

# Calibration Report



<b>Camera:</b>	<b>UltraCam D, S/N UCD-SU-1-0039</b>
<b>Manufacturer:</b>	<b>Vexcel Imaging GmbH, A-8010 Graz, Austria</b>
<b>Date of Calibration:</b>	<b>Mar-16-2006</b>
<b>Date of Report:</b>	<b>Mar-23-2006</b>
<b>Camera Revision:</b>	<b>1.0</b>
<b>Revision of Report:</b>	<b>1.0</b>

# Calibration Report

## Geometric Calibration



<b>Camera:</b>	<b>UltraCam D, S/N UCD-SU-1-0039</b>
<b>Manufacturer:</b>	<b>Vexcel Imaging GmbH, A-8010 Graz, Austria</b>
<b>Panchromatic Camera:</b>	<b>ck = 105.200mm</b>
<b>Multispectral Camera:</b>	<b>ck = 105.200mm</b>
<b>Date of Calibration:</b>	<b>Mar-16-2006</b>
<b>Date of Report:</b>	<b>Mar-23-2006</b>
<b>Camera Revision:</b>	<b>1.0</b>
<b>Revision of Report:</b>	<b>1.0</b>

## Panchromatic Camera

### Large Format Panchromatic Output Image

<b>Image Format</b>	long track	67.5mm	7500 pixel
	cross track	103.5mm	11500 pixel
<b>Image Extent</b>		(-33.75, -51.75)mm	(33.75, 51.75)mm
<b>Pixel Size</b>		9.000µm*9.000µm	
<b>Focal Length</b>	ck	105.200mm	± 0.002mm
<b>Principal Point (Level 2)</b>	X_ppa	0.000 mm	± 0.002mm
	Y_ppa	0.270 mm	± 0.002mm
<b>Lens Distortion</b>	Remaining Distortion less than 0.002mm		

## Multispectral Camera

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

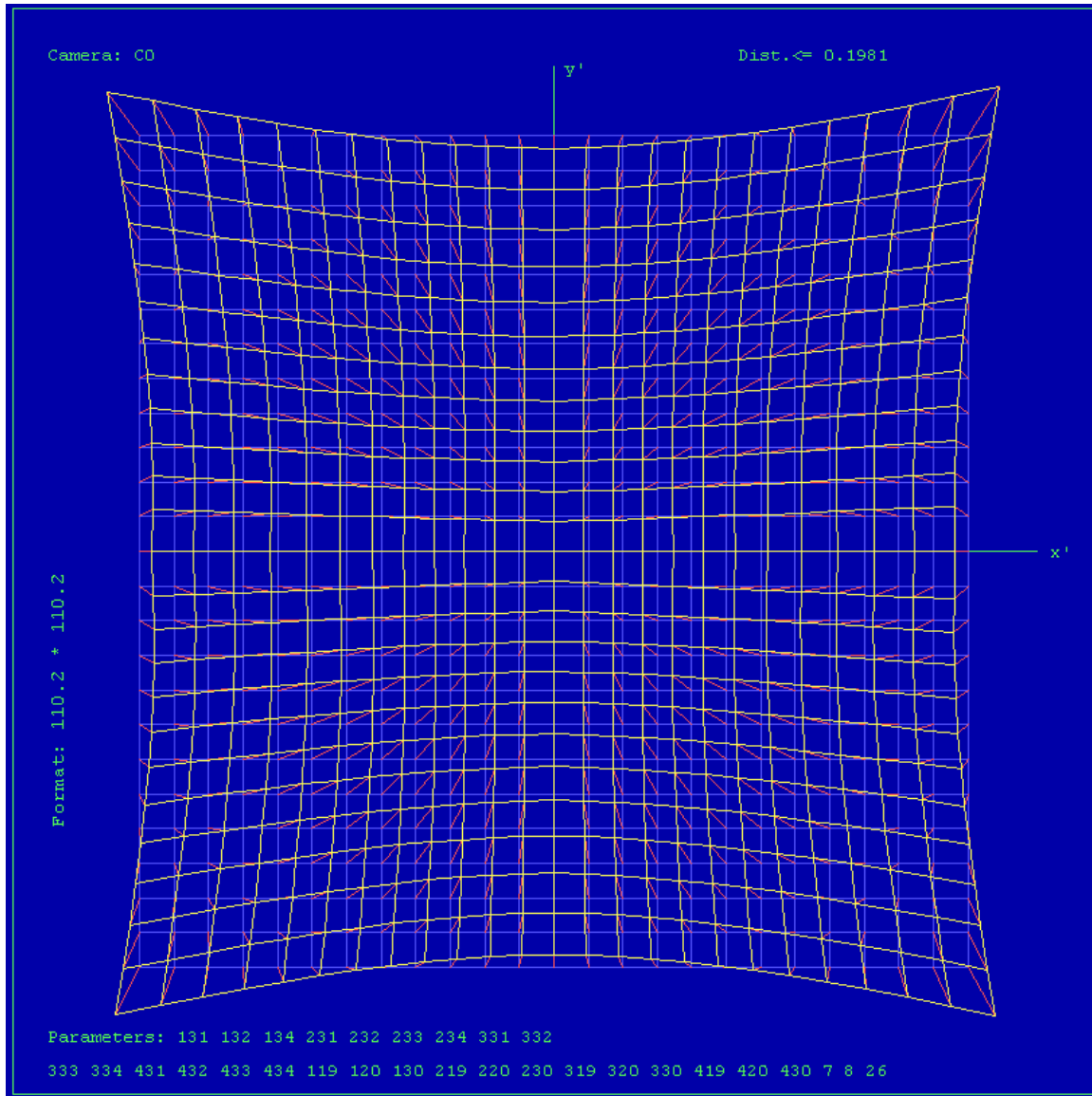
<b>Image Format</b>	long track	67.5mm	2400 pixel
	cross track	103.5mm	3680 pixel
<b>Image Extent</b>		(-33.75, -51.75)mm	(33.75, 51.75)mm
<b>Pixel Size</b>		28.125µm*28.125µm	
<b>Focal Length</b>	ck	105.200mm	
<b>Principal Point (Level 2)</b>	X_ppa	0.000 mm	± 0.002mm
	Y_ppa	0.270 mm	± 0.002mm
<b>Lens Distortion</b>	Remaining Distortion less than 0.002mm		

## Individual Panchromatic Cone Data

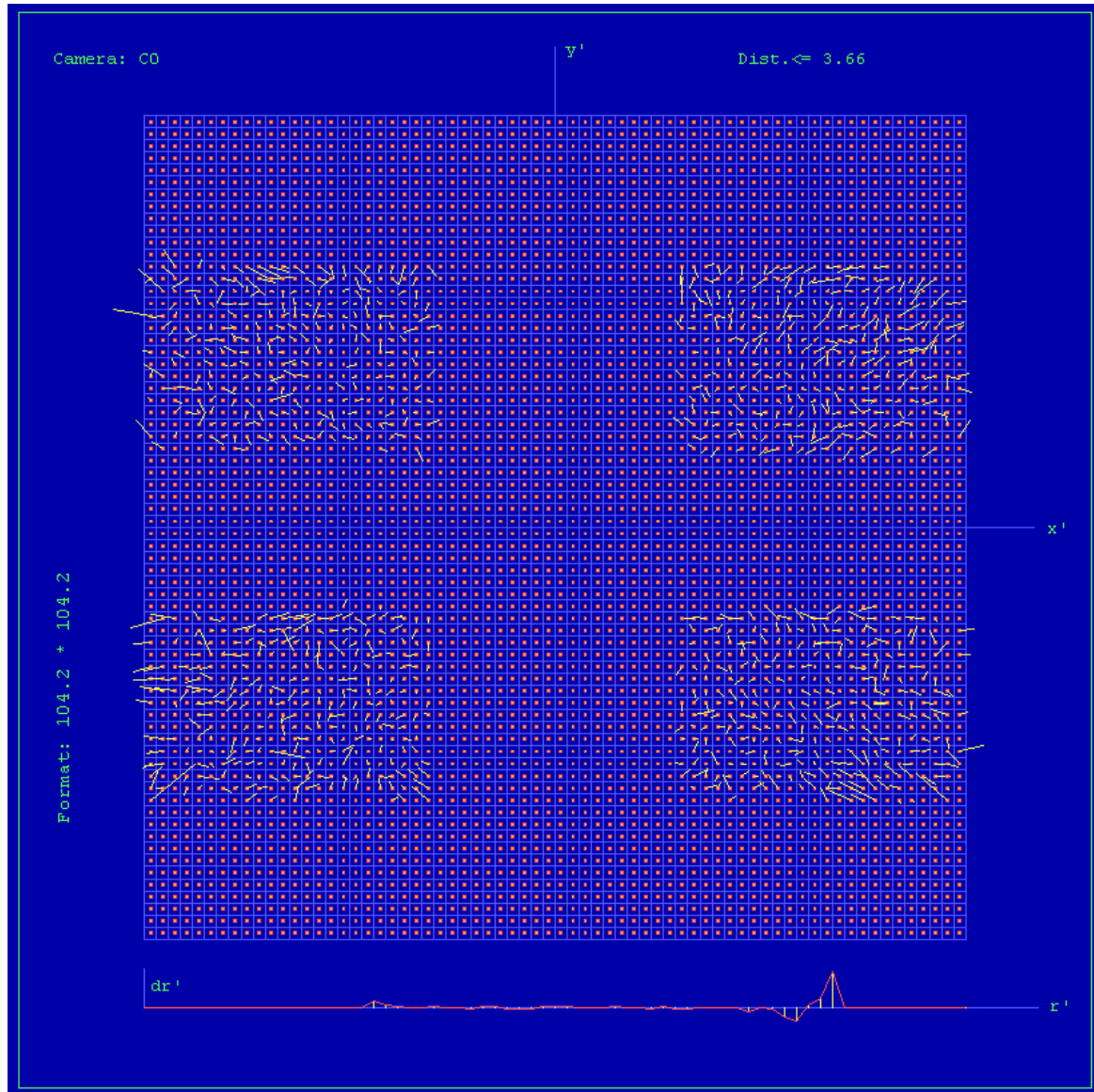
### Cone 0, Parametric Description, Not Effective in Output Image

<b>Cone # C0</b>													
<b>Lens</b>	Rodenstock Apo-Sironar Digital 105mm Linos GmbH, Germany												
<b>Shutter</b>	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH												
<b>Image Extent (nominally)</b>		(-33.75, -51.75)mm	( 33.75, 51.75)mm										
<b>Extent CCD 0</b>		(-33.75, -51.75)mm	(-9.75, -15.75)mm										
<b>Extent CCD 1</b>		(-33.75, 15.75)mm	(-9.75, 51.75)mm										
<b>Extent CCD 2</b>		( 9.75, -51.75)mm	( 33.75, -15.75)mm										
<b>Extent CCD 3</b>		( 9.75, 15.75)mm	(33.75, 51.75)mm										
<b>Parameters</b>	<b>Shift X</b>	<b>ShiftY</b>	<b>Rotation</b>	<b>Scale</b>									
<b>CCD0</b>	2.86450034E-02 mm ± 0.0015 mm	-2.62541827E-01 mm ± 0.0024 mm	1.00919403E-01 gon ± 0.0001 gon	1.00301060 ± 0.00005									
<b>CCD1</b>	7.82684491E-02 mm ± 0.0015 mm	-3.36975190E-01 mm ± 0.0024 mm	0.00000000 gon	1.00361840 ± 0.00005									
<b>CCD2</b>	-2.21483382E-02 mm ± 0.0015 mm	-2.80710147E-01 mm ± 0.0024 mm	3.12258523E-02 gon ± 0.0001 gon	1.00358290 ± 0.00005									
<b>CCD3</b>	1.97318221E-02 mm ± 0.0015 mm	-2.93435099E-01 mm ± 0.0024 mm	9.36314392E-02 gon ± 0.0001 gon	1.00411895 ± 0.00005									
<b>Radial Distortion</b>													
<b>R [mm]</b>	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
<b>dr [µm]</b>	-17.1	-35.2	-53.0	-69.2	-82.7	-92.3	-96.8	-95.2	-86.5	-69.6	-43.6	-7.5	39.6

