

Calibration Report



| | |
|-----------------------------|--|
| Camera: | UltraCam Eagle, S/N UC-Eagle-1-60914437-f80 |
| Manufacturer: | Vexcel Imaging GmbH, A-8010 Graz, Austria |
| Date of Calibration: | Apr-28-2015 |
| Date of Report: | May-06-2015 |
| Revision of Camera: | Rev01.00 |
| Version of Report: | V01 |

Calibration Report

Geometric Calibration



Camera: UltraCam Eagle, S/N UC-Eagle-1-60914437-f80

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

Panchromatic Camera: ck = 79.800 mm

Multispectral Camera: ck = 79.800 mm

Date of Calibration: Apr-28-2015
Date of Report: May-06-2015
Revision of Camera: Rev01.00
Version of Report: V01

Panchromatic Camera

Large Format Panchromatic Output Image

| | | | |
|----------------------------------|--|--------------------|------------------|
| Image Format | long track | 68.016mm | 13080pixel |
| | cross track | 104.052mm | 20010pixel |
| Image Extent | | (-34.01, -52.02)mm | (34.01, 52.02)mm |
| Pixel Size | | 5.200µm*5.200µm | |
| Focal Length | ck | 79.800 mm | ± 0.002mm |
| Principal Point (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 | | |

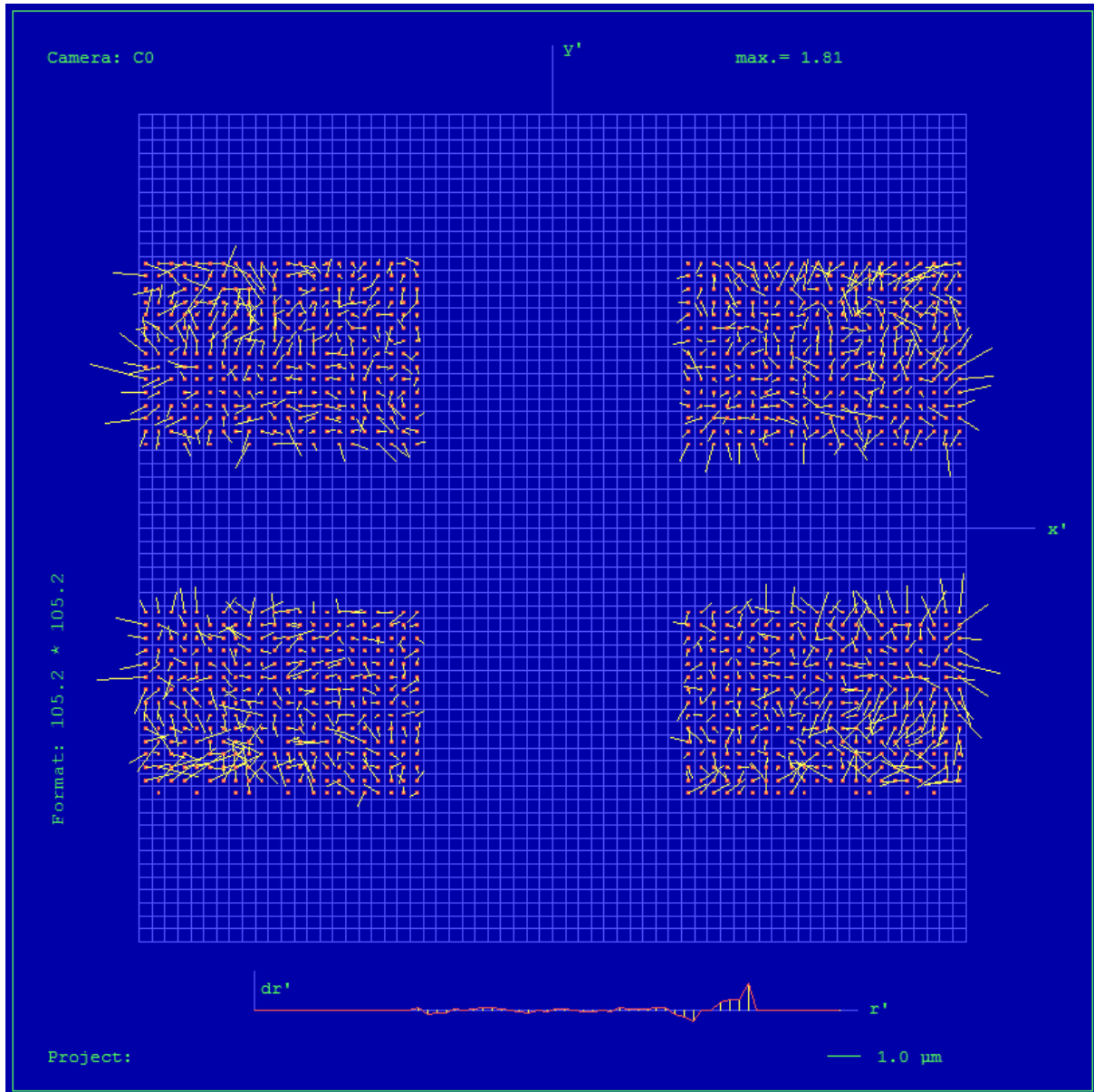
Individual Panchromatic Cone Data

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 | Shift Y | Rotation | Scale | | | | | | | | | |
| CCD0 | 4,4748498E-02 mm ± 0.0007 mm | 8,6635345E-02 mm ± 0.0011 mm | -9,4416952E-02 gon ± 0.0001 gon | 1,0081604 ± 0.00005 | | | | | | | | | |
| CCD1 | 4,3053873E-02 mm ± 0.0007 mm | 3,0633296E-02 mm ± 0.0011 mm | 0.00000000 gon | 1,0079323 ± 0.00005 | | | | | | | | | |
| CCD2 | -4,2477580E-02 mm ± 0.0007 mm | 1,3343682E-01 mm ± 0.0011 mm | -9,9524461E-02 gon ± 0.0001 gon | 1,0078809 ± 0.00005 | | | | | | | | | |
| CCD3 | 1,4747530E-02 mm ± 0.0007 mm | -6,5866981E-03 mm ± 0.0011 mm | -3,9575583E-02 gon ± 0.0001 gon | 1,0076740 ± 0.00005 | | | | | | | | | |
| Radial Distortion | | | | | | | | | | | | | |
| R [mm] | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 | 30.0 | 35.0 | 40.0 | 45.0 | 50.0 | 55.0 | 60.0 | 65.0 |
| dr [µm] | 36.4 | 71.2 | 106.0 | 139.7 | 169.4 | 189.4 | 191.8 | 166.4 | 100.6 | -20.5 | -214.2 | -500.1 | -900.2 |

