235	0
PIXEL	3782	812	0
PIXEL	3885	1159	0
PIXEL	141	2139	0
PIXEL	176	2169	0
PIXEL	269	1092	0
PIXEL	269	1093	0
PIXEL	270	1092	0
PIXEL	270	1093	0
PIXEL	296	2222	0
PIXEL	601	250	0
PIXEL	621	1705	0
PIXEL	622	1705	0
PIXEL	623	1705	0
PIXEL	711	1242	0
PIXEL	972	762	0
PIXEL	972	763	0
PIXEL	1203	2524	0
PIXEL	1784	1309	0
PIXEL	1784	1310	0
PIXEL	1785	1310	0
PIXEL	1786	1308	0
PIXEL	1786	1310	0
PIXEL	1787	1309	0
PIXEL	2120	2438	0
PIXEL	2623	1604	0
PIXEL	3540	2429	0

(56 of 64)



UltraCam D, Serial Number UCD-SU-1-0039

PIXEL	3900	1912	0
07_00			
PIXEL	54	846	0
PIXEL	443	2577	0
PIXEL	814	626	0
PIXEL	1862	2440	0
PIXEL	1908	2312	0
PIXEL	1962	1980	0
PIXEL	2941	384	0
PIXEL	4000	731	0
PIXEL	44	1003	0
PIXEL	99	69	0
PIXEL	443	2577	0
PIXEL	1574	649	0
PIXEL	1575	649	0
PIXEL	2092	1641	0
PIXEL	2092	1642	0
PIXEL	2093	1641	0
PIXEL	2093	1642	0
PIXEL	2185	2473	0
PIXEL	2613	758	0

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).



UltraCam D, Serial Number UCD-SU-1-0039

Explanations:

Calibration Method:

The radiometric calibration is based on a series of 60 flat field images for each aperture size and sensor. The flat field is illuminated by two 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



ULTRACAM_D
Large Format Digital Aerial Camera

Camera:	UltraCam D, S/N UCD-SU-1-0039
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:	Nov-28-2006
Date of Report:	Nov-28-2006
Camera Revision:	2.0
Revision of Report:	2.0

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	Shutter Release Time [ms]	Measurement Tolerance [ms]
C0 (Pan 4CCD)	11 80 80 20	11.7	+/- 0.2
C1 (Pan 2CCD V)	11 80 80 00	11.5	+/- 0.2
C2 (Pan 2CCD H)	11 80 80 22	11.8	+/- 0.2
C3 (Pan Central)	11 80 79 26	12.3	+/- 0.2
C4 (Red)	11 79 77 26	12.3	+/- 0.2
C5 (Green)	11 76 32 80	11.8	+/- 0.2
C6 (Blue)	11 80 25 66	12.5	+/- 0.2
C7 (NIR)	11 80 25 68	10.2	+/- 0.2

Calibration Report

Electronics and Sensor Calibration



Camera:	UltraCam D, S/N UCD-SU-1-0039
Manufacturer:	Vexcel Imaging GmbH, A-8010 Graz, Austria
Panchromatic Camera:	4 * FTF4027-M Area CCD Sensor by DALSA
Multispectral Camera:	4 * FTF4027-M Area CCD Sensor by DALSA
Date of Calibration:	Nov-28-2006
Date of Report:	Nov-28-2006
Camera Revision:	2.0
Revision of Report:	2.0



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	FTF4027-M	87 888/118	26.80
00_01	FTF4027-M	87 888/105	26.80
00_02	FTF4027-M	87 888/53	27.00
00_03	FTF4027-M	87 888/124	26.40
01_00	FTF4027-M	87 888/116	27.00
01_01	FTF4027-M	87 888/28	26.80
02_00	FTF4027-M	87 888/117	26.40
02_01	FTF4027-M	87 888/121	27.00
03_00	FTF4027-M	87 888/66	27.00
04_00 (red)	FTF4027-M	87 888/74	26.80
05_00 (green)	FTF4027-M	87 888/86	27.00
06_00 (blue)	FTF4027-M	87 888/112	26.80
07_00 (NIR)	FTF4027-M	87 888/110	27.00

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 behaviour 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 UCD.

Cone_Sensor	Sensor Type	Sensor Serial Number	Intensity Threshold [DN]
00_00	FTF4027-M	87 888/118	7000
00_01	FTF4027-M	87 888/105	7000
00_02	FTF4027-M	87 888/53	7000
00_03	FTF4027-M	87 888/124	7000
01_00	FTF4027-M	87 888/116	7000
01_01	FTF4027-M	87 888/28	7000
02_00	FTF4027-M	87 888/117	7000
02_01	FTF4027-M	87 888/121	7000
03_00	FTF4027-M	87 888/66	7000
04_00 (red)	FTF4027-M	87 888/74	7000
05_00 (green)	FTF4027-M	87 888/86	7000
06_00 (blue)	FTF4027-M	87 888/112	7000
07_00 (NIR)	FTF4027-M	87 888/110	7000

Calibration Report

Summary



Camera: UltraCam D, S/N UCD-SU-1-0039

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

Date of Calibration: Nov-28-2006

Date of Report: Nov-28-2006

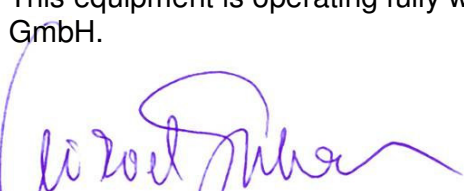
Camera Revision: 2.0

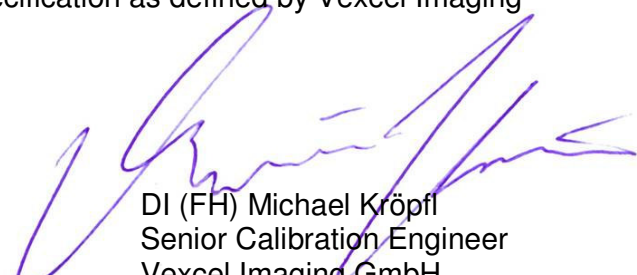
Revision of Report: 2.0

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.


DI (FH) Michael Kröpfl
Senior Calibration Engineer
Vexcel Imaging GmbH