### Cone 0, Distortion Diagram, Not Effective in Output Image



### Cone 0, Residual Error Diagram



**Residual Error (RMS):            0.91  $\mu\text{m}$**

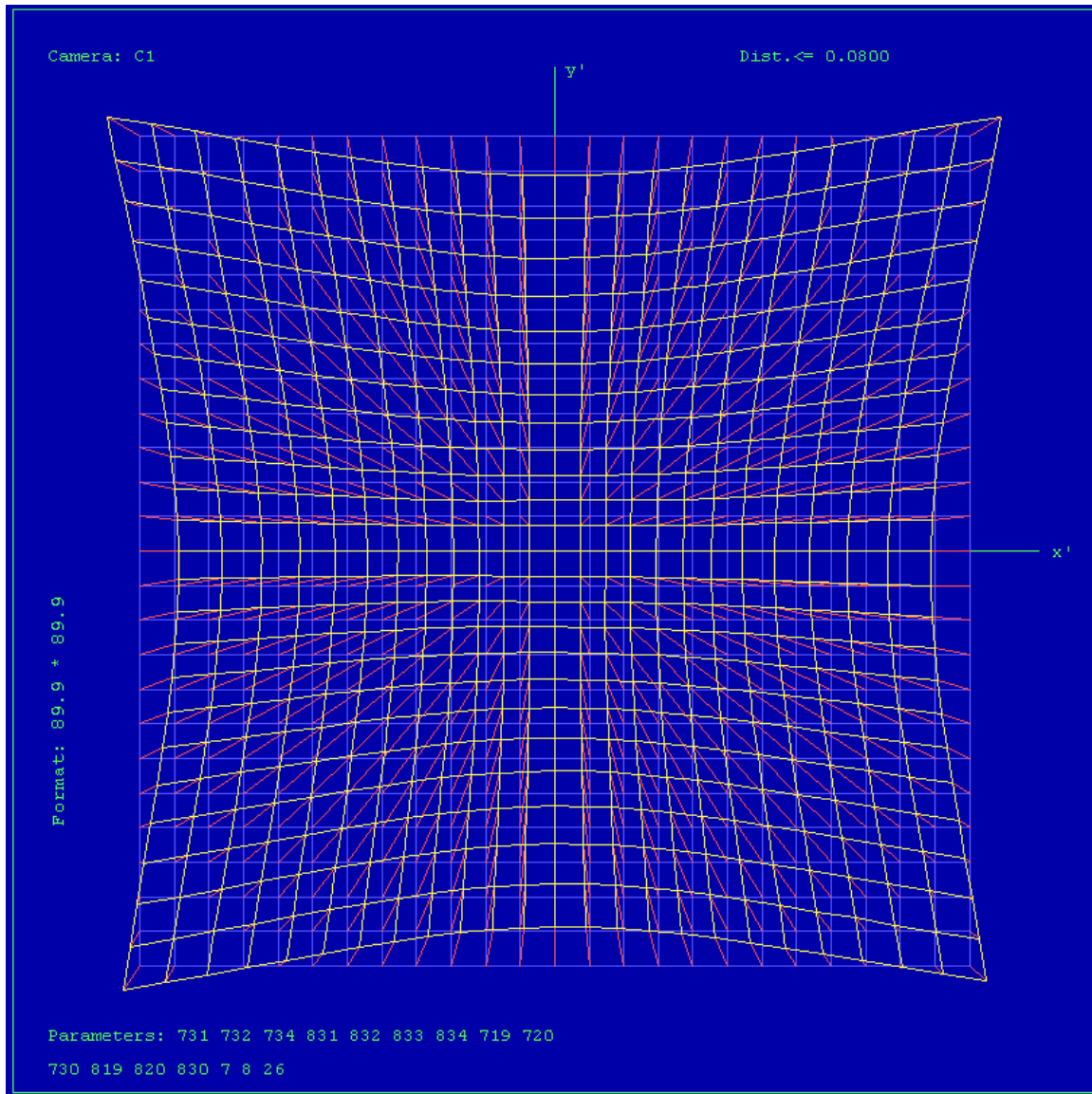


UltraCam D, Serial Number UCD-SU-1-0039

**Cone 1, Parametric Description, Not Effective in Output Image**

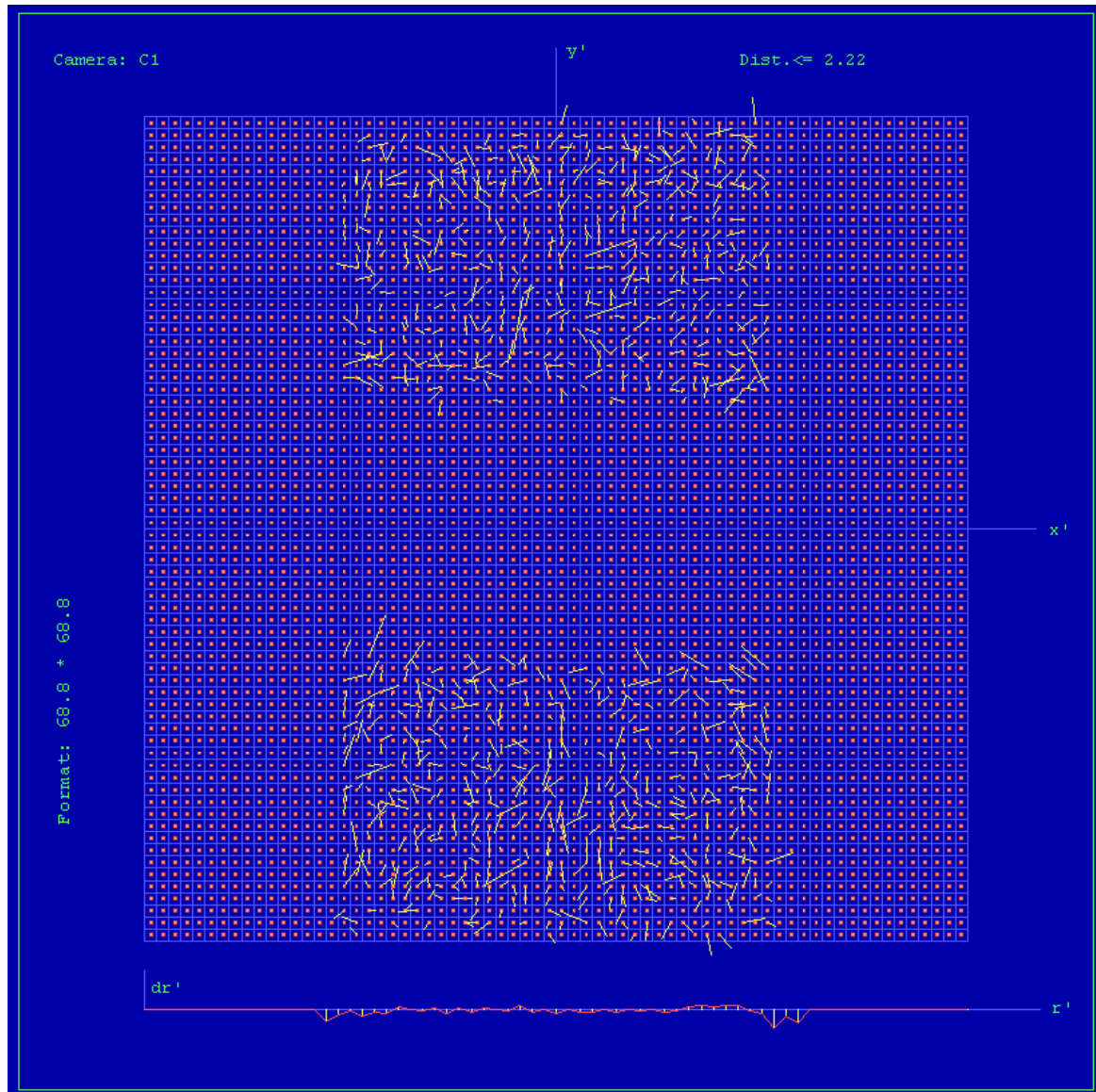
<b>Cone # C1</b>												
<b>Lens</b>	Rodenstock Apo-Sironar Digital 105mm Linos GmbH, Germany											
<b>Shutter</b>	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH											
<b>Image Extent (nominally)</b>		(-33.75, -18.04)mm	( 33.75, 18.04)mm									
<b>Extent CCD 0</b>		(-33.75, -18.04)mm	( -9.75, 18.04)mm									
<b>Extent CCD 1</b>		( 9.75, -18.04)mm	(33.75, 18.04)mm									
<b>Parameters</b>	<b>Shift X</b>	<b>Shift Y</b>	<b>Rotation</b>	<b>Scale</b>								
<b>CCD0</b>	5.15746393E-02 mm ± 0.0025 mm	-2.27900828E-01 mm ± 0.0021 mm	0.00000000 gon	1.00490701 ± 0.00005								
<b>CCD1</b>	-4.2660090E-02 mm ± 0.0025 mm	-2.16817609E-01 mm ± 0.0020 mm	2.36117110E-02 gon ±0.0001 gon	1.00540933 ± 0.00005								
<b>Radial Distortion</b>												
<b>R [mm]</b>	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0
<b>dr [µm]</b>	-16.4	-34.1	-50.9	-64.9	-74.5	-78.7	-76.8	-68.6	-54.2	-34.3	-9.9	17.7

### Cone 1, Distortion Diagram, Not Effective in Output Image





### Cone 1, Residual Error Diagram



**Residual Error (RMS):**                      **0.94  $\mu\text{m}$**

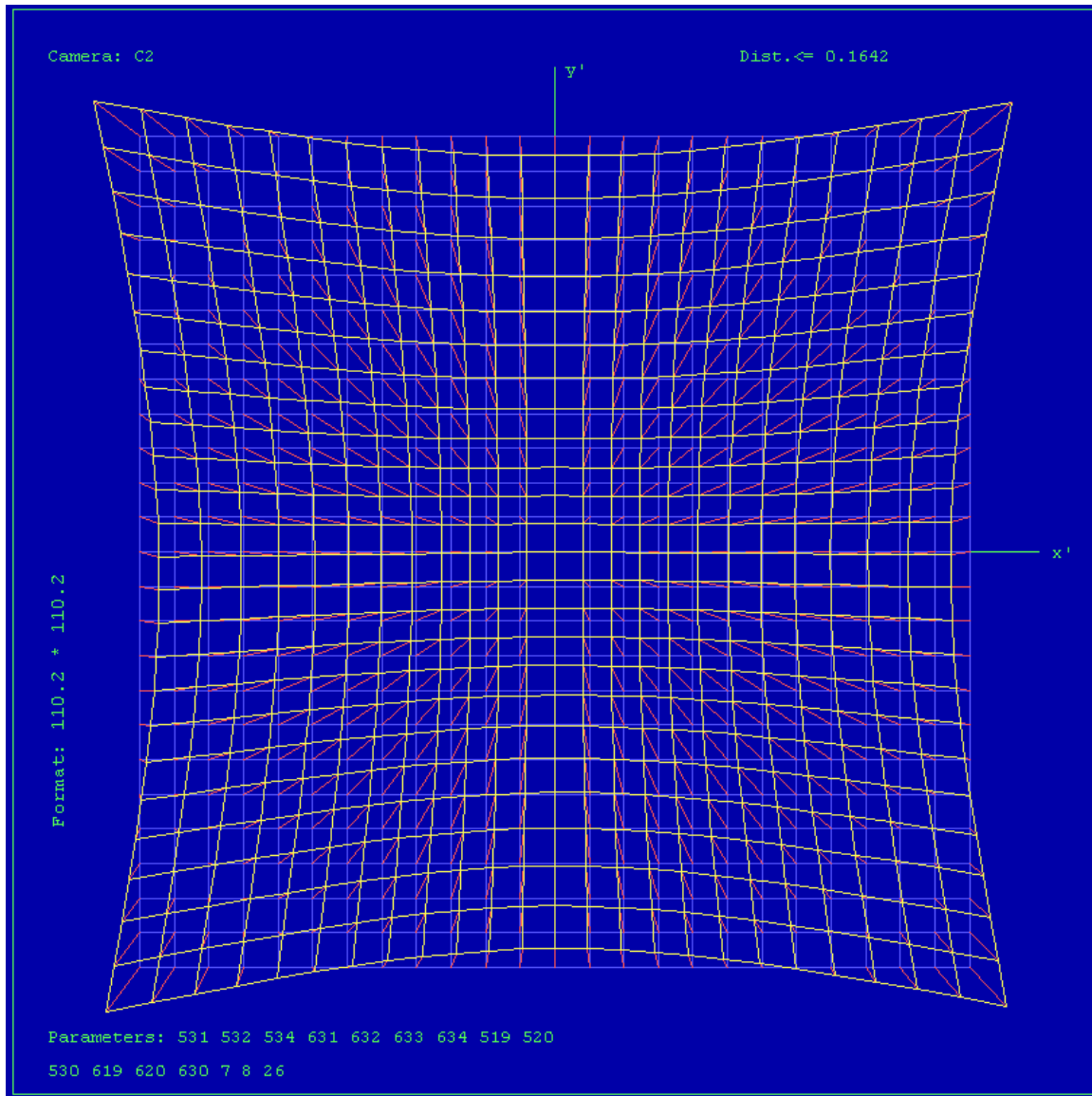


**UltraCam D, Serial Number UCD-SU-1-0039**

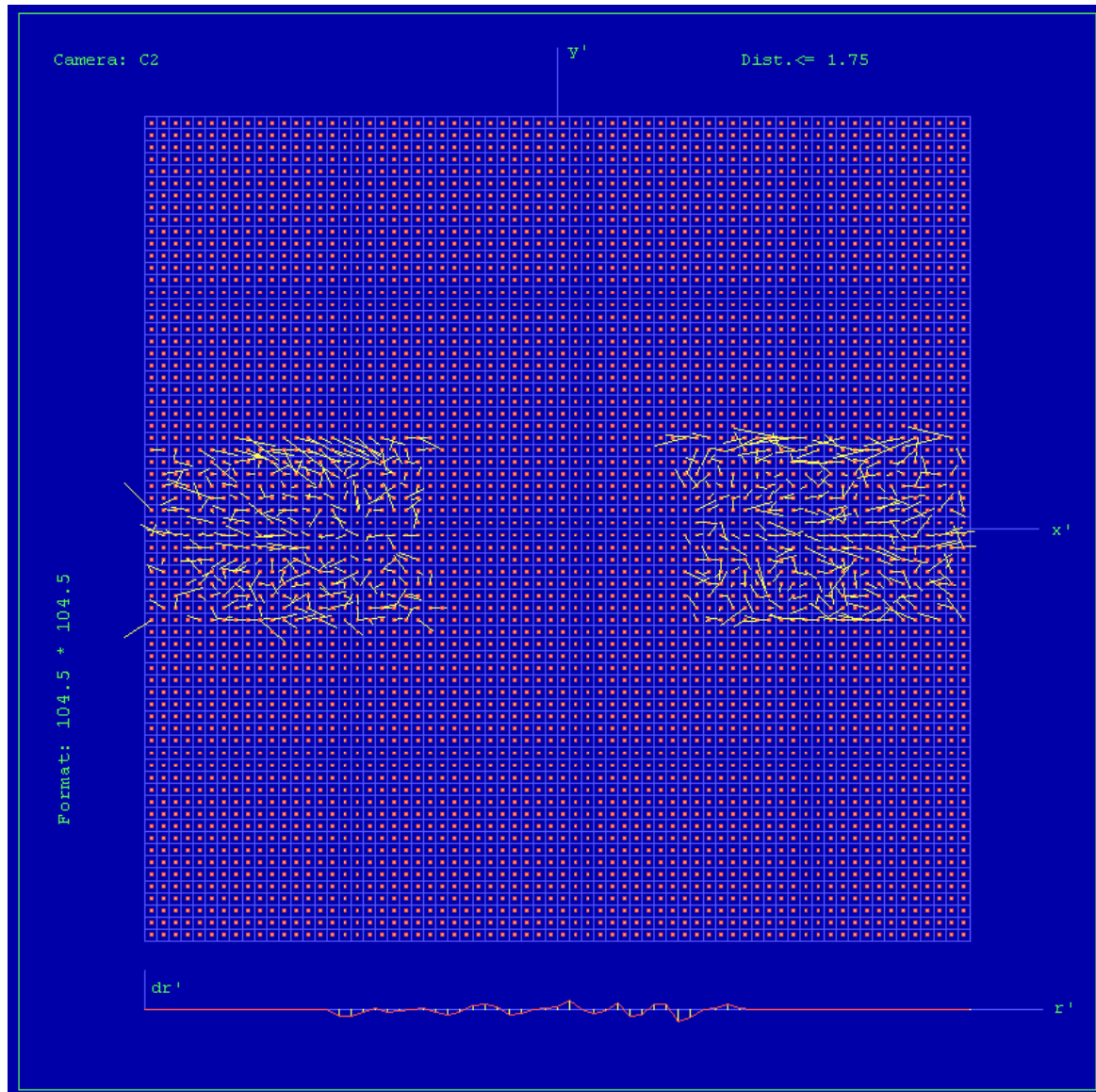
**Cone 2, Parametric Description, Not Effective in Output Image**

<b>Cone # C2</b>												
<b>Lens</b>	Rodenstock Apo-Sironar Digital 105mm Linos GmbH, Germany											
<b>Shutter</b>	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH											
<b>Image Extent (nominally)</b>		(-12.01, -51.75)mm	( 12.01, 51.75)mm									
<b>Extent CCD 0</b>		(-12.01, -51.75)mm	( 12.01, -15.75)mm									
<b>Extent CCD 1</b>		(-12.01, 15.75)mm	( 12.01, 51.75)mm									
<b>Parameters</b>	<b>Shift X</b>	<b>ShiftY</b>	<b>Rotation</b>	<b>Scale</b>								
<b>CCD0</b>	-1.92193991E-01 mm ± 0.0017 mm	-1.70913022E-01 mm ± 0.0062 mm	-3.54317335E-02 gon ± 0.0001 gon	1.00540933 ± 0.00005								
<b>CCD1</b>	1.93035386E-01 mm ± 0.0017 mm	-2.77491637E-01 mm ± 0.0062 mm	0.00000000 gon	1.00293366 ± 0.00005								
<b>Radial Distortion</b>												
<b>R [mm]</b>	5.0	10.0	15.0	20.0	25.0	30.0	35.0	40.0	45.0	50.0	55.0	60.0
<b>dr [µm]</b>	-19.8	-40.1	-59.4	-76.7	-90.6	-100.2	-104.5	-102.8	-94.3	-78.5	-55.0	-23.2