UltraCamEagle, Serial Number UC-Eagle-1-60814437-f80

Cone 0, Residual Error Diagram



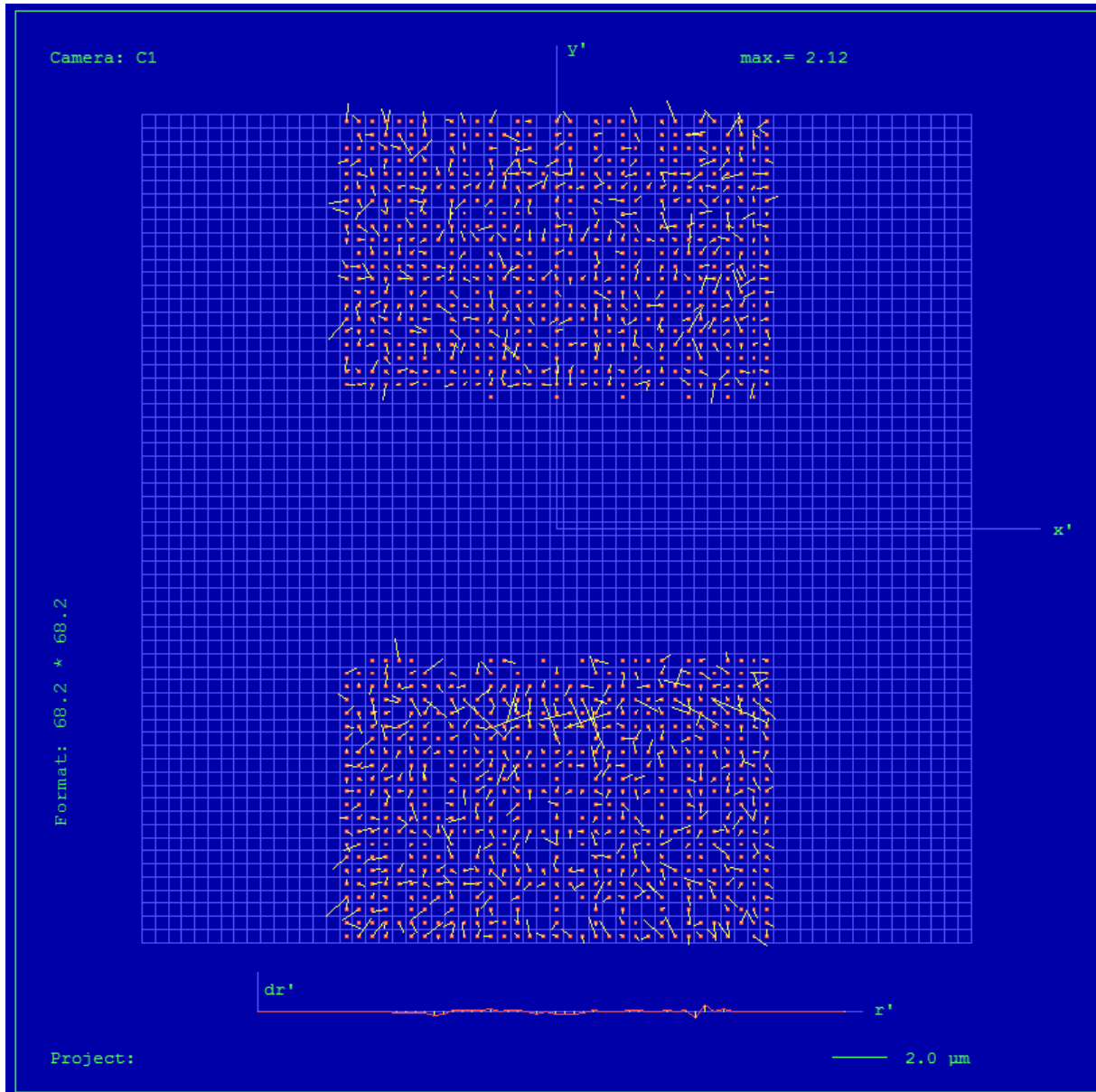
Residual Error (RMS): **1.36 μm**

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 | | 1,6375221E-01 mm ± 0.0011 mm | | | 9,2043015E-03 mm ± 0.0008 mm | | | 0.00000000 gon | | | 0,9998927 ± 0.00005 | |
| CCD1 | | 1,0139878E-01 mm ± 0.0011 mm | | | -3,7529467E-02 mm ± 0.0008 mm | | | 8,3065835E-03 gon ±0.0001 gon | | | 0,9999194 ± 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] | 10.3 | 17.5 | 24.2 | 30.1 | 32.8 | 26.9 | 4.6 | -44.3 | -132.8 | -276.4 | -493.1 | -803.5 |

UltraCamEagle, Serial Number UC-Eagle-1-60814437-f80

Cone 1, Residual Error Diagram

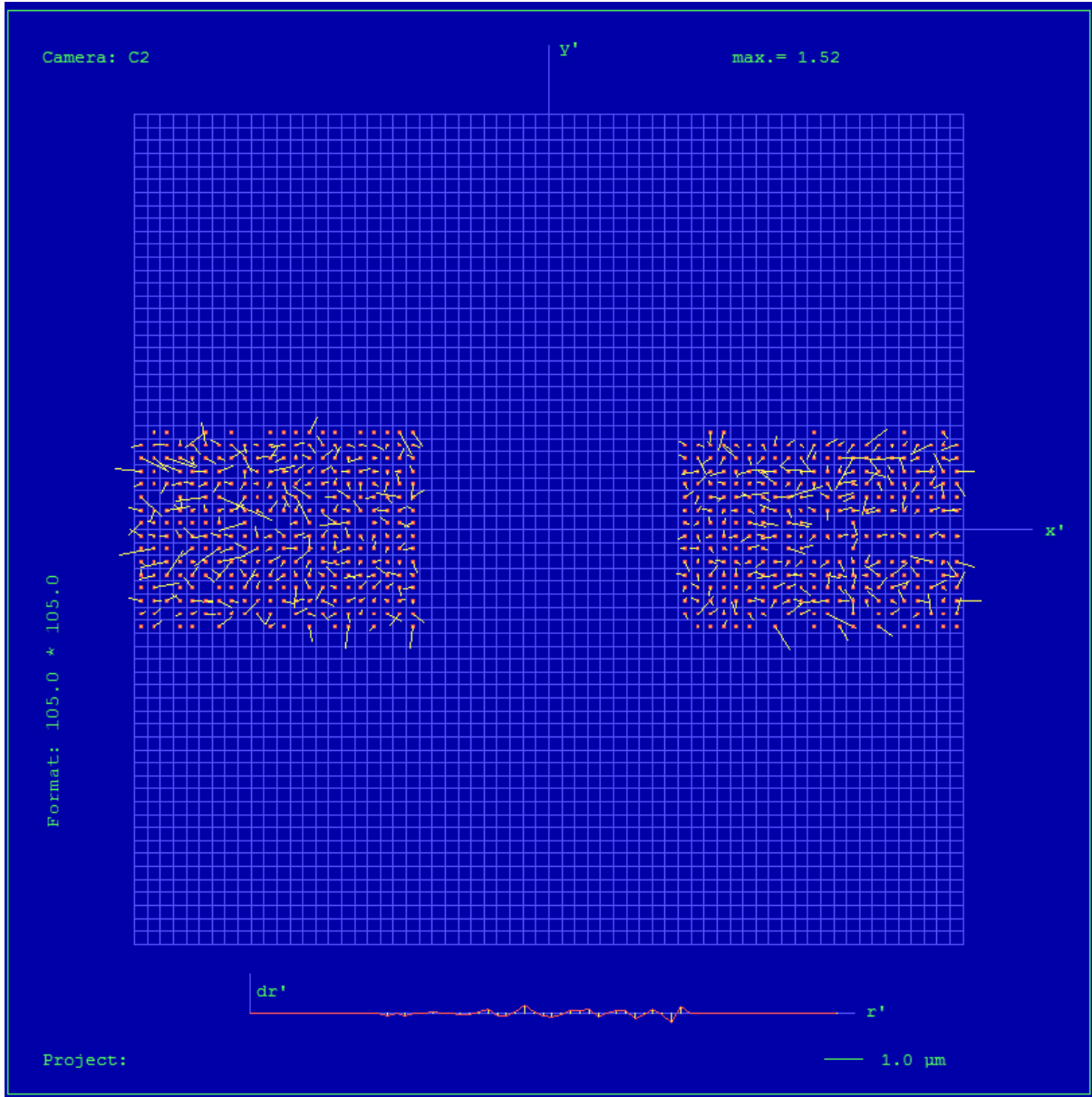


Residual Error (RMS): 1.12 μm

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 | 3,6808866E-02 mm ± 0.0006 mm | 2,3051067E-03 mm ± 0.0028 mm | 7,7167802E-02 gon ± 0.0001 gon | 1,0070711 ± 0.00005 | | | | | | | | |
| CCD1 | 9,0279882E-02 mm ± 0.0006 mm | -2,5680022E-02 mm ± 0.0028 mm | 0.00000000 gon | 1,0072424 ± 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] | 37.4 | 71.5 | 104.4 | 135.7 | 162.7 | 180.0 | 179.9 | 152.2 | 84.0 | -39.7 | -236.6 | -526.9 |

Cone 2, Residual Error Diagram

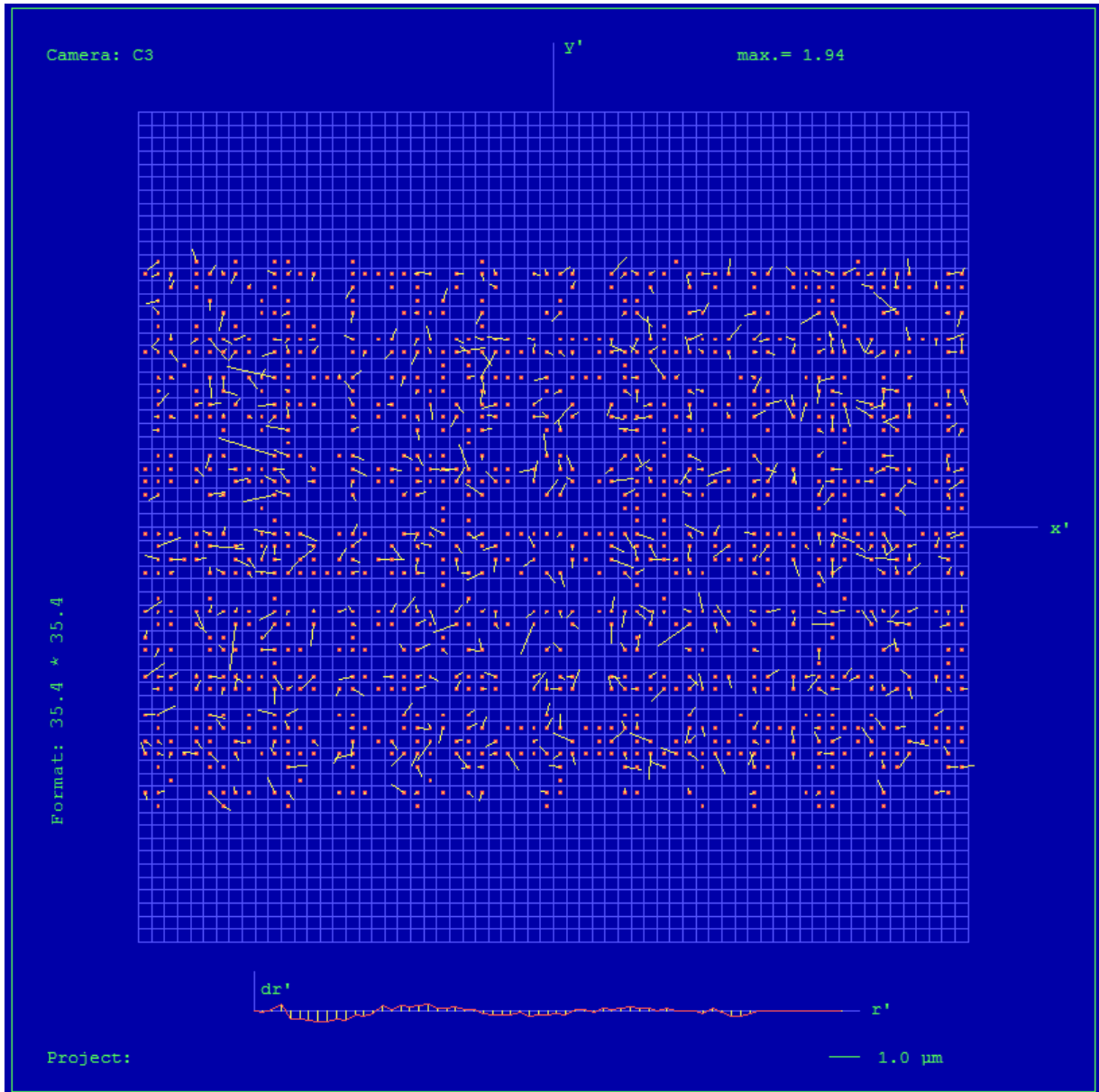


Residual Error (RMS): 1.04 µm

Cone 3, Parametric Description, Not Effective in Output Image

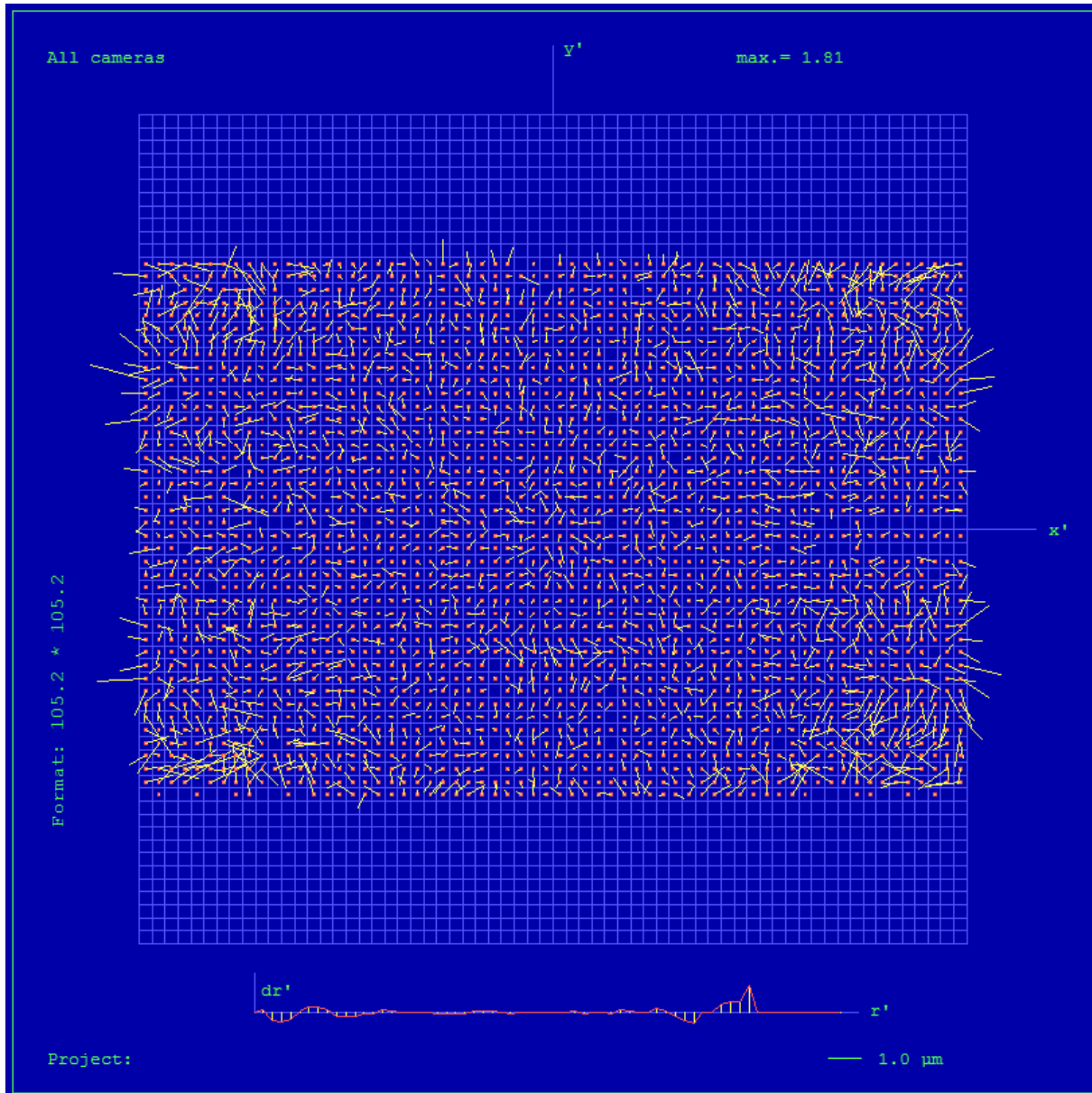
| Cone # C3 | | | | | |
|---------------------------------|---|----------------------------------|--------------------|------------------------|-------|
| Lens | Linos Vexcel Apo-Sironar Digital HR 1:5,6/80mm Linos GmbH, Germany | | | | |
| Shutter | Prontor Magnetic Prontor-Werk Alfred Gauthier GmbH | | | | |
| 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 | 4,0988308E-02 mm ± 0.0015 mm | -3,2531912E-03 mm ± 0.0037 mm | 0.00000000 gon | 1,0005120 ± 0.00005 | |
| Radial Distortion | | | | | |
| R [mm] | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 |
| dr [µm] | -0.8 | -1.8 | -2.8 | -5.5 | -14.1 |

Cone 3, Residual Error Diagram



Residual Error (RMS): **0.63 μm**

Full Pan Image, Residual Error Diagram



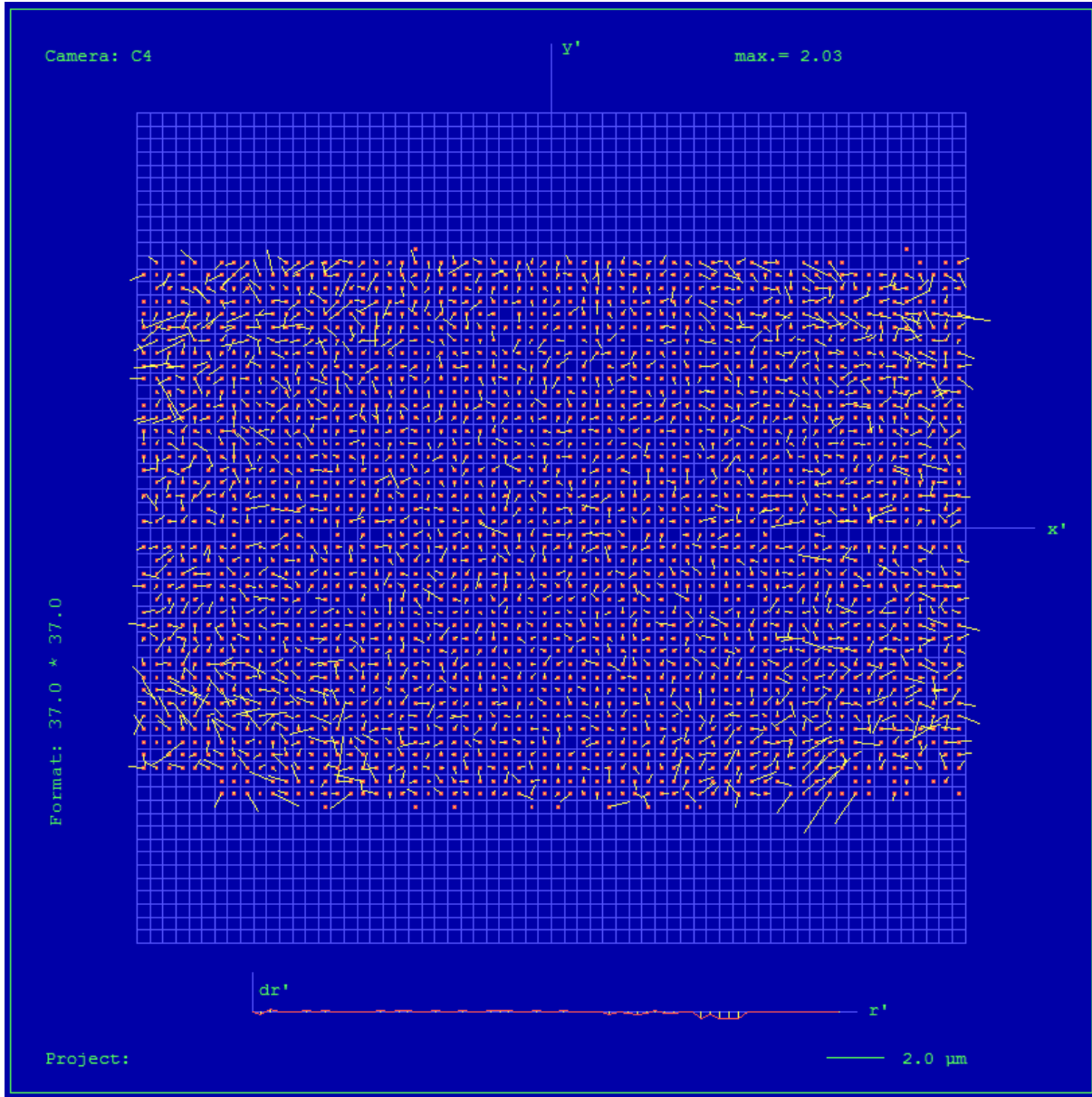
Residual Error (RMS): 0.98 μm

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 | 6,8722144E-02 mm ± 0.0001 mm | -7,5202184E-03 mm ± 0.0001 mm | 0.00000000 gon | 1,0553845 ± 0.00005 | |
| Radial Distortion | | | | | |
| R [mm] | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 |
| dr [µm] | 117.6 | 181.4 | 169.5 | 114.4 | 119.9 |