### Cone 2, Distortion Diagram, Not Effective in Output Image



### Cone 2, Residual Error Diagram



**Residual Error (RMS):**                      **0.96  $\mu\text{m}$**

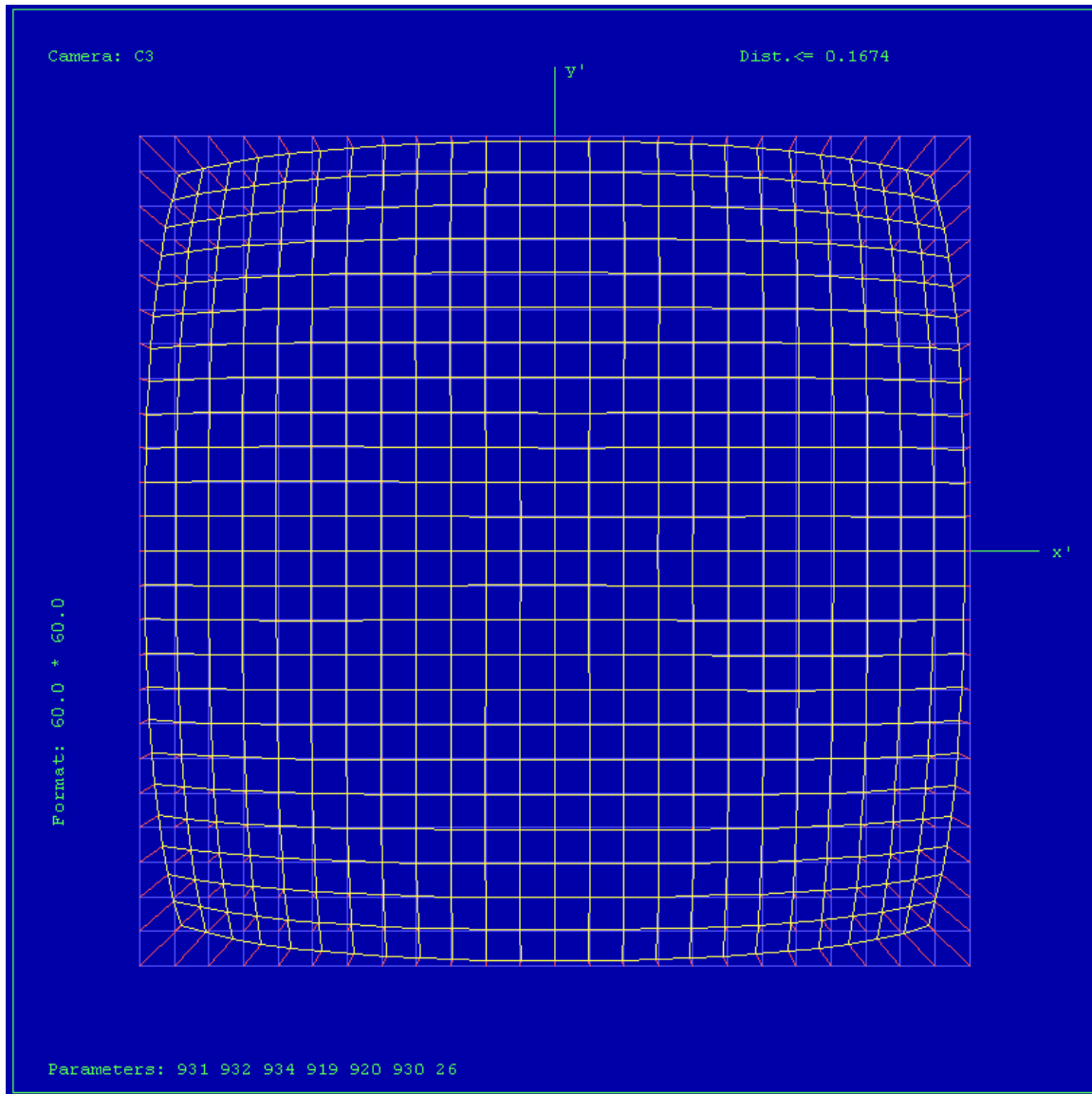


UltraCam D, Serial Number UCD-SU-1-0039

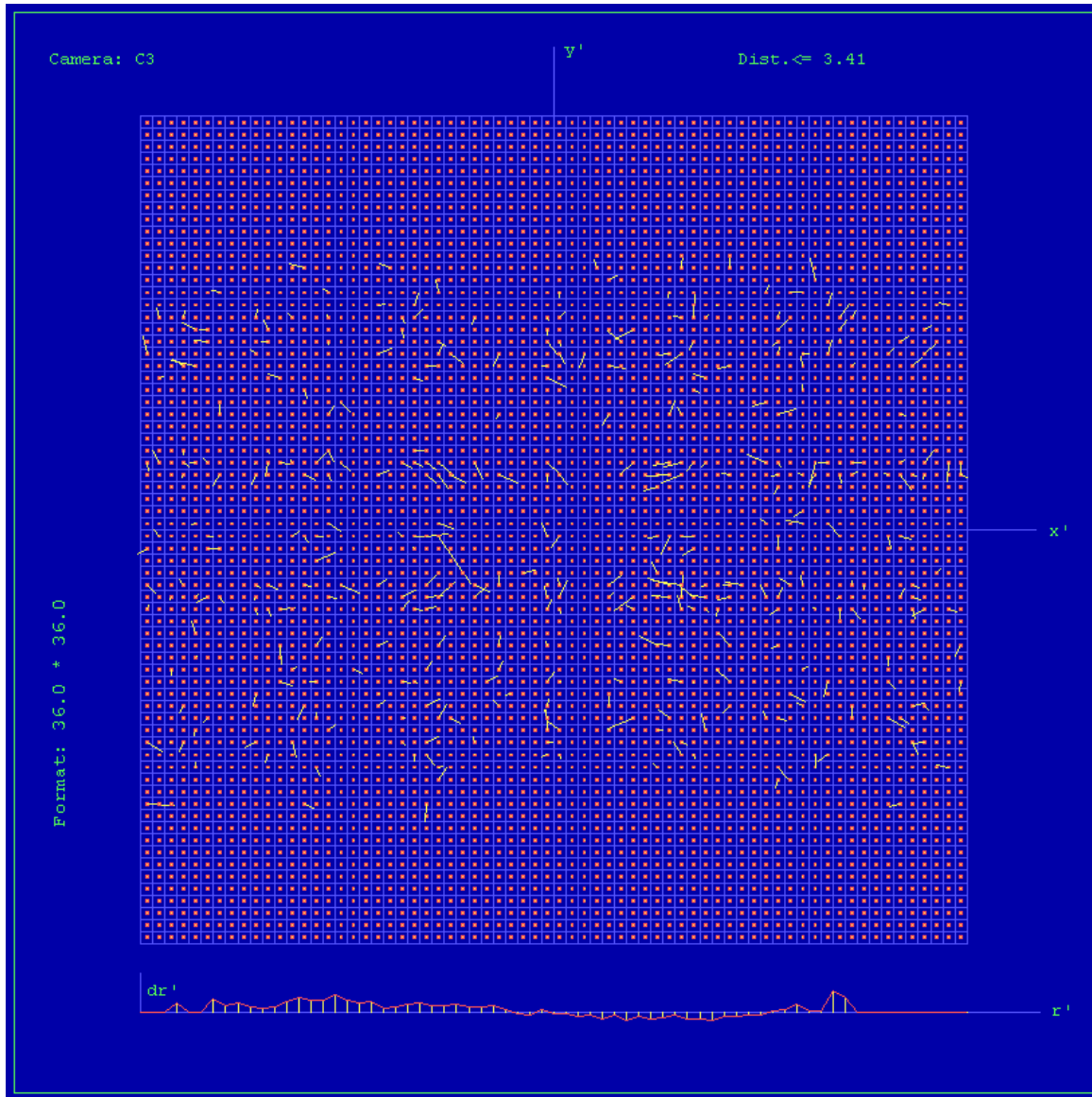
**Cone 3, Parametric Description, Not Effective in Output Image**

<b>Cone # C3</b>				
<b>Lens</b>	Rodenstock Apo-Sironar Digital 105mm Linos GmbH, Germany			
<b>Shutter</b>	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH			
<b>Image Extent (nominally)</b>		(-12.01, -18.04)mm	( 12.01, 18.04)mm	
<b>Extent CCD 0</b>		(-12.01, -18.04)mm	( 12.01 , 18.04)mm	
<b>Parameters</b>	Shift X	ShiftY	Rotation	Scale
<b>CCD0</b>	-1.97612746E-02 mm ± 0.0042 mm	-1.68943195E-01 mm ± 0.0097 mm	0.00000000 gon	1.00767320 ± 0.00005
<b>Radial Distortion</b>				
<b>R [mm]</b>	5.0	10.0	15.0	20.0 25.0
<b>dr [µm]</b>	-1.9	-0.3	3.4	5.8 2.2