Cone 4, Residual Error Diagram



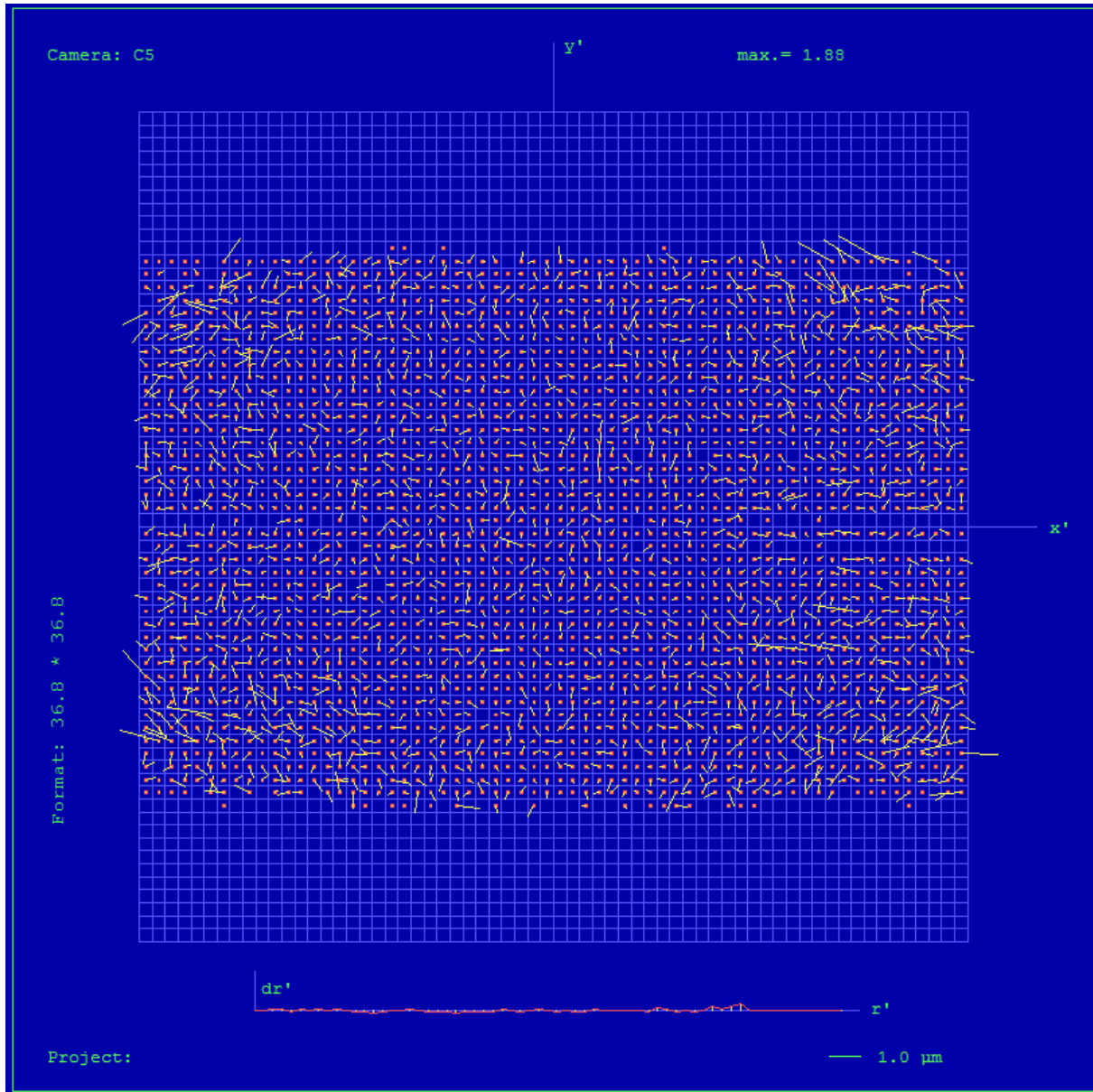
Residual Error (RMS): 0.84 μm

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 | 4,8672601E-05 mm ± 0.0001 mm | -3,2853448E-02 mm ± 0.0001 mm | 0.0000000 gon | 1,0511745 ± 0.00005 | |
| Radial Distortion | | | | | |
| R [mm] | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 |
| dr [µm] | 115.2 | 177.5 | 166.8 | 113.7 | 105.4 |

UltraCamEagle, Serial Number UC-Eagle-1-60814437-f80

Cone 5, Residual Error Diagram



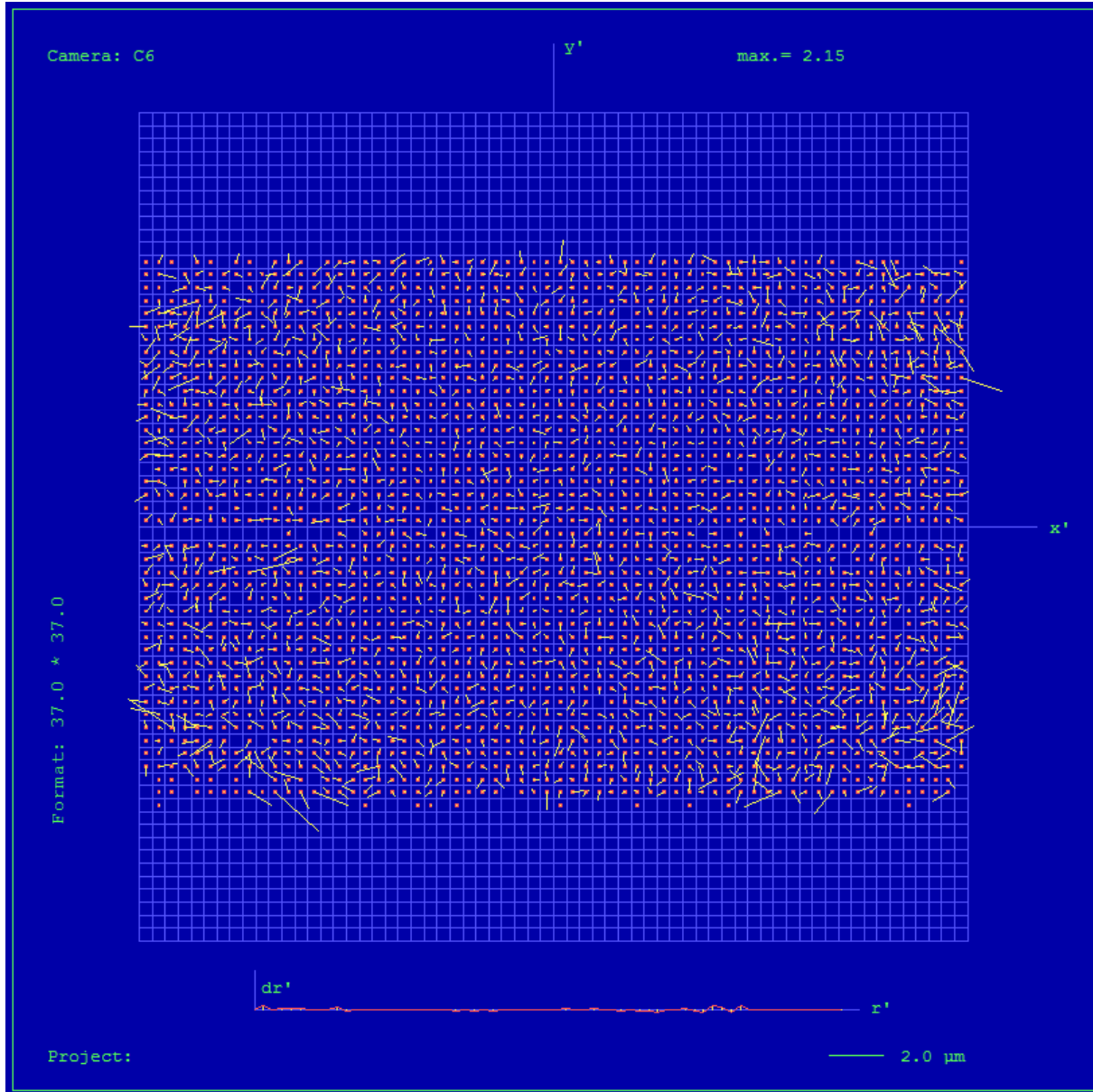
Residual Error (RMS): 0.83 μm

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 | 4,5521294E-02 mm ± 0.0001 mm | -1,3755387E-02 mm ± 0.0002 mm | 0.00000000 gon | 1,0551989 ± 0.00005 | |
| Radial Distortion | | | | | |
| R [mm] | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 |
| dr [µm] | 114.8 | 176.9 | 166.7 | 116.9 | 119.0 |

UltraCamEagle, Serial Number UC-Eagle-1-60814437-f80

Cone 6, Residual Error Diagram



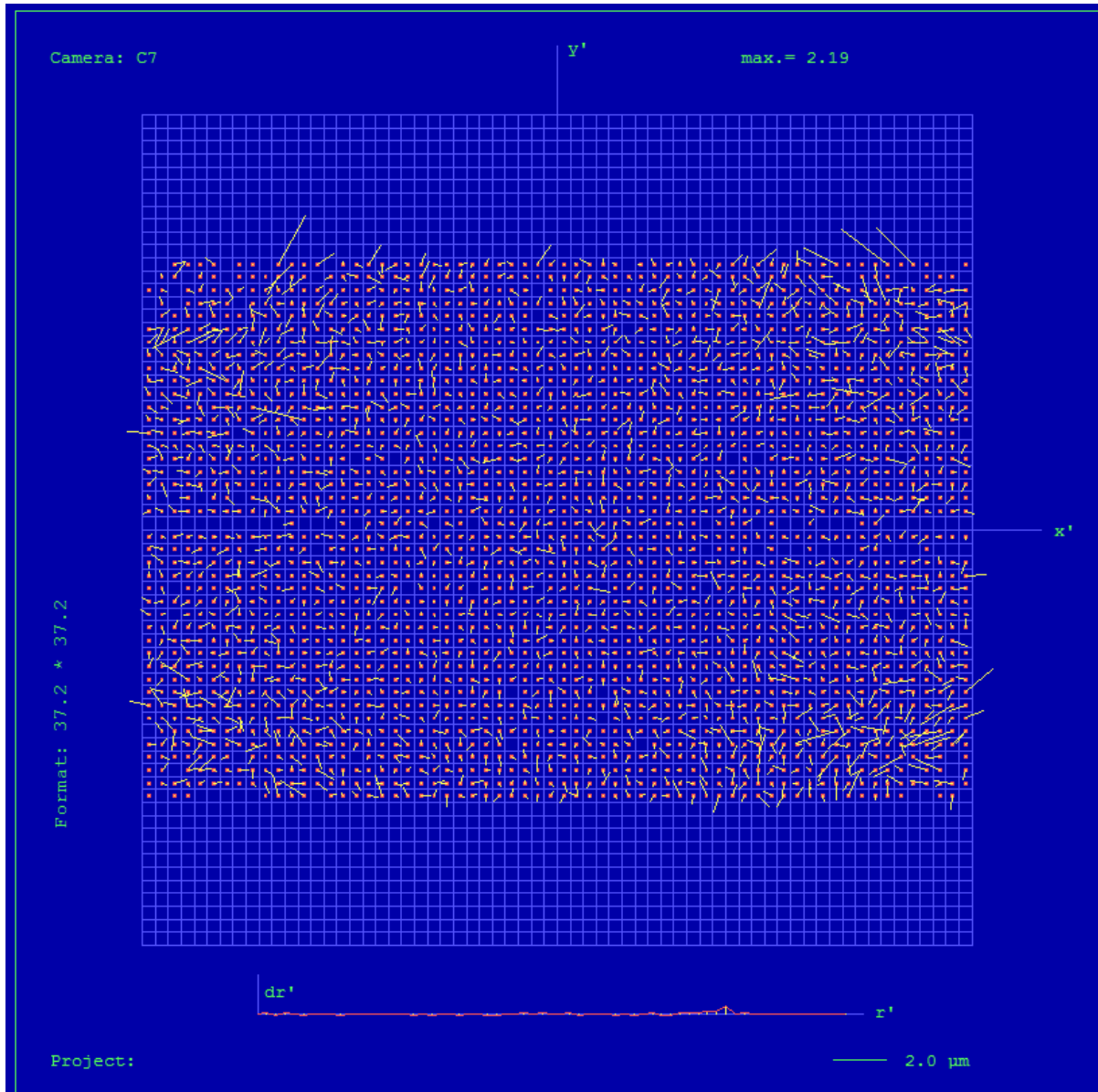
Residual Error (RMS): 0.85 μm

Cone 7, Parametric Description, Not Effective in Output Image

| Cone # C7 (NIR) | | | | | |
|---------------------------------|---|----------------------------------|--------------------|------------------------|-------|
| Lens | Linus Vexcel HR Digaron 1:4/27mm Linus 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 | 1,1802855E-01 mm ± 0.0001 mm | -3,1345627E-02 mm ± 0.0001 mm | 0.00000000 gon | 1,0561772 ± 0.00005 | |
| Radial Distortion | | | | | |
| R [mm] | 5.0 | 10.0 | 15.0 | 20.0 | 25.0 |
| dr [µm] | 118.6 | 160.1 | 186.4 | 145.3 | 101.1 |

UltraCamEagle, Serial Number UC-Eagle-1-60814437-f80

Cone 7, Residual Error Diagram



Residual Error (RMS): **0.85 μm**

Explanations:

1) Calibration Method:

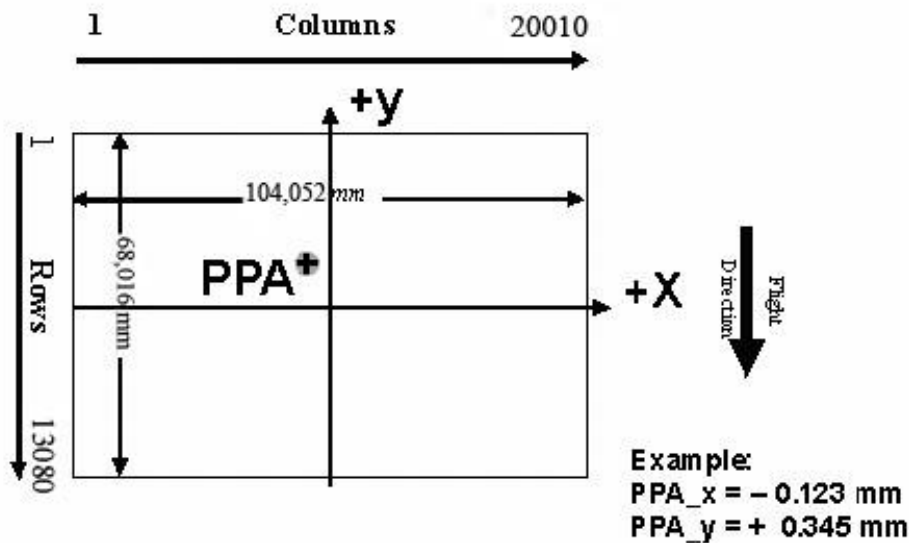
The geometric calibration is based on a set of 84 images of a defined geometry target with 394 GCPs.

Number of point measurements for the panchromatic camera : 19230
 Number of point measurements for the multispectral camera : 74330

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

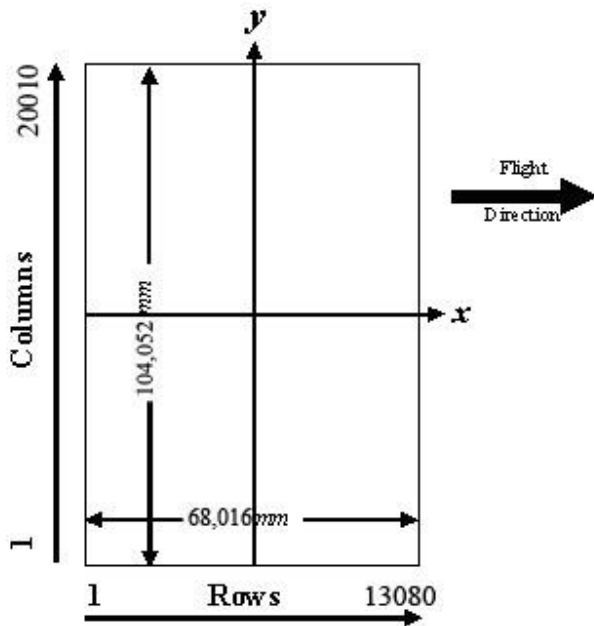
Lvl2, Camera prop. Orientation



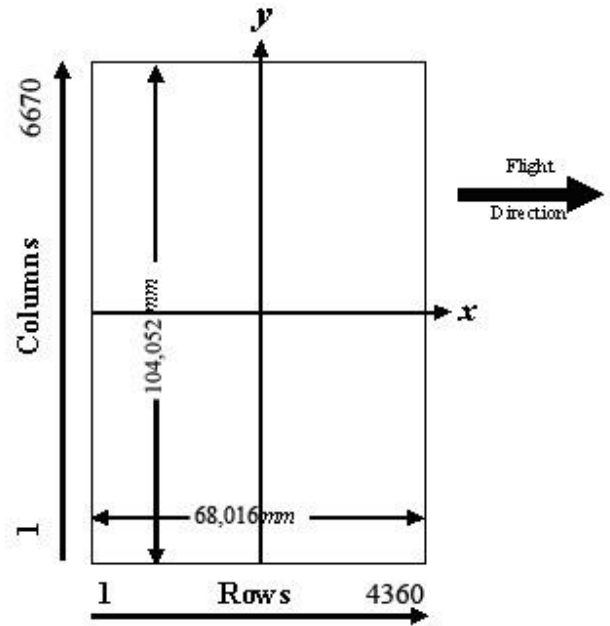
The image coordinate system of the Level 2 images is shown in the above figure. The level 2 image consists of 20010 columns and 13080 rows, which leads to a total image format of 104.052 x 68.016 mm. The coordinate of the principal point in the level 2 image is given on page 3 of this report. The above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

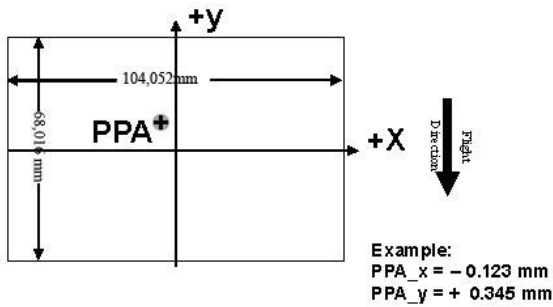
=====
4) Position of Principal Point in Level 3 Image

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.