### Cone 3, Distortion Diagram, Not Effective in Output Image

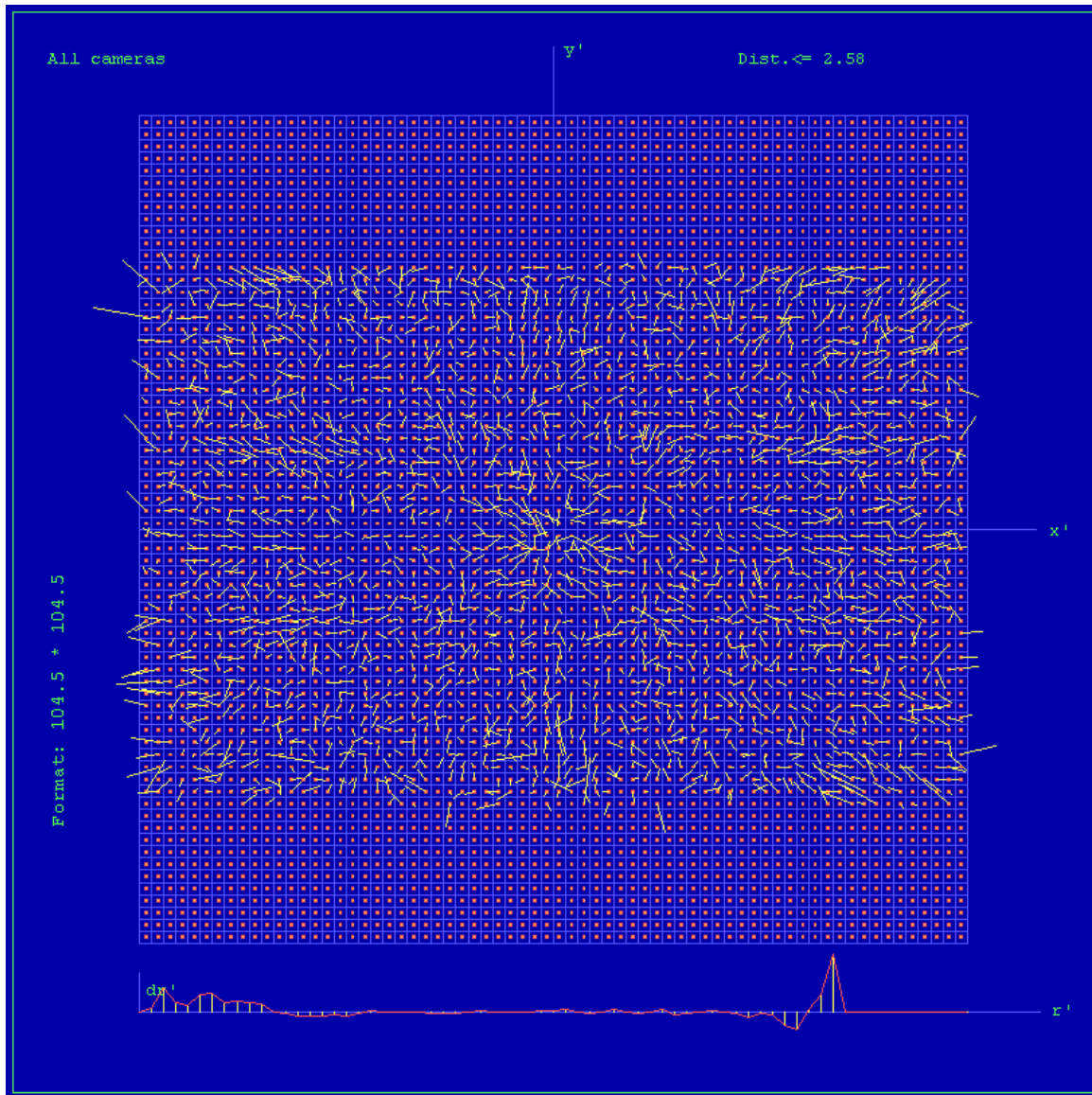


### Cone 3, Residual Error Diagram



**Residual Error (RMS):**                      **0.89  $\mu\text{m}$**

### Full Pan Image, Residual Error Diagram



**Residual Error (RMS):**                      **0.82  $\mu\text{m}$**

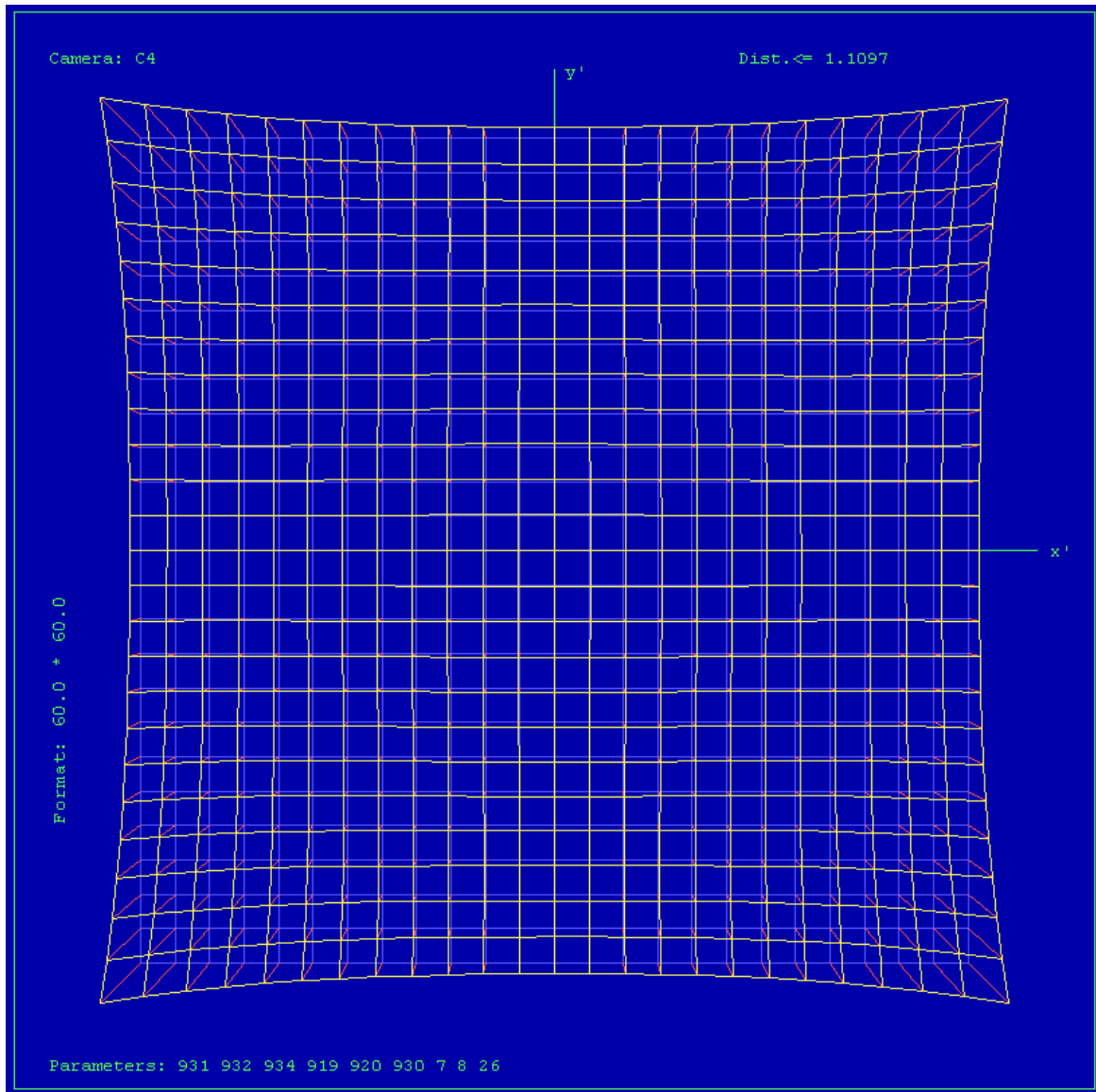


## Individual Multispectral Cone Data

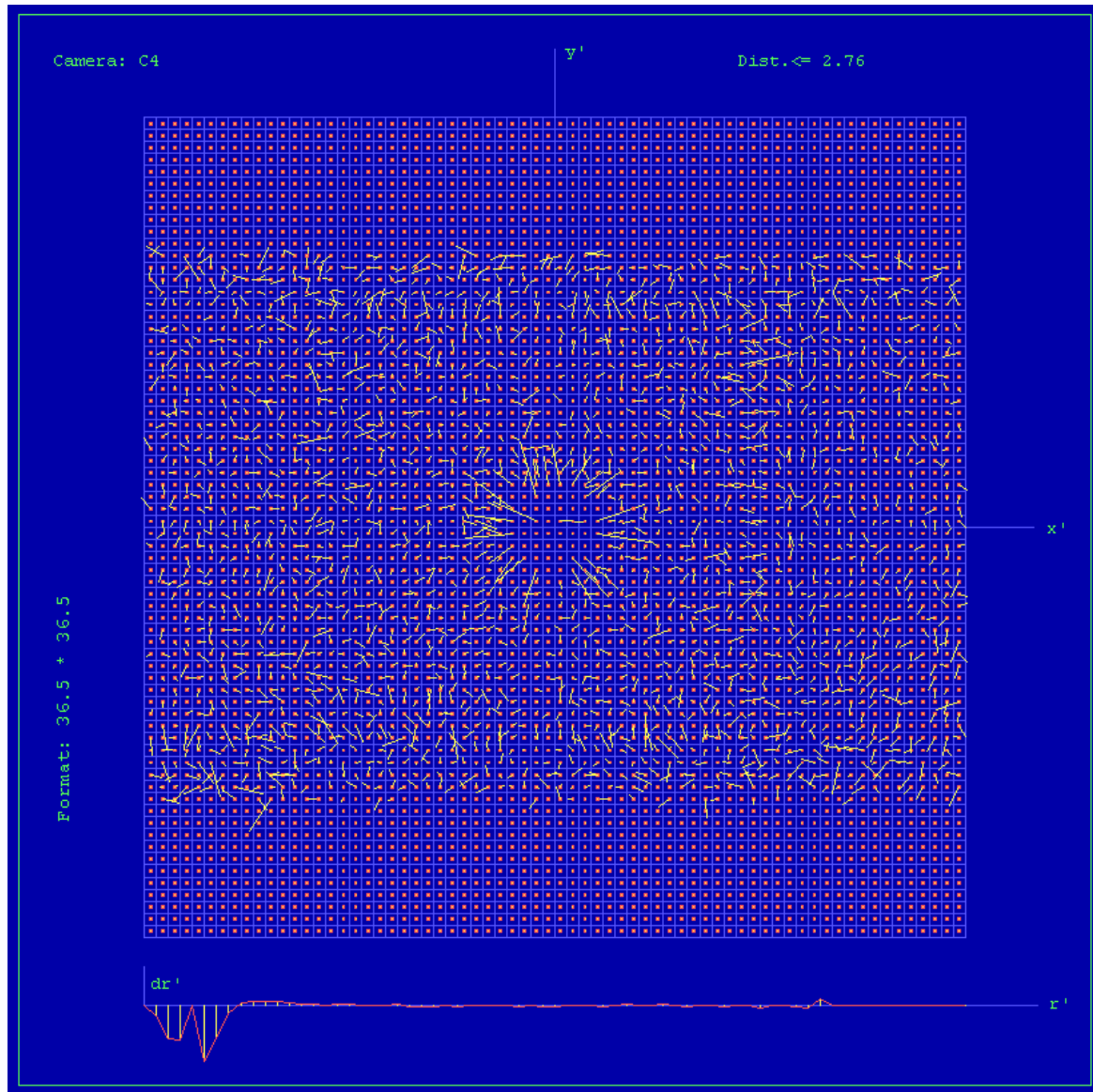
### Cone 4, Parametric Description, Not Effective in Output Image

<b>Cone # C4 (red)</b>				
<b>Lens</b>	Rodenstock Apo-Sironar Digital HR 35mm Linos GmbH, Germany			
<b>Shutter</b>	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH			
<b>Image Extent (nominally)</b>		(-10.08, -16.56)mm	(10.08, 16.56)mm	
<b>Extent CCD 0</b>		(-12.08, -18.04)mm	(12.08, 18.04)mm	
<b>Parameters</b>	Shift X	ShiftY	Rotation	Scale
<b>CCD0</b>	-3.83131876E-02 mm ± 0.0002 mm	1.61519980E-02 mm ± 0.0003 mm	0.00000000 gon	1.02936457 ± 0.00005
<b>Radial Distortion</b>				
<b>R [mm]</b>	5.0	10.0	15.0	20.0 25.0
<b>dr [µm]</b>	51.8	88.1	103.4	108.6 130.7

### Cone 4, Distortion Diagram, Not Effective in Output Image



### Cone 4, Residual Error Diagram

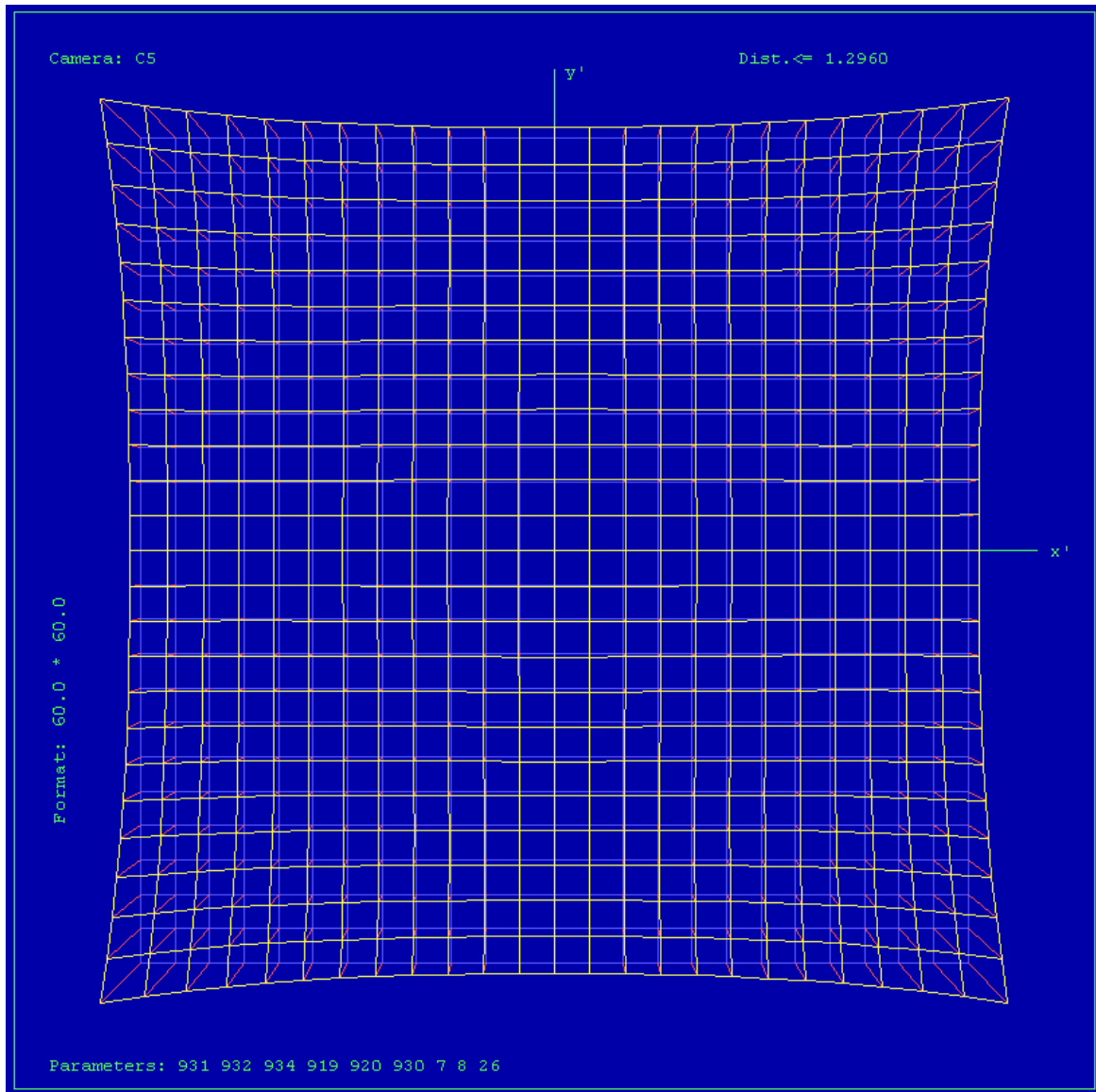


**Residual Error (RMS):            0.96  $\mu\text{m}$**

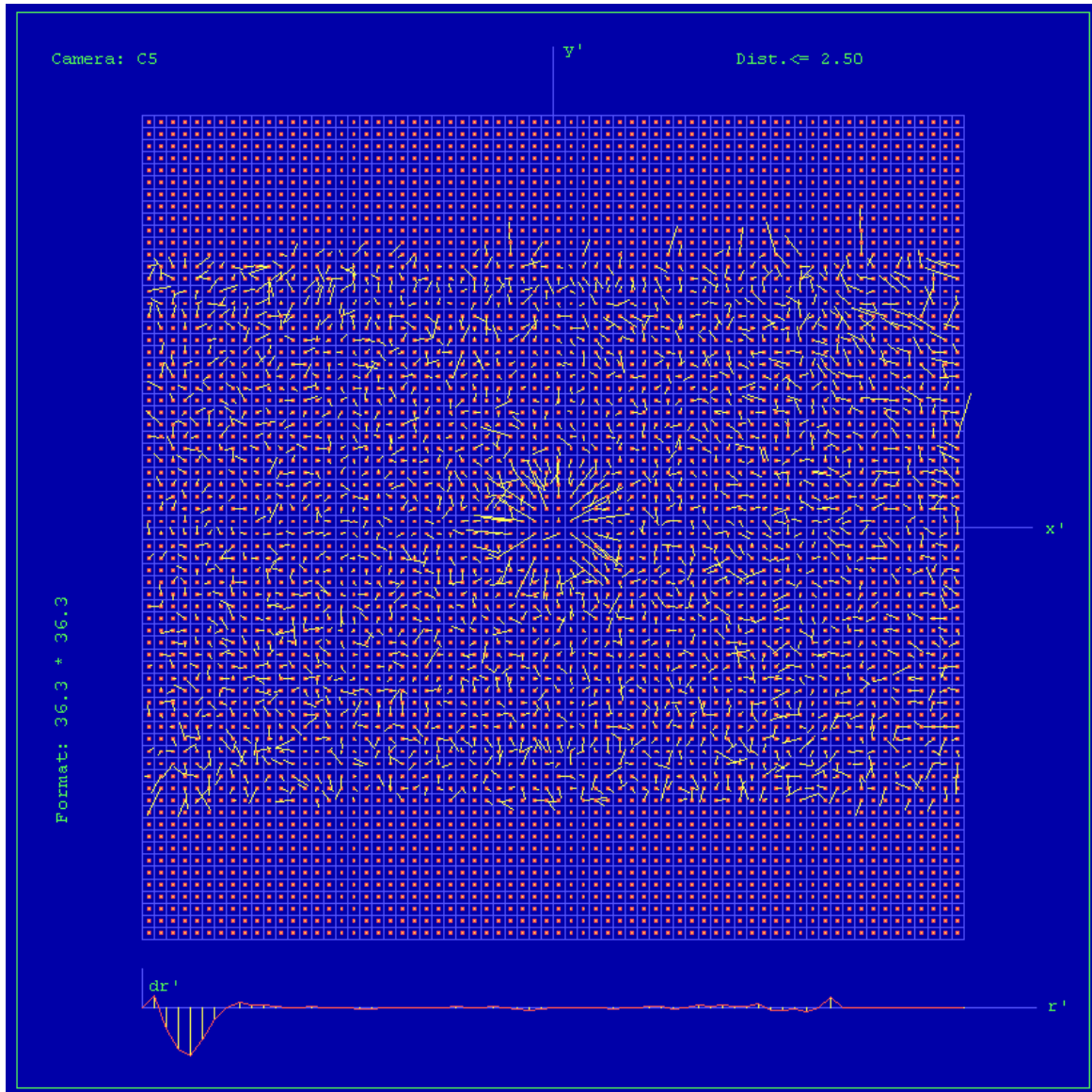
**Cone 5, Parametric Description, Not Effective in Output Image**

<b>Cone # C5 (green)</b>				
<b>Lens</b>	Rodenstock Apo-Sironar Digital HR 35mm Linor GmbH, Germany			
<b>Shutter</b>	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH			
<b>Image Extent (nominally)</b>		(-10.08, -16.56)mm	(10.08, 16.56)mm	
<b>Extent CCD 0</b>		(-12.08, -18.04)mm	(12.08, 18.04)mm	
<b>Parameters</b>	Shift X	Shift Y	Rotation	Scale
<b>CCD0</b>	3.64318044E-02 mm ± 0.0002 mm	9.04706099E-03 mm ± 0.0003 mm	0.00000000 gon	1.02562620 ± 0.00005
<b>Radial Distortion</b>	<b>Not effective in Production Image</b>			
<b>R [mm]</b>	5.0	10.0	15.0	20.0 25.0
<b>dr [µm]</b>	54.1	92.5	108.9	115.6 143.5