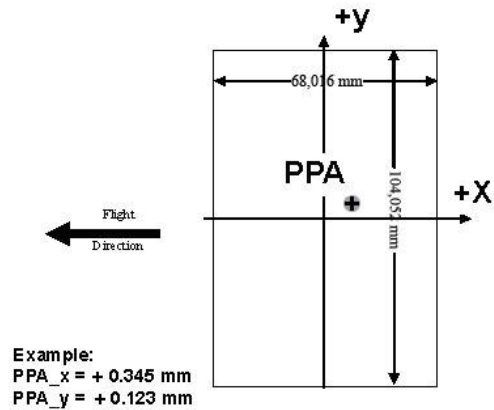
| Image Format | Clockwise Rotation (Degree) | PPA | |
|--------------|-----------------------------|-------|-------|
| | | X | Y |
| Level 2 | - | 0.000 | 0.000 |
| Level 3 | 0 | 0.000 | 0.000 |
| Level 3 | 90 | 0.000 | 0.000 |
| Level 3 | 180 | 0.000 | 0.000 |
| Level 3 | 270 | 0.000 | 0.000 |

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.

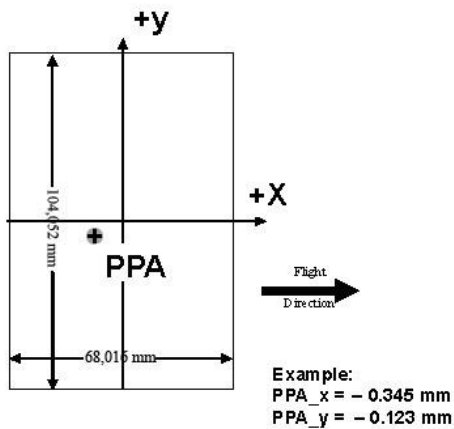
Lvl3, Rotation 0 deg clockwise



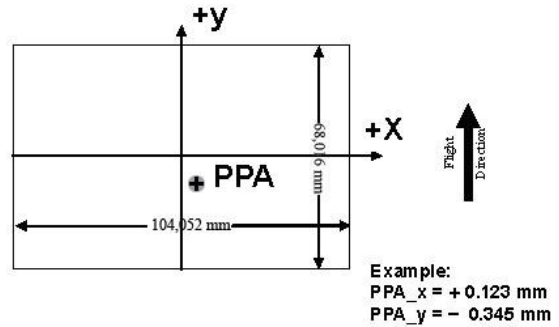
Lvl3, Rotation 90 deg clockwise



Lvl3, Rotation 270 deg clockwise



Lvl3, Rotation 180 deg clockwise



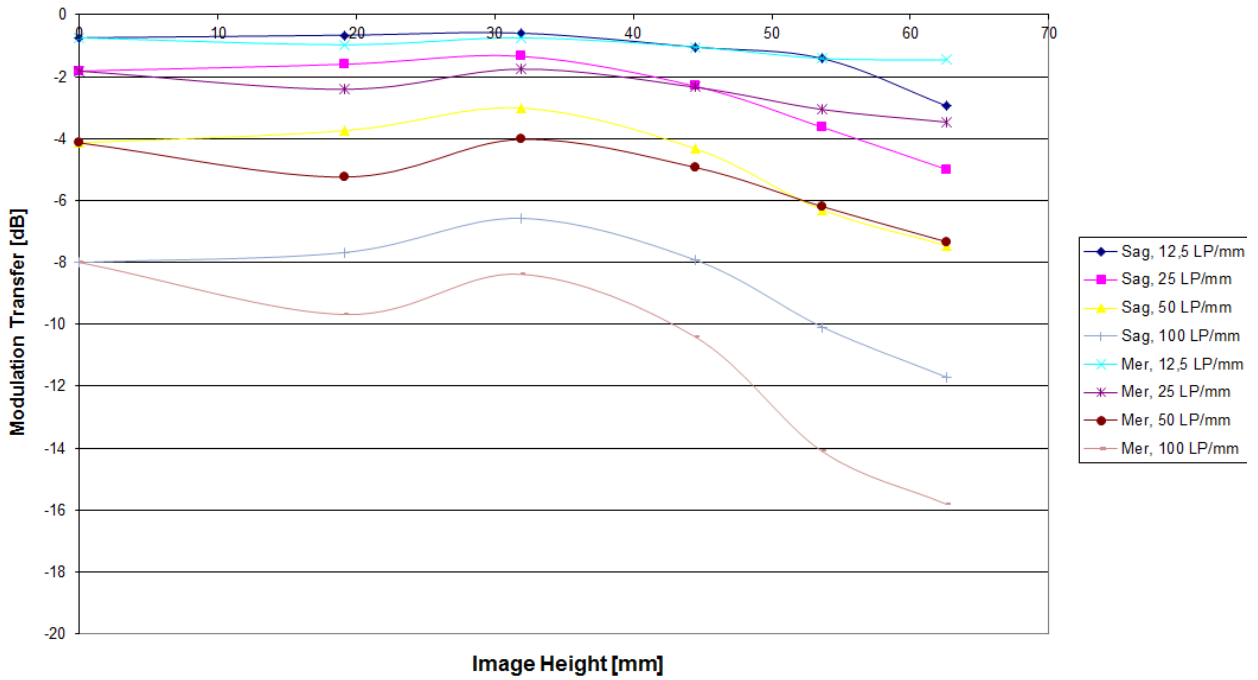
Lens Resolving Power

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).

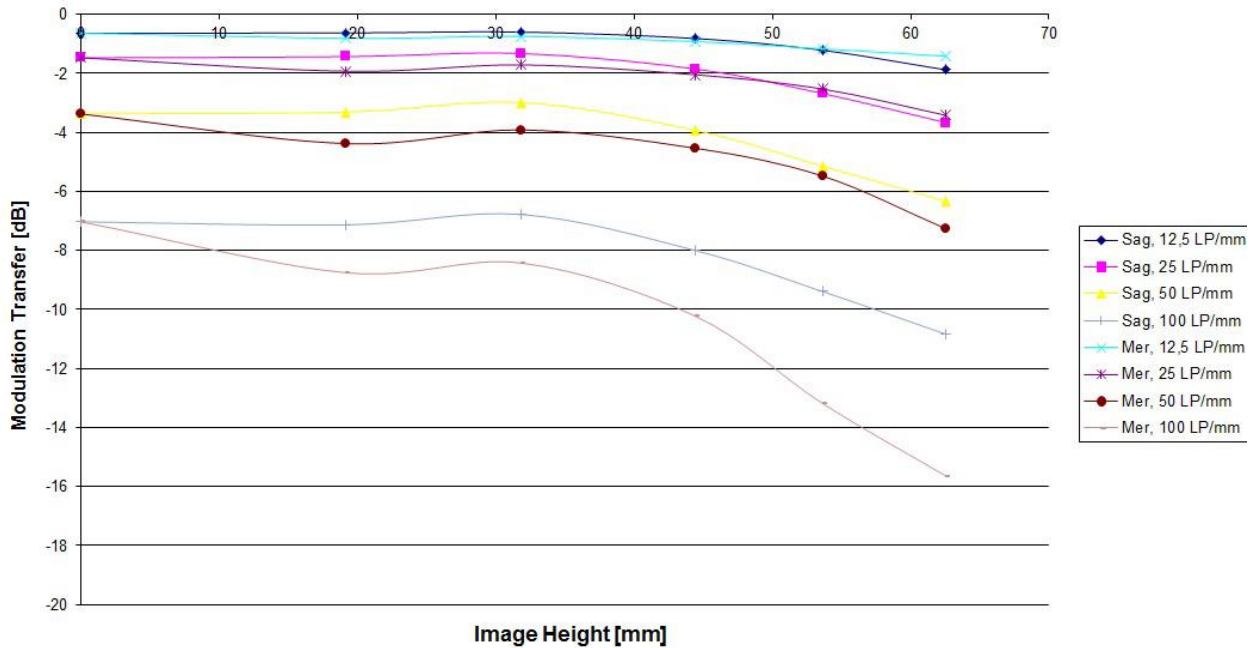
The curves are given for the meridional (tangential) and sagittal (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

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

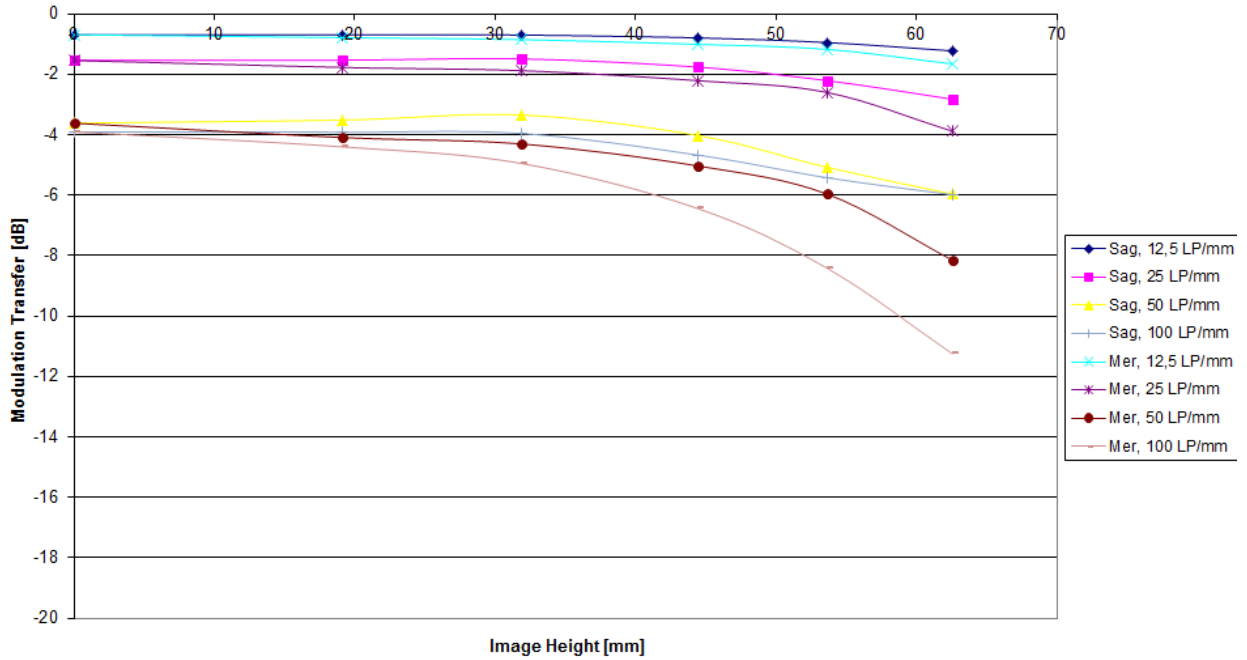
Modulation versus Image Height - Aperture f/ 5.6