**Cone 5, Distortion Diagram, Not Effective in Output Image**



### Cone 5, Residual Error Diagram

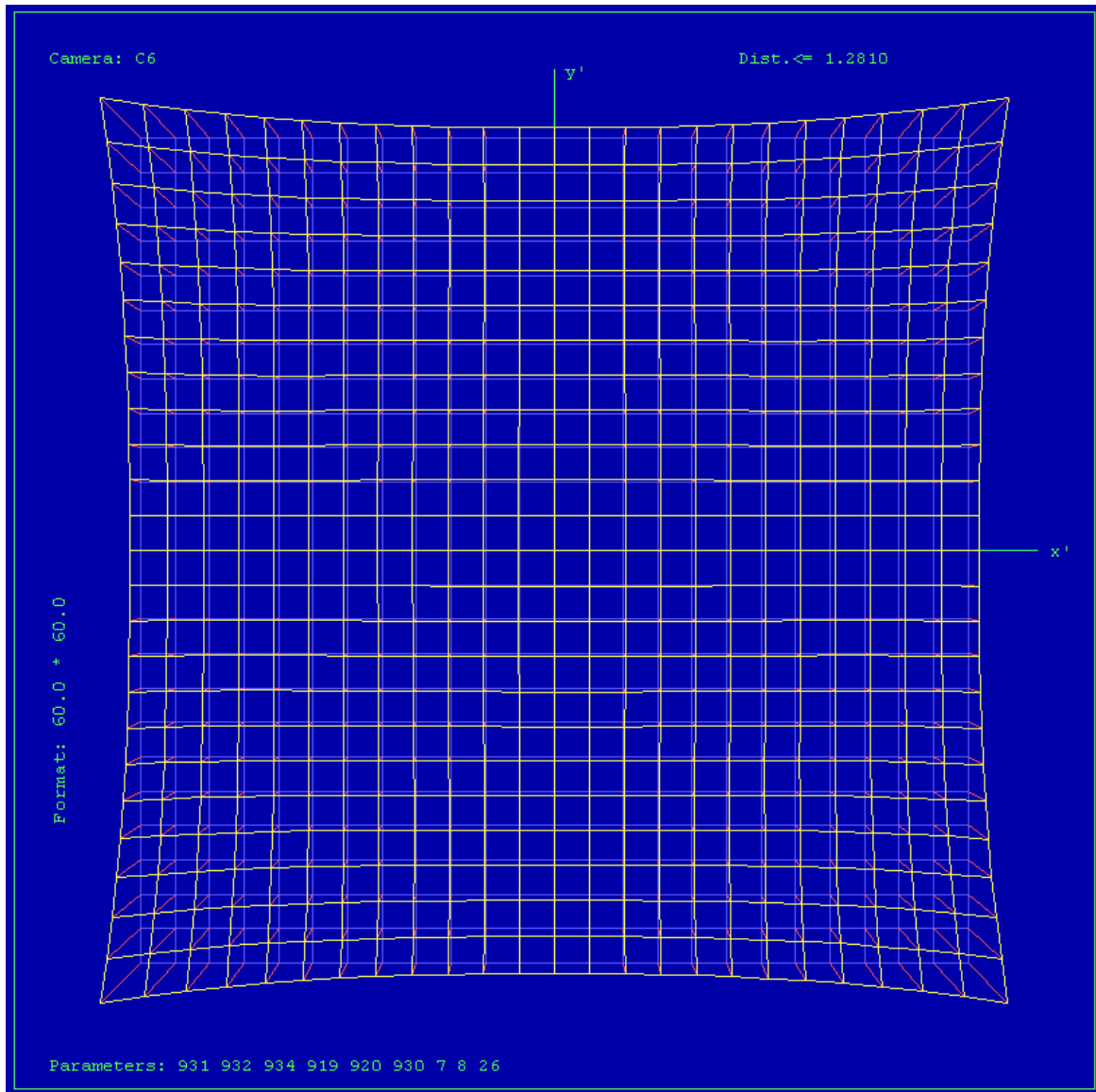


**Residual Error (RMS):**            **0.83  $\mu\text{m}$**

**Cone 6, Parametric Description, Not Effective in Output Image**

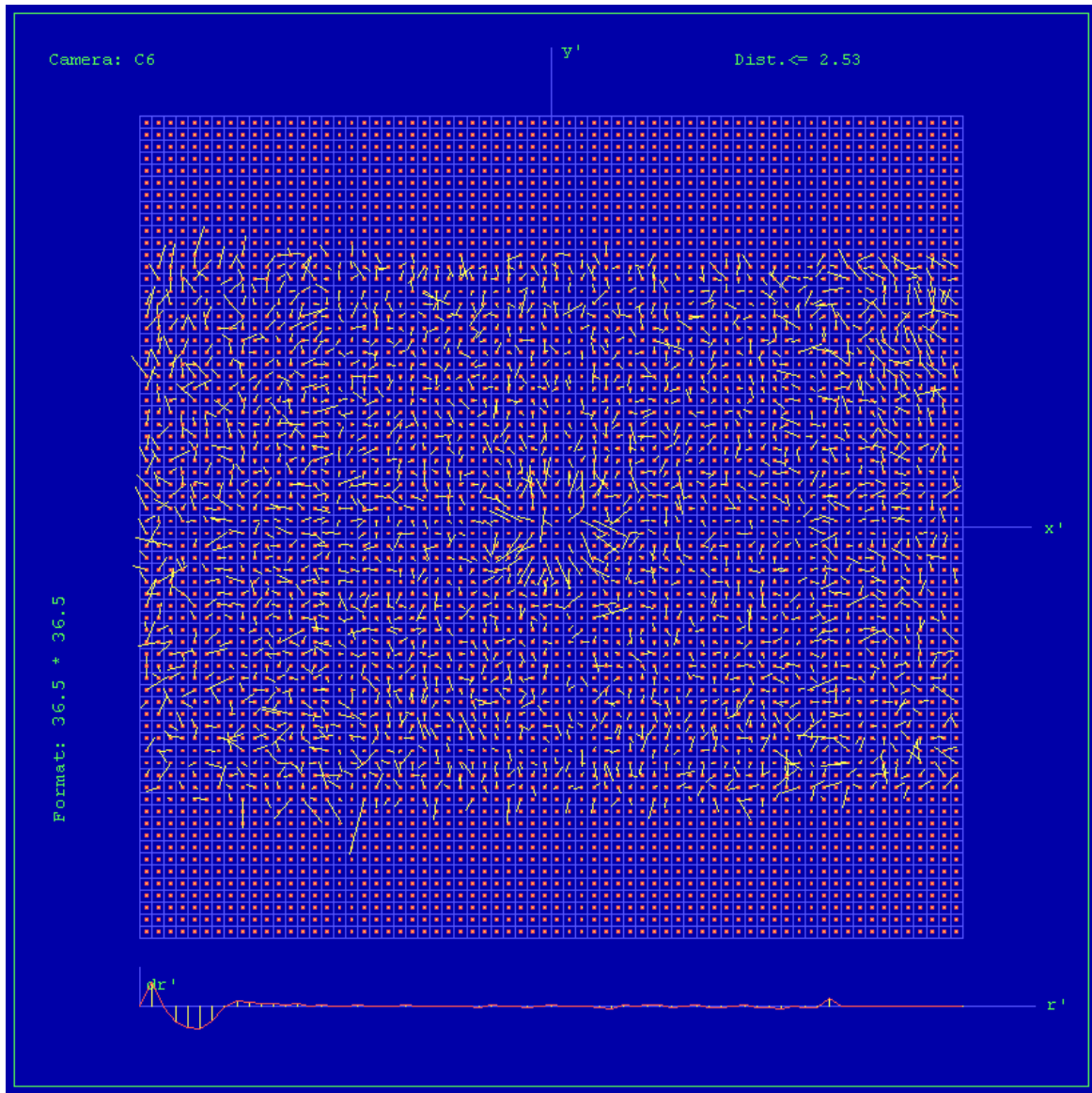
<b>Cone # C6 (blue)</b>				
<b>Lens</b>	Rodenstock Apo-Sironar Digital HR 35mm Linos GmbH, Germany			
<b>Shutter</b>	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH			
<b>Image Extent (nominally)</b>		(-10.08, -16.56)mm	(10.08, 16.56)mm	
<b>Extent CCD 0</b>		(-12.08, -18.04)mm	(12.08, 18.04)mm	
<b>Parameters</b>	Shift X	ShiftY	Rotation	Scale
<b>CCD0</b>	2.27586250E-02 mm ± 0.0002 mm	-4.46970150E-02 mm ± 0.0003 mm	0.00000000 gon	1.02817913 ± 0.00005
<b>Radial Distortion</b>	<b>Not effective in Production Image</b>			
<b>R [mm]</b>	5.0	10.0	15.0	20.0 25.0
<b>dr [µm]</b>	51.5	88.5	104.7	111.8 140.4

**Cone 6, Distortion Diagram, Not Effective in Output Image**





### Cone 6, Residual Error Diagram

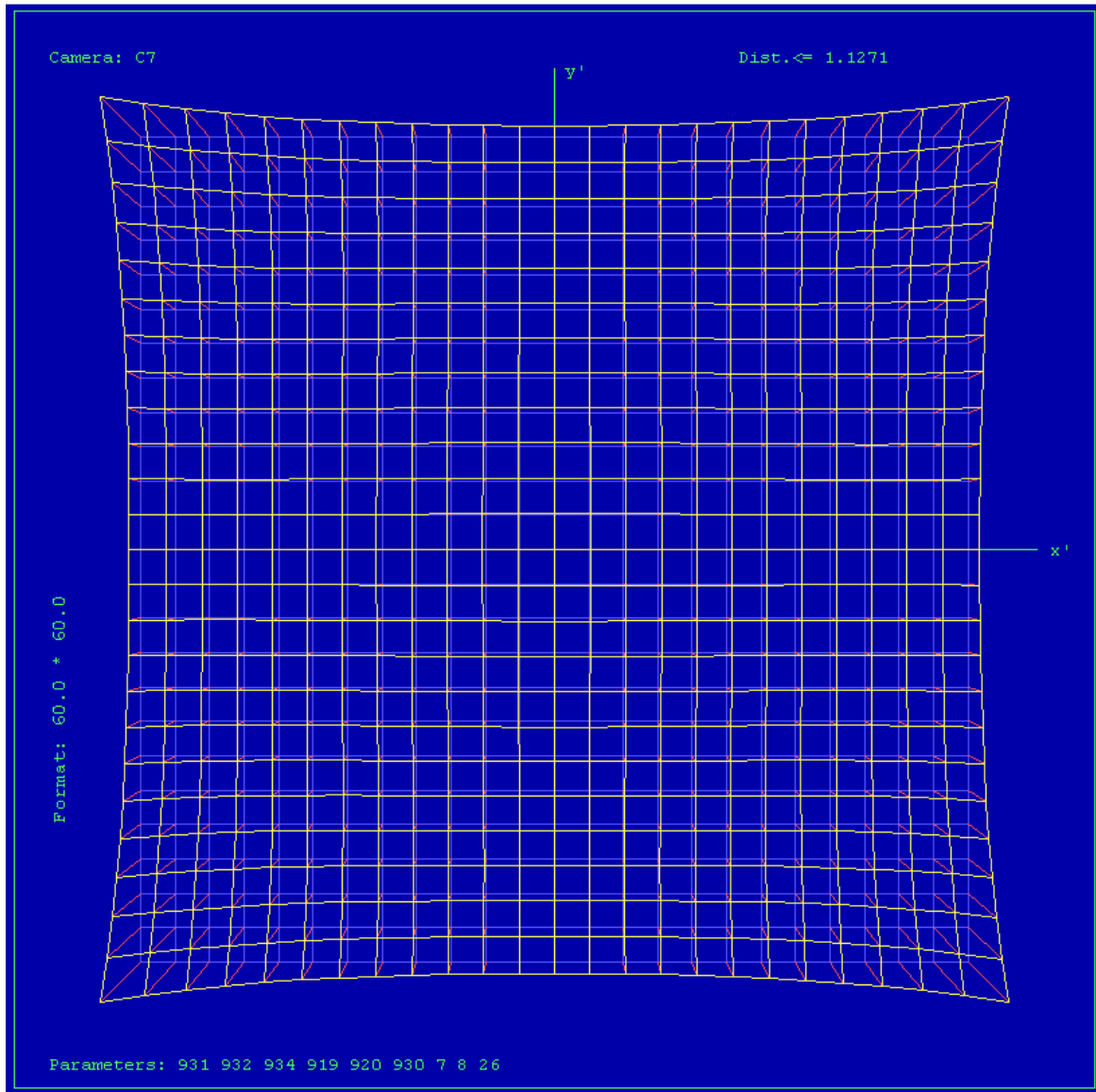


**Residual Error (RMS):**                      **0.83  $\mu\text{m}$**

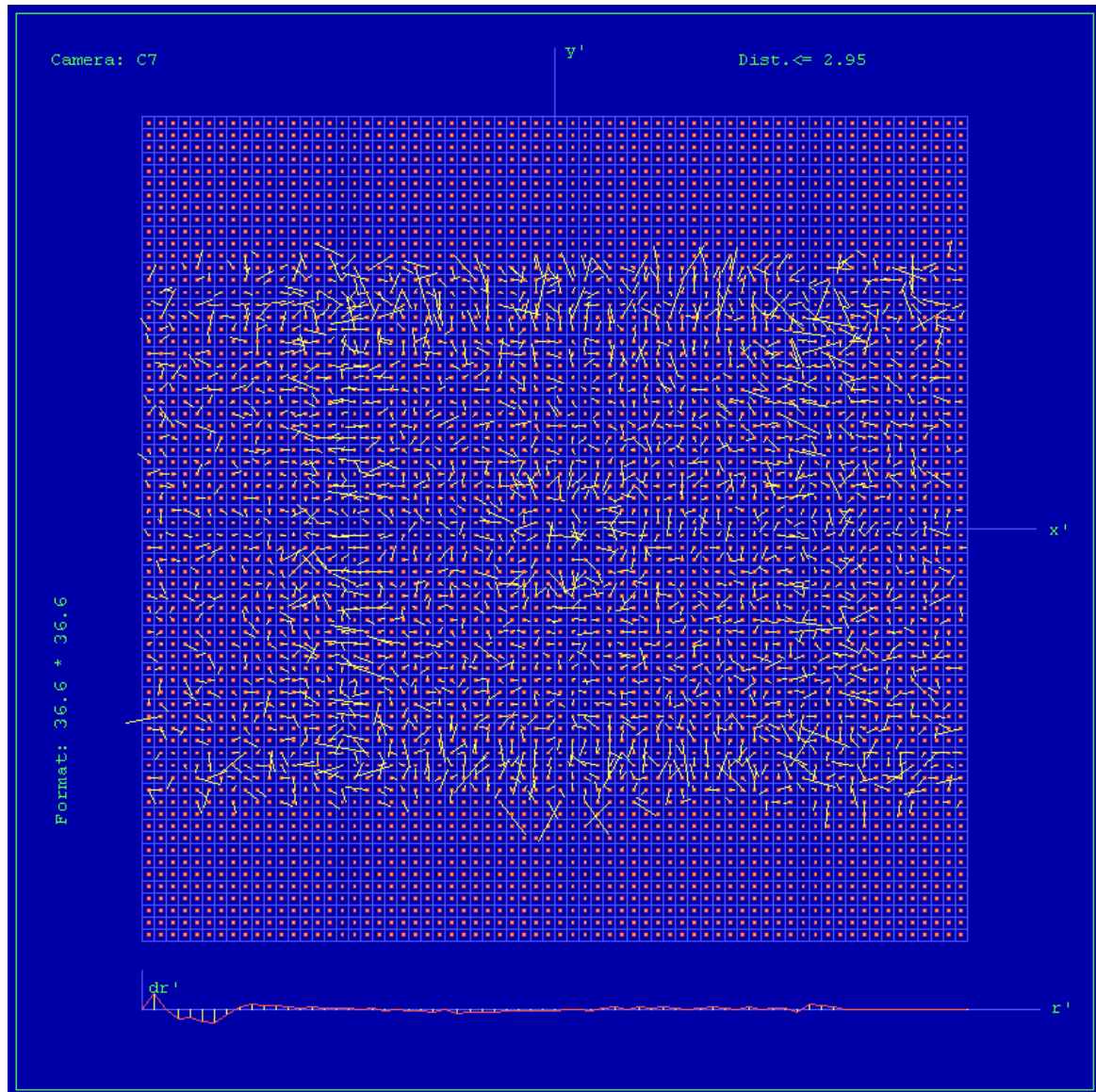
**Cone 7, Parametric Description, Not Effective in Output Image**

<b>Cone # C7 (NIR)</b>				
<b>Lens</b>	Rodenstock Apo-Sironar Digital HR 35mm Linos GmbH, Germany			
<b>Shutter</b>	Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH			
<b>Image Extent (nominally)</b>		(-10.08, -16.56)mm		(10.08, 16.56)mm
<b>Extent CCD 0</b>		(-12.08, -18.04)mm		(12.08, 18.04)mm
<b>Parameters</b>	Shift X	ShiftY	Rotation	Scale
<b>CCD0</b>	3.08754968E-02 mm ± 0.0002 mm	-4.03536476E-03 mm ± 0.0003 mm	0.00000000 gon	1.03078612 ± 0.00005
<b>Radial Distortion</b>	<b>Not effective in Production Image</b>			
<b>R [mm]</b>	5.0	10.0	15.0	20.0 25.0
<b>dr [µm]</b>	57.1	98.8	118.3	125.6 147.8

### Cone 7, Distortion Diagram, Not Effective in Output Image



### Cone 7, Residual Error Diagram

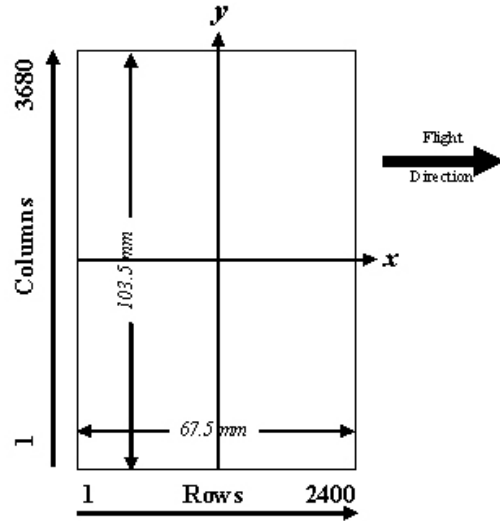
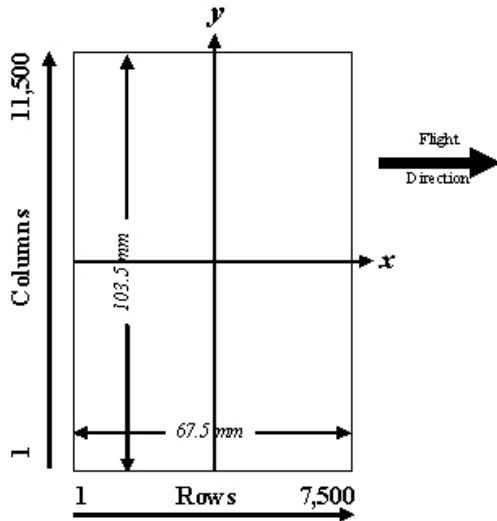


**Residual Error (RMS):**                      **1.11  $\mu\text{m}$**



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

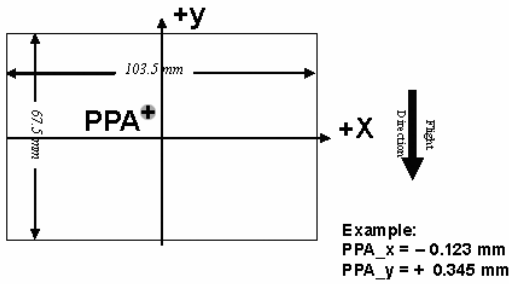
4) Position of Principal Point in Level 3 Image

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.

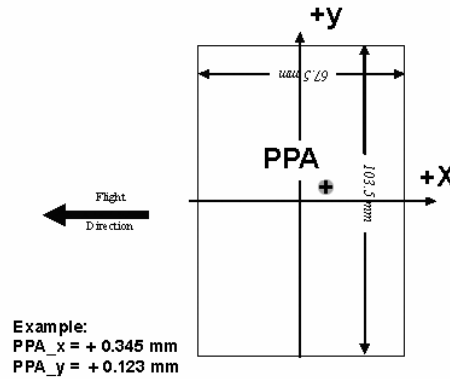
Image Format	Clockwise Rotation (Degree)	PPA	
		X	Y
Level 2	-	0.000	0.270
Level 3	0	0.000	0.270
Level 3	90	0.270	0.000
Level 3	180	0.000	-0.270
Level 3	270	-0.270	0.000

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.

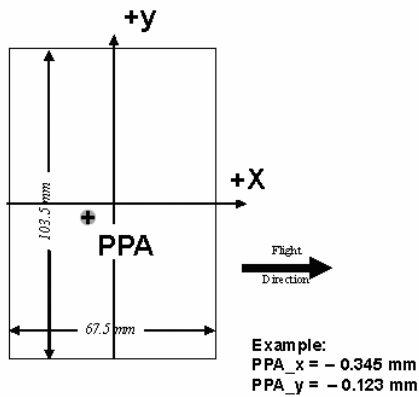
**Lvl3, Rotation 0 deg clockwise**



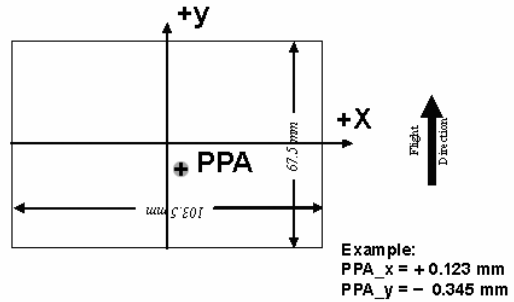
**Lvl3, Rotation 90 deg clockwise**



**Lvl3, Rotation 270 deg clockwise**



**Lvl3, Rotation 180 deg clockwise**

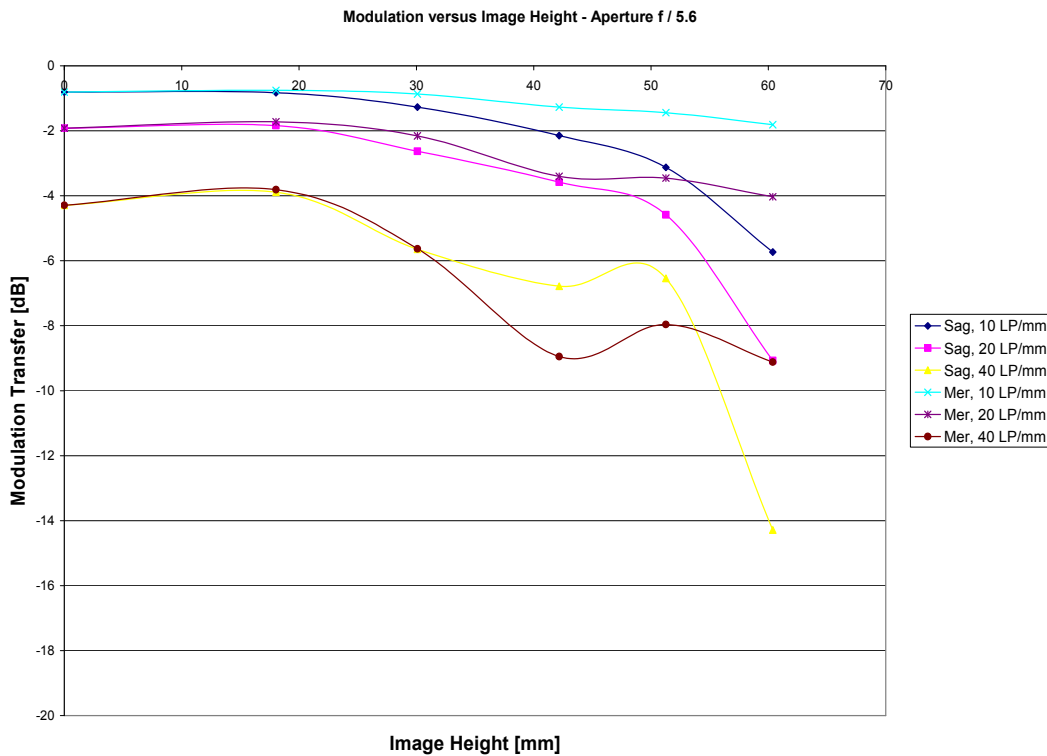


## Lens Resolving Power

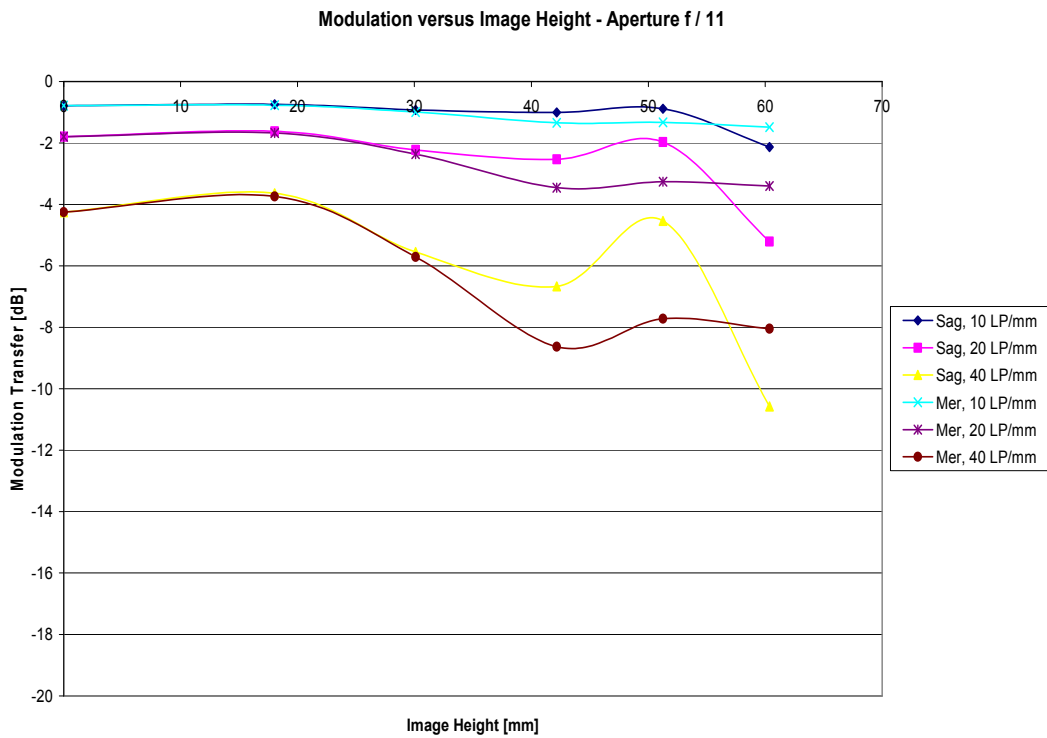
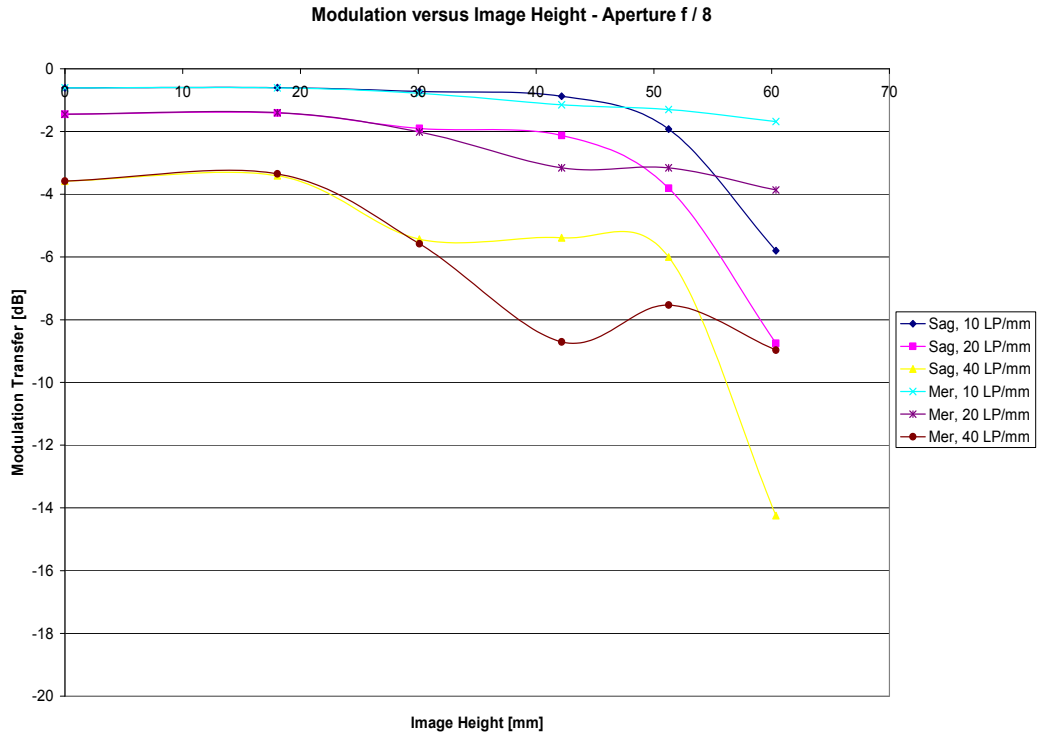
The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones.

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.

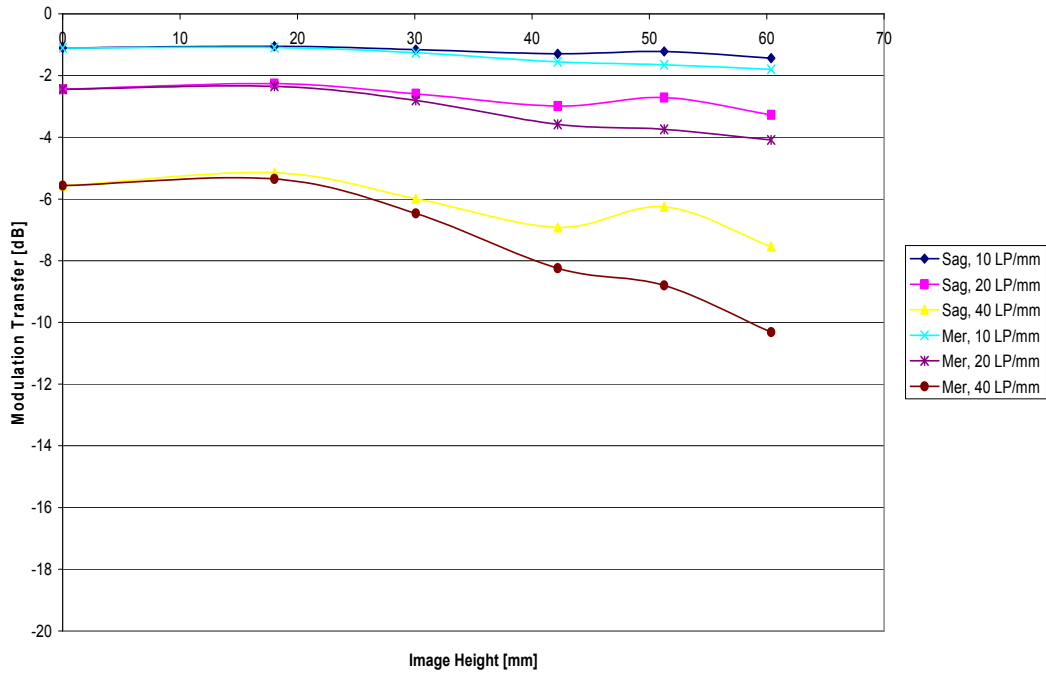
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.



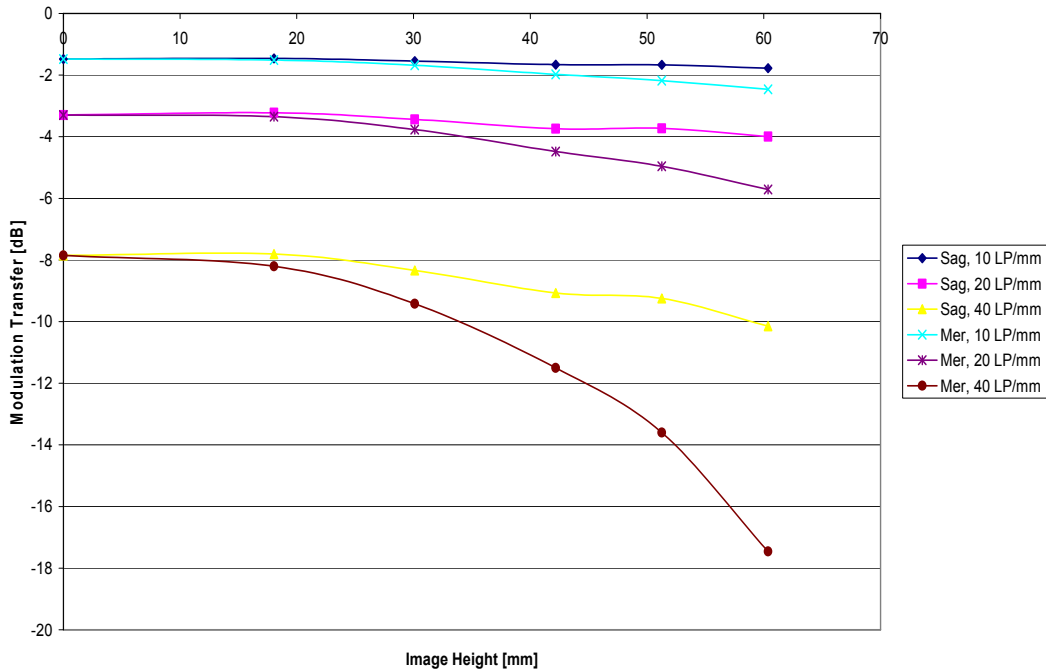




Modulation versus Image Height - Aperture f / 16



Modulation versus Image Height - Aperture f / 22



# Calibration Report

## Radiometric Calibration



<b>Camera:</b>	<b>UltraCam D, S/N UCD-SU-1-0039</b>
<b>Manufacturer:</b>	<b>Vexcel Imaging GmbH, A-8010 Graz, Austria</b>
<b>Panchromatic Camera:</b>	<b>Apertures: f/5.6, f/8, f/11, f/16, f/22 (All Pan)</b>
<b>Multispectral Camera:</b>	<b>Apertures: f/4, f/5.6, f/8, f/11, f/16 (Red, Green) f/2.8, f/4, f/5.6, f/8, f/11 (Blue, NIR)</b>
<b>Date of Calibration:</b>	<b>Mar-16-2006</b>
<b>Date of Report:</b>	<b>Mar-23-2006</b>
<b>Camera Revision:</b>	<b>1.0</b>
<b>Revision of Report:</b>	<b>1.0</b>

## Calibration of Vignetting for Aperture Setting 1

**Panchromatic:** f / 5.6  
**Red Channel:** f / 4  
**Green Channel:** f / 4  
**Blue Channel:** f / 2.8  
**NIR Channel:** f / 2.8

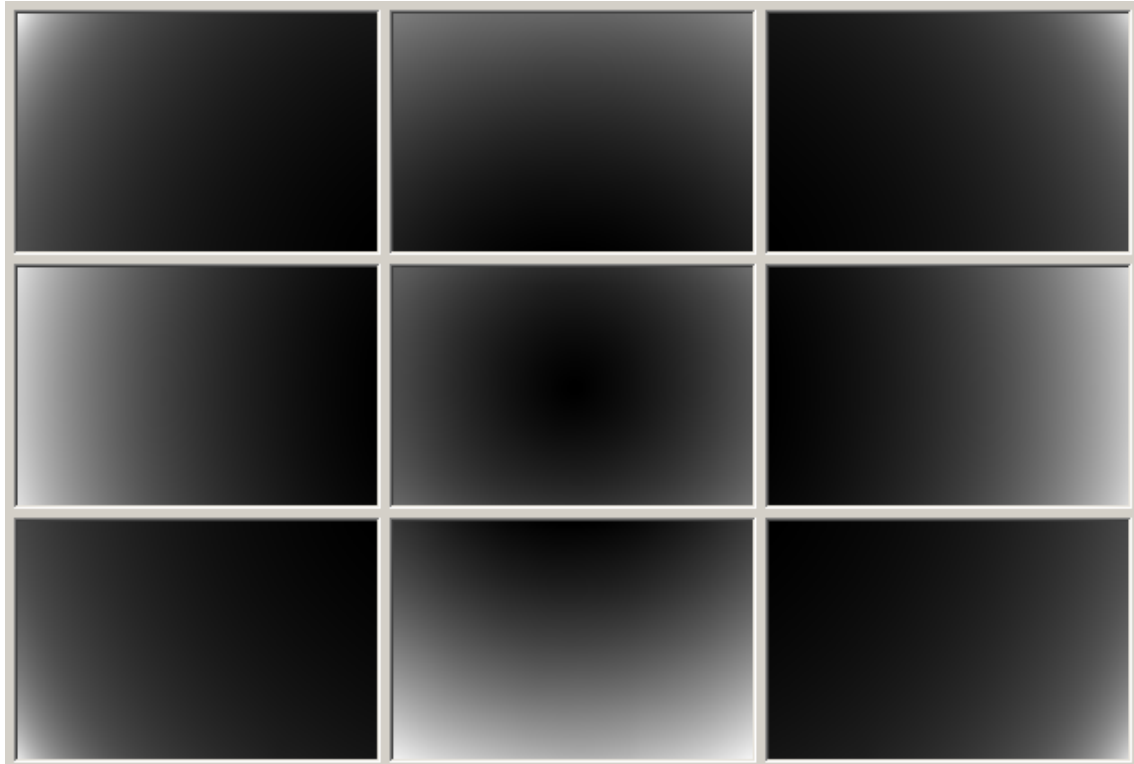
**Stepper Motor Position:** 1000h

### Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain $\geq$	Maximum Gain $\leq$
00_00	f / 5.6	1.00	8.00
00_01	f / 5.6	1.00	9.00
00_02	f / 5.6	1.00	9.00
00_03	f / 5.6	1.00	9.00
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 / 2.8	1.00	2.00
07_00 (NIR)	f / 2.8	1.00	3.00

## Calibration of Vignetting for Aperture Setting 1

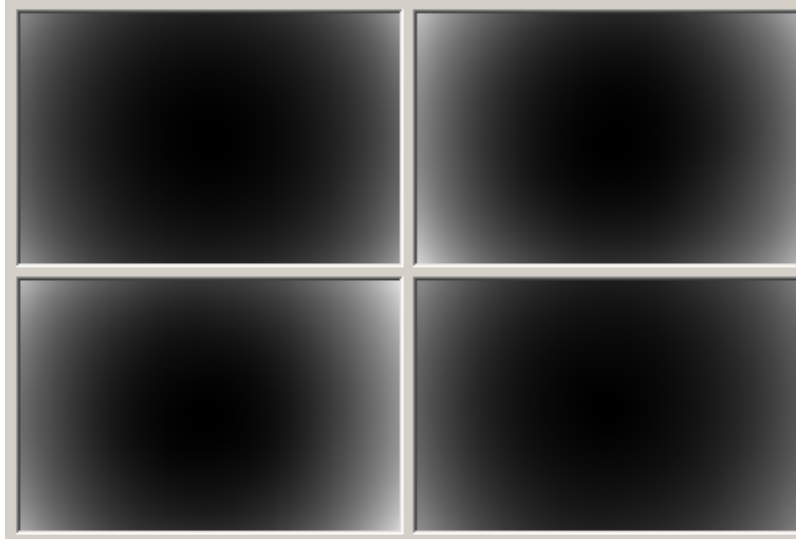
### Graphical Overview of Pan Sensor Gain Values:



<b>00_00</b>	<b>01_00</b>	<b>00_01</b>
<b>02_00</b>	<b>03_00</b>	<b>02_01</b>
<b>00_02</b>	<b>01_01</b>	<b>00_03</b>

## Calibration of Vignetting for Aperture Setting 1

### Graphical Overview of Multispectral Sensor Gain Values:



<b>04_00</b> <b>(red)</b>	<b>06_00</b> <b>(blue)</b>
<b>05_00</b> <b>(green)</b>	<b>07_00</b> <b>(NIR)</b>

## 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

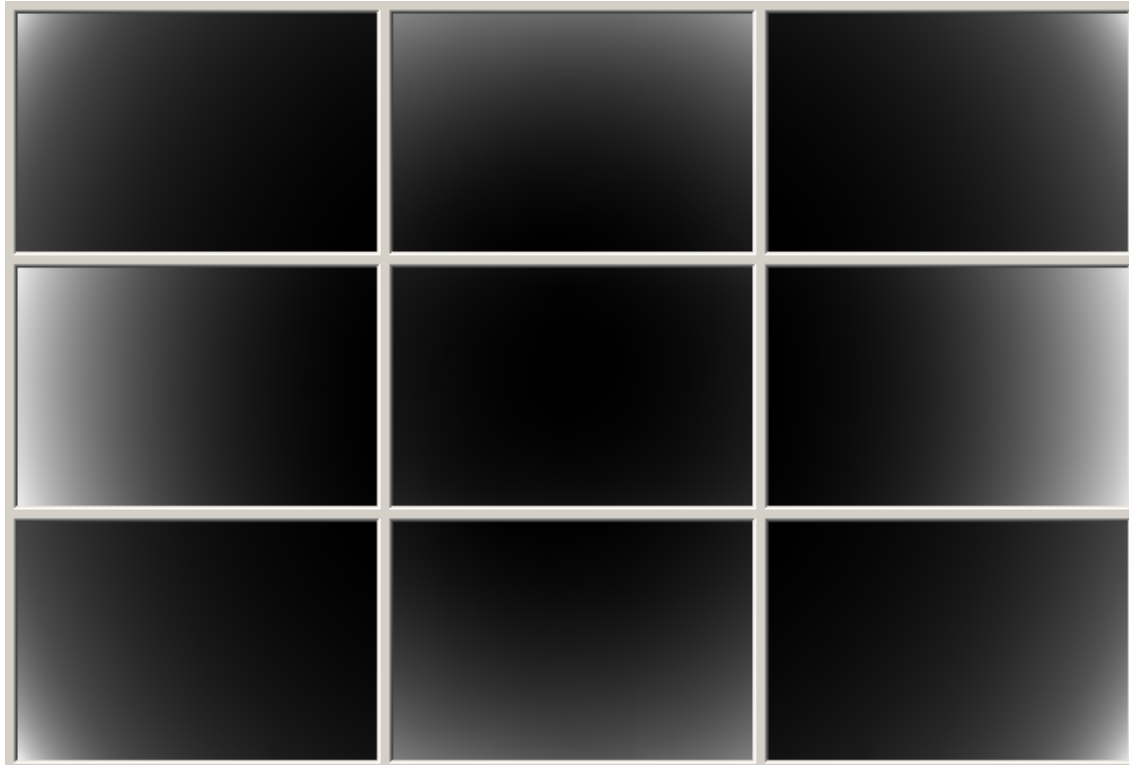
**Stepper Motor Position:** 1022h

### Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain $\geq$	Maximum Gain $\leq$
00_00	f / 8	1.00	7.00
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:

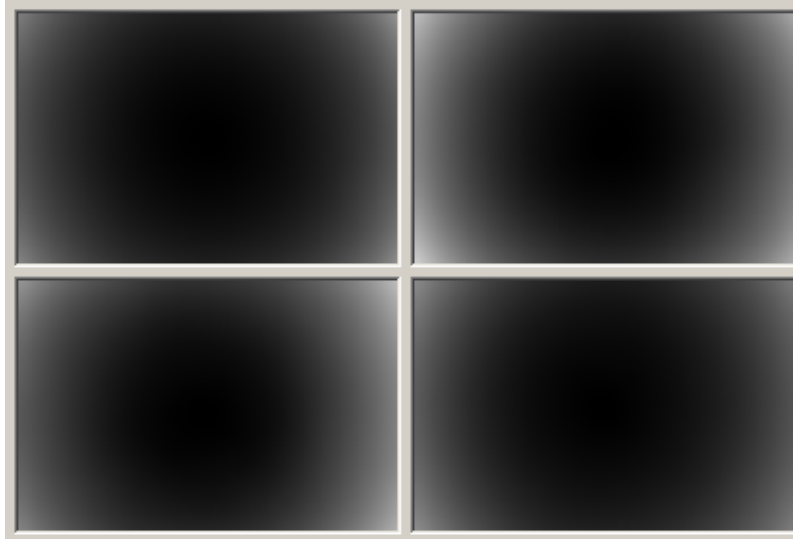


<b>00_00</b>	<b>01_00</b>	<b>00_01</b>
<b>02_00</b>	<b>03_00</b>	<b>02_01</b>
<b>00_02</b>	<b>01_01</b>	<b>00_03</b>



## Calibration of Vignetting for Aperture Setting 2

### Graphical Overview of Multispectral Sensor Gain Values:



<b>04_00</b> <b>(red)</b>	<b>06_00</b> <b>(blue)</b>
<b>05_00</b> <b>(green)</b>	<b>07_00</b> <b>(NIR)</b>

### 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

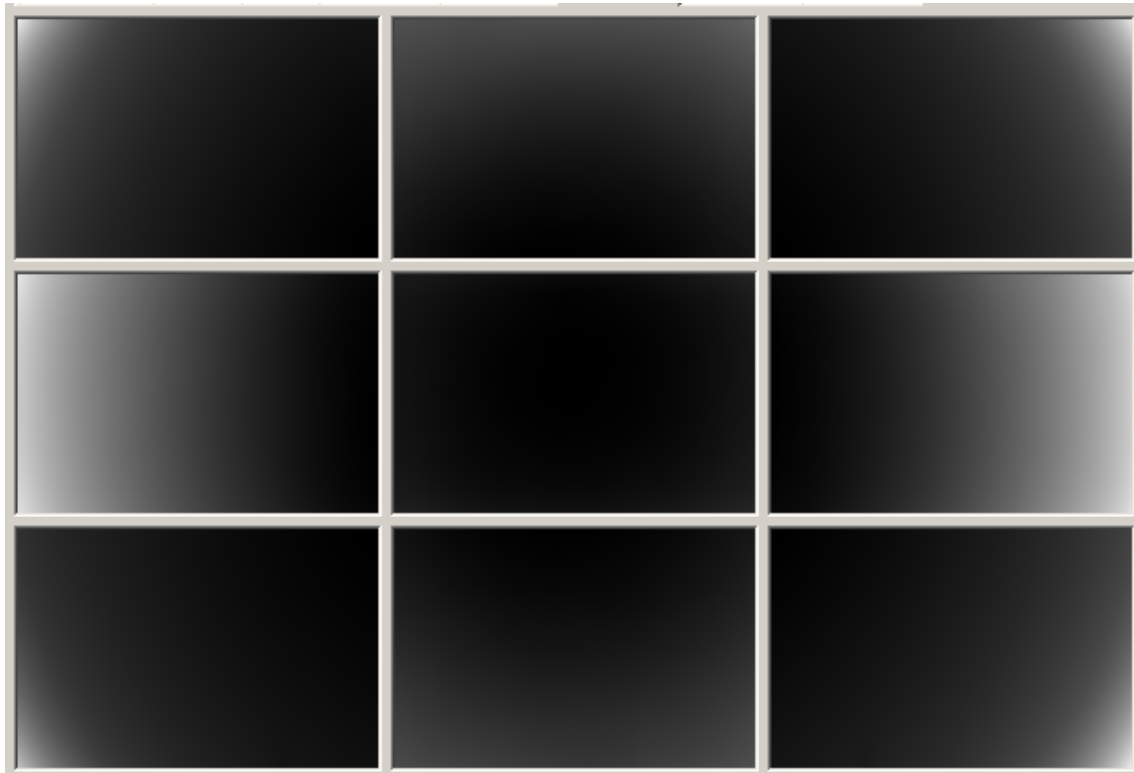
**Stepper Motor Position:** 1044h

### 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	5.00
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

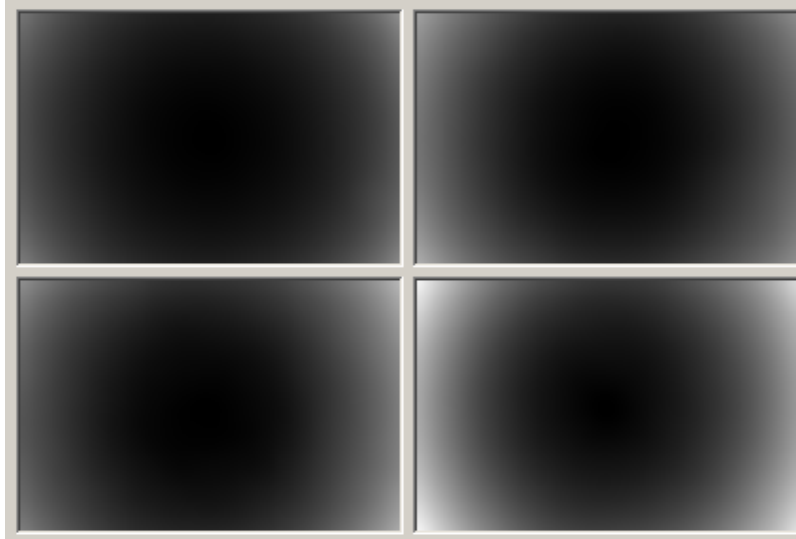
#### Graphical Overview of Pan Sensor Gain Values:



<b>00_00</b>	<b>01_00</b>	<b>00_01</b>
<b>02_00</b>	<b>03_00</b>	<b>02_01</b>
<b>00_02</b>	<b>01_01</b>	<b>00_03</b>

### Calibration of Vignetting for Aperture Setting 3

### Graphical Overview of Multispectral Sensor Gain Values:



<b>04_00</b> <b>(red)</b>	<b>06_00</b> <b>(blue)</b>
<b>05_00</b> <b>(green)</b>	<b>07_00</b> <b>(NIR)</b>

## 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

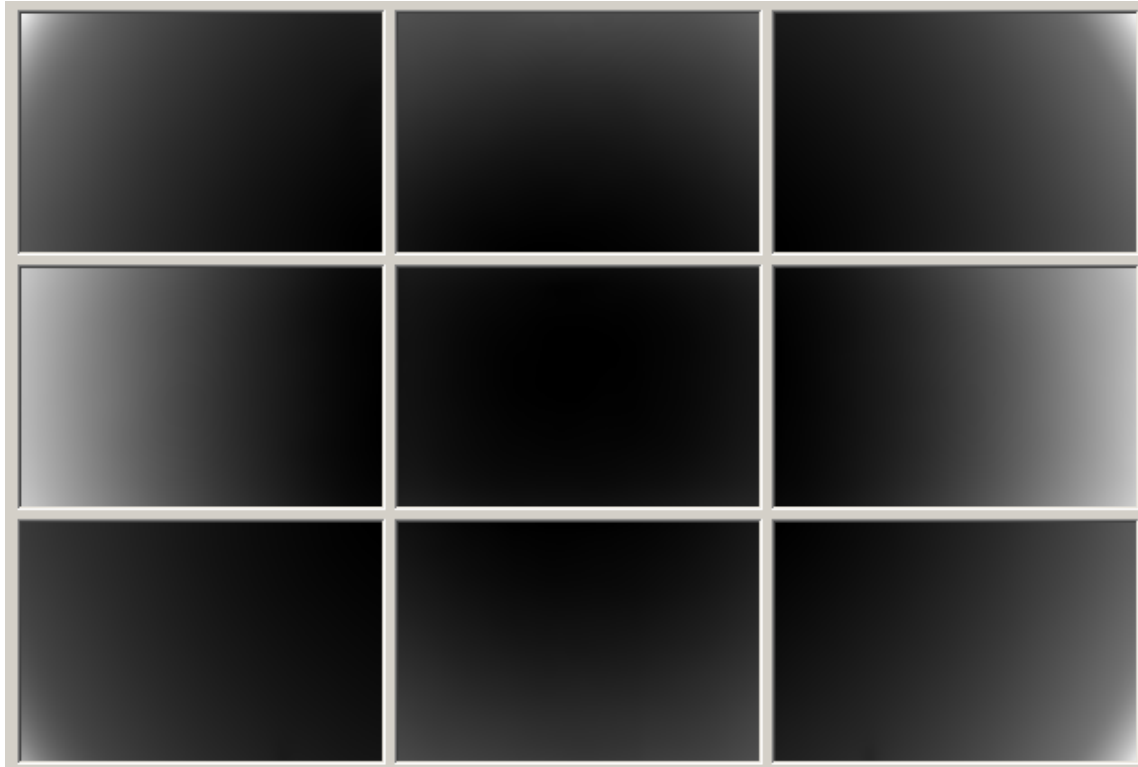
**Stepper Motor Position:** 1066h

### Overview of Individual Sensor Gain Values:

Cone_Sensor	Aperture	Minimum Gain $\geq$	Maximum Gain $\leq$
00_00	f / 16	1.00	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	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

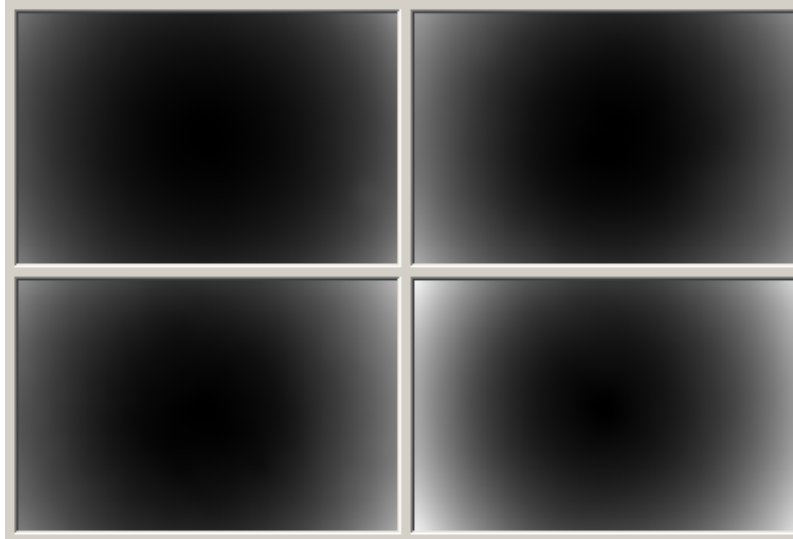
### Graphical Overview of Pan Sensor Gain Values:



<b>00_00</b>	<b>01_00</b>	<b>00_01</b>
<b>02_00</b>	<b>03_00</b>	<b>02_01</b>
<b>00_02</b>	<b>01_01</b>	<b>00_03</b>

## Calibration of Vignetting for Aperture Setting 4

### Graphical Overview of Multispectral Sensor Gain Values:



<b>04_00</b> <b>(red)</b>	<b>06_00</b> <b>(blue)</b>
<b>05_00</b> <b>(green)</b>	<b>07_00</b> <b>(NIR)</b>

## 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

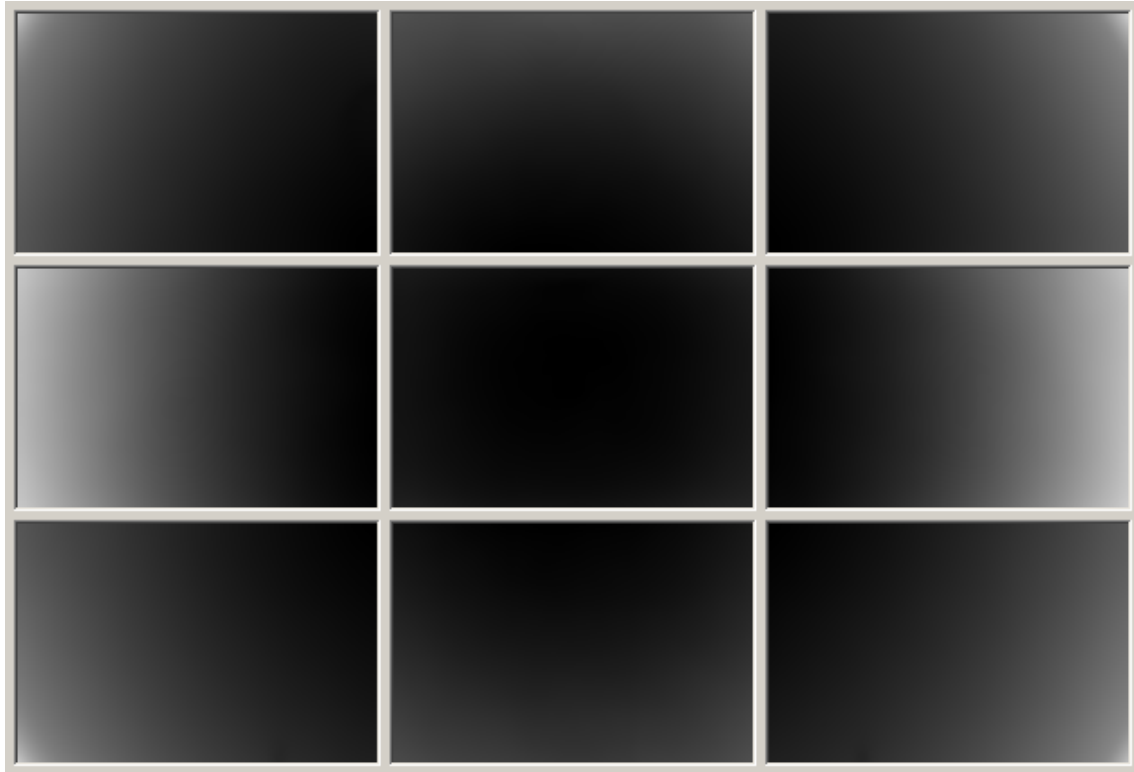
### Overview of Individual Sensor Gain Values:

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

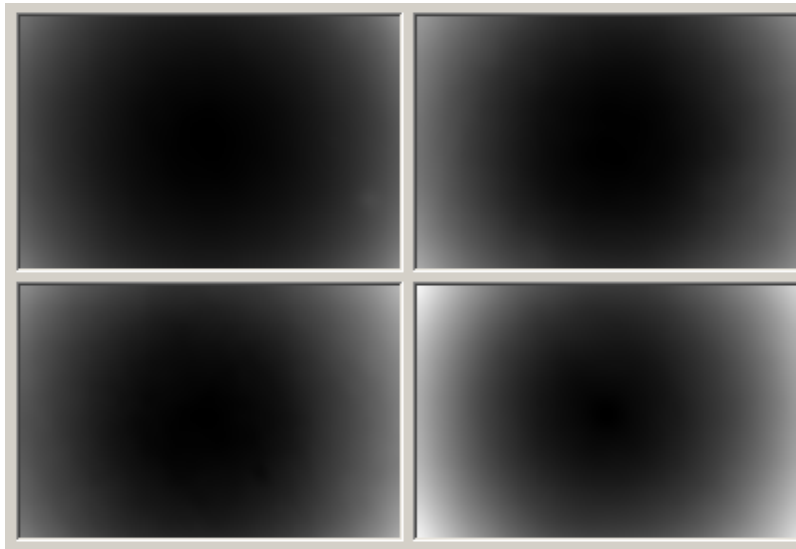
### Graphical Overview of Pan Sensor Gain Values:



<b>00_00</b>	<b>01_00</b>	<b>00_01</b>
<b>02_00</b>	<b>03_00</b>	<b>02_01</b>
<b>00_02</b>	<b>01_01</b>	<b>00_03</b>

## Calibration of Vignetting for Aperture Setting 5

### Graphical Overview of Multispectral Sensor Gain Values:



<b>04_00</b> <b>(red)</b>	<b>06_00</b> <b>(blue)</b>
<b>05_00</b> <b>(green)</b>	<b>07_00</b> <b>(NIR)</b>



### Defective Pixel Report:

Sensor		
Anomaly Type	X	Y

#### 00\_00

PIXEL	2764	1199	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	1406	797	0
PIXEL	2908	2482	0
PIXEL	2914	2483	0
PIXEL	3333	362	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	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	1520	0
PIXEL	978	1519	0
PIXEL	979	1519	0
PIXEL	1772	2331	0
PIXEL	1773	2332	0
PIXEL	2773	1274	0
PIXEL	2774	1275	0
PIXEL	2886	2641	0



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

### 00\_02

COLUMN	724	135	0
COLUMN	1279	1904	0
COLUMN	2363	2177	0
COLUMN	2364	2180	0
PIXEL	2770	495	0
PIXEL	3938	2271	0
PIXEL	3993	111	0
PIXEL	724	133	0
PIXEL	1279	1904	0
PIXEL	1580	671	0

### 00\_03

COLUMN	3713	2462	0
COLUMN	3714	2463	0
PIXEL	2722	1263	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	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	475	538	0
PIXEL	3369	2583	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	3586	1681	0
PIXEL	3613	90	0
PIXEL	3963	1877	0

### 01\_01

PIXEL	165	2612	0
PIXEL	1654	608	0
PIXEL	1979	503	0
PIXEL	2512	1461	0
PIXEL	54	52	0
PIXEL	55	52	0
PIXEL	113	162	0
PIXEL	1462	844	0
PIXEL	3233	878	0
PIXEL	3748	1896	0

### 02\_00

PIXEL	48	2665	0
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## UltraCam D, Serial Number UCD-SU-1-0039

PIXEL	419	2440	0
PIXEL	455	2216	0
PIXEL	456	2215	0
PIXEL	456	2216	0
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	632	2384	0
PIXEL	2775	1381	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	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	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	2252	0
COLUMN	3302	2254	0
PIXEL	933	2446	0
PIXEL	1495	2665	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

( 53 of 62 )



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

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	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	1117	1626	0
PIXEL	1181	880	0
PIXEL	1444	2651	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
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
COLUMN	262	1738	0
COLUMN	1902	1705	0
PIXEL	1756	1318	0
PIXEL	2278	2274	0
PIXEL	3197	1953	0
PIXEL	196	2445	0
PIXEL	197	2446	0
PIXEL	198	2445	0
PIXEL	231	2280	0
PIXEL	261	1737	0
PIXEL	353	665	0
PIXEL	1049	42	0
PIXEL	1401	891	0

( 54 of 62 )



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

PIXEL	1402	891	0
PIXEL	2079	1753	0
PIXEL	2463	1130	0
PIXEL	3615	1666	0

### 06\_00

COLUMN	2623	1604	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	898	937	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	1310	0
PIXEL	1787	1309	0
PIXEL	2120	2438	0
PIXEL	2623	1604	0
PIXEL	3540	2429	0
PIXEL	3900	1912	0

### 07\_00

PIXEL	3706	814	0
PIXEL	44	1003	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



<b>Camera:</b>	<b>UltraCam D, S/N UCD-SU-1-0039</b>
<b>Manufacturer:</b>	<b>Vexcel Imaging GmbH, A-8010 Graz, Austria</b>
<b>Panchromatic Camera:</b>	<b>4 * Prontor Magnetic 0 Prontor-Werk Alfred Gauthier GmbH, Germany</b>
<b>Multispectral Camera:</b>	<b>4 * Prontor Magnetic 0 Prontor-Werk Alfred Gauthier GmbH, Germany</b>
<b>Date of Calibration:</b>	<b>Mar-16-2006</b>
<b>Date of Report:</b>	<b>Mar-23-2006</b>
<b>Camera Revision:</b>	<b>1.0</b>
<b>Revision of Report:</b>	<b>1.0</b>

### 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	11.3	+/- 0.2
C1 (Pan 2CCD V)	11 80 80 00	11.2	+/- 0.2
C2 (Pan 2CCD H)	11 80 80 22	11.2	+/- 0.2
C3 (Pan Central)	11 80 79 26	12.1	+/- 0.2
C4 (Red)	11 79 77 26	12.4	+/- 0.2
C5 (Green)	11 76 32 80	11.4	+/- 0.2
C6 (Blue)	11 80 25 66	10.7	+/- 0.2
C7 (NIR)	11 80 25 68	11.0	+/- 0.2

# Calibration Report

## Electronics and Sensor Calibration



<b>Camera:</b>	<b>UltraCam D, S/N UCD-SU-1-0039</b>
<b>Manufacturer:</b>	<b>Vexcel Imaging GmbH, A-8010 Graz, Austria</b>
<b>Panchromatic Camera:</b>	<b>4 * FTF4027-M Area CCD Sensor by DALSA</b>
<b>Multispectral Camera:</b>	<b>4 * FTF4027-M Area CCD Sensor by DALSA</b>
<b>Date of Calibration:</b>	<b>Mar-16-2006</b>
<b>Date of Report:</b>	<b>Mar-23-2006</b>
<b>Camera Revision:</b>	<b>1.0</b>
<b>Revision of Report:</b>	<b>1.0</b>

### 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.

<b>Cone_Sensor</b>	<b>Sensor Type</b>	<b>Sensor Serial Number</b>	<b>Intensity Threshold [DN]</b>
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:** Mar-16-2006

**Date of Report:** Mar-23-2006


**Camera Revision:** 1.0

**Revision of Report:** 1.0

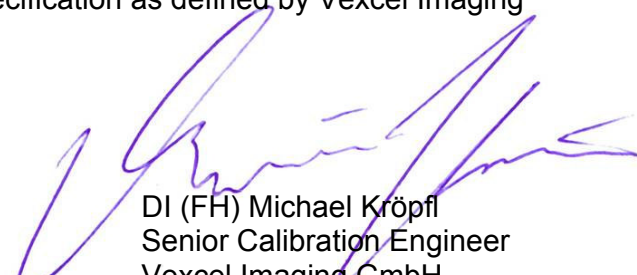
The following calibrations have been performed for the above mentioned digital aerial mapping camera:

- 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