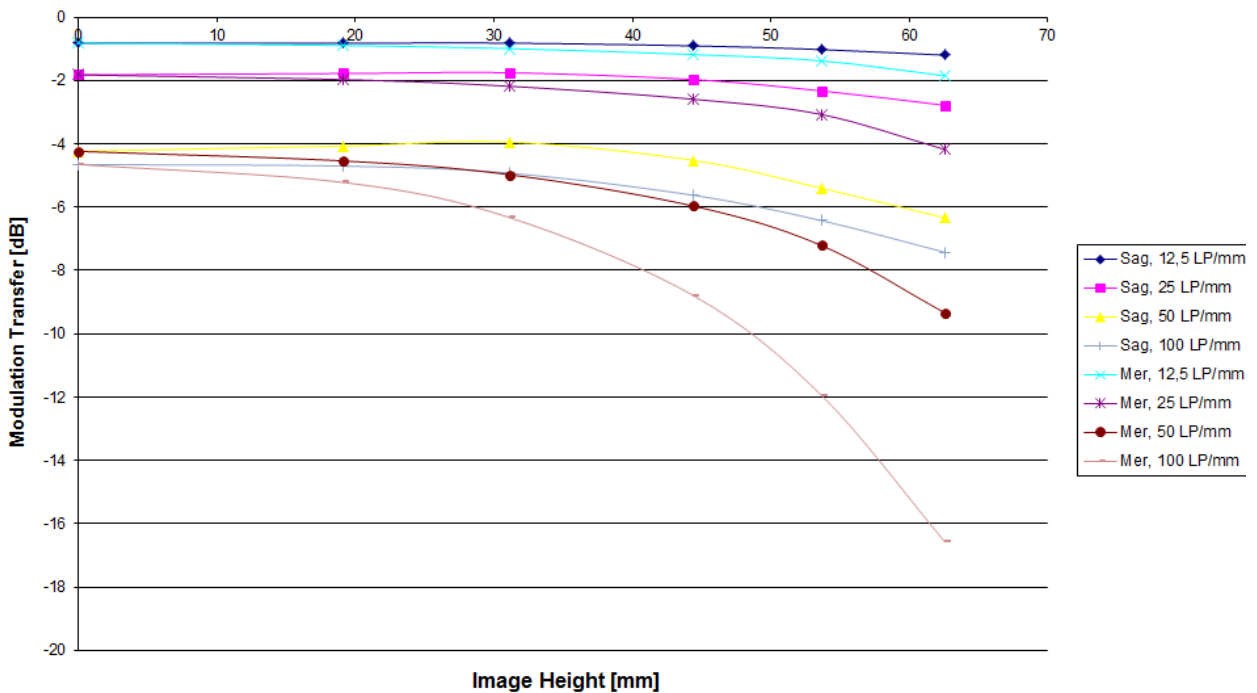
Modulation versus Image Height - Aperture f/ 6.7



Modulation versus Image Height - Aperture f / 8

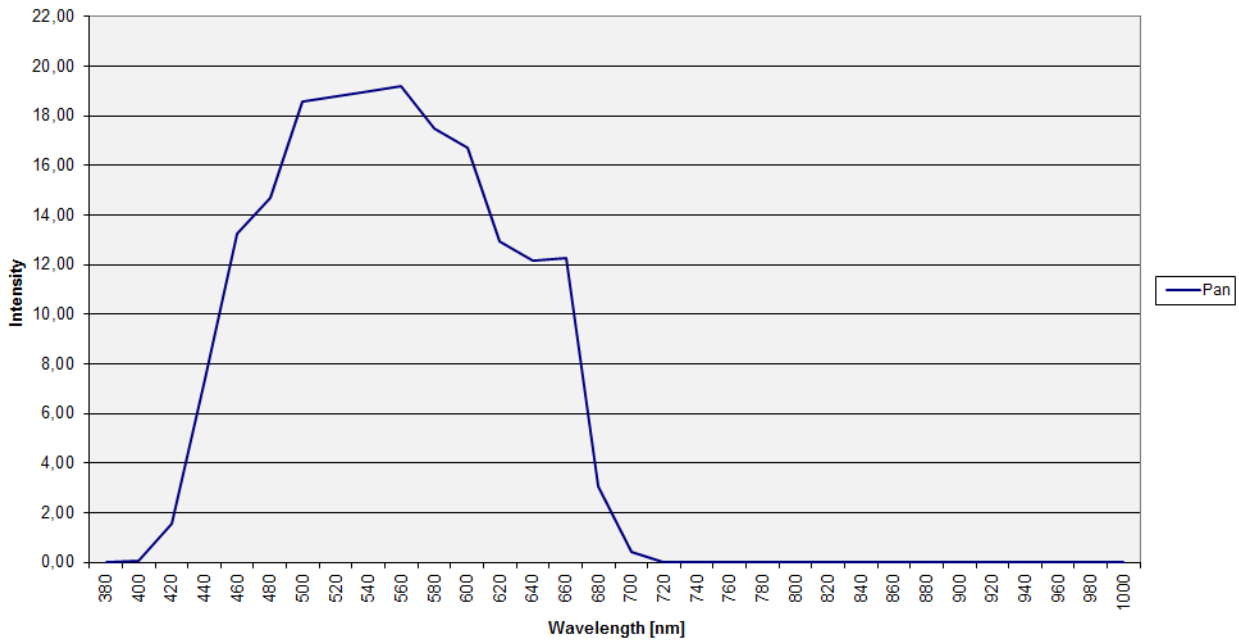


Modulation versus Image Height - Aperture f / 9.5

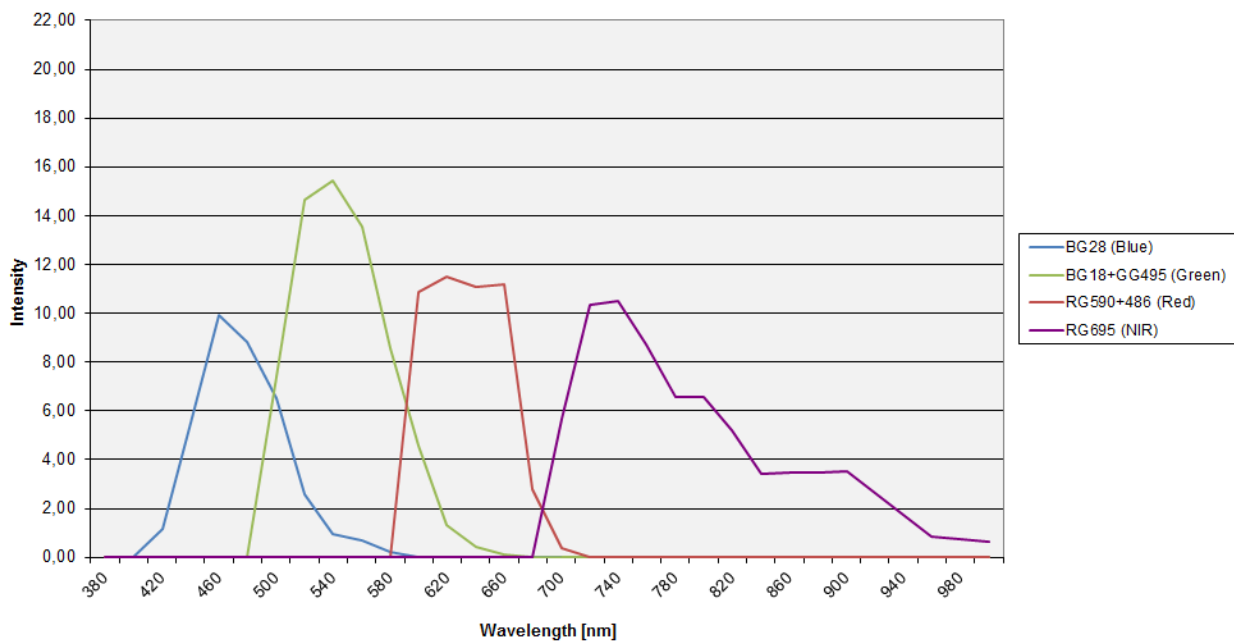


Spectral Sensitivity

Spectral Sensitivity Vexcel UltraCam Eagle - Panchromatic with AR-106 Coating



Spectral Sensitivity Vexcel UltraCam Eagle - Multispectral with AR-106 Coating



Calibration Report

Radiometric Calibration



Camera:

UltraCam Eagle, S/N UC-Eagle-1-60914437-f80

Manufacturer:

Vexcel Imaging GmbH, A-8010 Graz,
Austria

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

Date of Calibration:

Apr-28-2015

Date of Report:

May-06-2015

Revision of Camera:

Rev01.00

Version of Report:

V01

Calibration of Vignetting for Aperture Setting 1








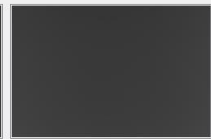

| | PAN | R, G, NIR | B |
|----------|------|-----------|------|
| Aperture | F5.6 | F8.0 | F5.6 |

Overview of Individual Sensor Gain Values:

| Cone_Sensor | Aperture | Minimum Gain \geq | Maximum Gain \leq |
|---------------|----------|------------------------|------------------------|
| 00_00 | f / 5.6 | 1.00 | 4,00 |
| 00_01 | f / 5.6 | 1.00 | 4,00 |
| 00_02 | f / 5.6 | 1.00 | 4,00 |
| 00_03 | f / 5.6 | 1.00 | 4,00 |
| 01_00 | f / 5.6 | 1.00 | 2,00 |
| 01_01 | f / 5.6 | 1.00 | 2,00 |
| 02_00 | f / 5.6 | 1.00 | 3,00 |
| 02_01 | f / 5.6 | 1.00 | 3,00 |
| 03_00 | f / 5.6 | 1.00 | 2,00 |
| 04_00 (red) | f / 8 | 1.00 | 5,00 |
| 05_00 (green) | f / 8 | 1.00 | 3,00 |
| 06_00 (blue) | f / 5.6 | 1.00 | 3,00 |
| 07_00 (NIR) | f / 8 | 1.00 | 4,00 |

Calibration of Vignetting for Aperture Setting 1

Graphical Overview of Pan Sensor Gain Values:

| | | |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

Graphical Overview of Multispectral Sensor Gain Values:

| | |
|---|---|
|  |  |
|  |  |

Calibration of Vignetting for Aperture Setting 2







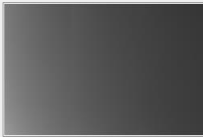
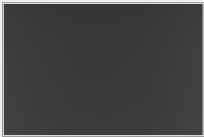
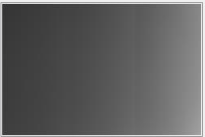
| | | | |
|----------|------------|------------------|----------|
| | PAN | R, G, NIR | B |
| Aperture | F6.7 | F9.3 | F6.7 |

Overview of Individual Sensor Gain Values:

| Cone_Sensor | Aperture | Minimum Gain ≥ | Maximum Gain ≤ |
|---------------|----------|-------------------|-------------------|
| 00_00 | f / 6.5 | 1.00 | 3,00 |
| 00_01 | f / 6.5 | 1.00 | 4,00 |
| 00_02 | f / 6.5 | 1.00 | 3,00 |
| 00_03 | f / 6.5 | 1.00 | 4,00 |
| 01_00 | f / 6.5 | 1.00 | 2,00 |
| 01_01 | f / 6.5 | 1.00 | 2,00 |
| 02_00 | f / 6.5 | 1.00 | 3,00 |
| 02_01 | f / 6.5 | 1.00 | 3,00 |
| 03_00 | f / 6.5 | 1.00 | 2,00 |
| 04_00 (red) | f / 9.3 | 1.00 | 5,00 |
| 05_00 (green) | f / 9.3 | 1.00 | 3,00 |
| 06_00 (blue) | f / 6.5 | 1.00 | 3,00 |
| 07_00 (NIR) | f / 9.3 | 1.00 | 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




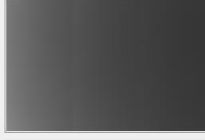
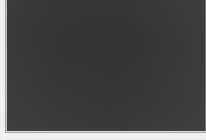
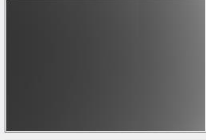
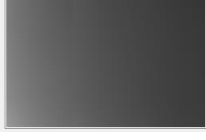
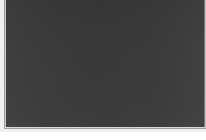
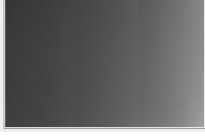
| | PAN | R, G, NIR | B |
|----------|-----|-----------|----|
| Aperture | F8 | F11 | F8 |

Overview of Individual Sensor Gain Values:

| Cone_Sensor | Aperture | Minimum Gain \geq | Maximum Gain \leq |
|---------------|----------|------------------------|------------------------|
| 00_00 | f / 8 | 1.00 | 3,00 |
| 00_01 | f / 8 | 1.00 | 4,00 |
| 00_02 | f / 8 | 1.00 | 3,00 |
| 00_03 | f / 8 | 1.00 | 4,00 |
| 01_00 | f / 8 | 1.00 | 2,00 |
| 01_01 | f / 8 | 1.00 | 2,00 |
| 02_00 | f / 8 | 1.00 | 3,00 |
| 02_01 | f / 8 | 1.00 | 3,00 |
| 03_00 | f / 8 | 1.00 | 2,00 |
| 04_00 (red) | f / 11 | 1.00 | 5,00 |
| 05_00 (green) | f / 11 | 1.00 | 3,00 |
| 06_00 (blue) | f / 8 | 1.00 | 3,00 |
| 07_00 (NIR) | f / 11 | 1.00 | 3,00 |

Calibration of Vignetting for Aperture Setting 3

Graphical Overview of Pan Sensor Gain Values:

| | | |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

Graphical Overview of Multispectral Sensor Gain Values:

| | |
|---|---|
|  |  |
|  |  |

Calibration of Vignetting for Aperture Setting 4





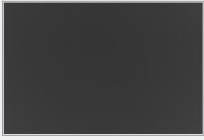

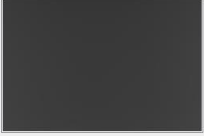
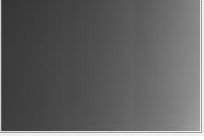
| | PAN | R, G, NIR | B |
|----------|------|-----------|------|
| Aperture | F9.5 | F13 | F9.5 |

Overview of Individual Sensor Gain Values:

| Cone_Sensor | Aperture | Minimum Gain \geq | Maximum Gain \leq |
|---------------|----------|------------------------|------------------------|
| 00_00 | f / 9.5 | 1.00 | 3,00 |
| 00_01 | f / 9.5 | 1.00 | 4,00 |
| 00_02 | f / 9.5 | 1.00 | 3,00 |
| 00_03 | f / 9.5 | 1.00 | 4,00 |
| 01_00 | f / 9.5 | 1.00 | 2,00 |
| 01_01 | f / 9.5 | 1.00 | 2,00 |
| 02_00 | f / 9.5 | 1.00 | 3,00 |
| 02_01 | f / 9.5 | 1.00 | 3,00 |
| 03_00 | f / 9.5 | 1.00 | 2,00 |
| 04_00 (red) | f / 13 | 1.00 | 5,00 |
| 05_00 (green) | f / 13 | 1.00 | 3,00 |
| 06_00 (blue) | f / 9.5 | 1.00 | 3,00 |
| 07_00 (NIR) | f / 13 | 1.00 | 3,00 |

Calibration of Vignetting for Aperture Setting 4

Graphical Overview of Pan Sensor Gain Values:

| | | |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

Graphical Overview of Multispectral Sensor Gain Values:

| | |
|---|---|
|  |  |
|  |  |

Calibration of Vignetting for Aperture Setting 5



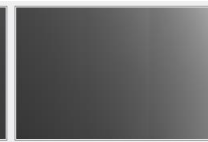
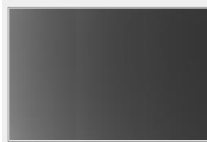
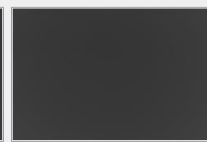
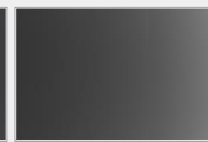

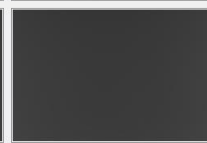

| | | | |
|----------|------------|------------------|----------|
| | PAN | R, G, NIR | B |
| Aperture | F11 | F16 | F11 |

Overview of Individual Sensor Gain Values:

| Cone_Sensor | Aperture | Minimum Gain ≥ | Maximum Gain ≤ |
|---------------|----------|-------------------|-------------------|
| 00_00 | f / 11 | 1.00 | 3,00 |
| 00_01 | f / 11 | 1.00 | 4,00 |
| 00_02 | f / 11 | 1.00 | 3,00 |
| 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 | 3,00 |
| 02_01 | f / 11 | 1.00 | 3,00 |
| 03_00 | f / 11 | 1.00 | 2,00 |
| 04_00 (red) | f / 16 | 1.00 | 5,00 |
| 05_00 (green) | f / 16 | 1.00 | 3,00 |
| 06_00 (blue) | f / 11 | 1.00 | 3,00 |
| 07_00 (NIR) | f / 16 | 1.00 | 3,00 |

Calibration of Vignetting for Aperture Setting 5

Graphical Overview of Pan Sensor Gain Values:

| | | |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

Graphical Overview of Multispectral Sensor Gain Values:

| | |
|---|---|
|  |  |
|  |  |

Calibration of Vignetting for Aperture Setting 6





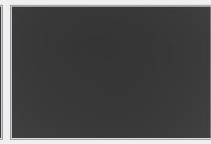


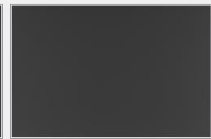

| | | | |
|----------|------------|------------------|----------|
| | PAN | R, G, NIR | B |
| Aperture | F13 | F19 | F13 |

Overview of Individual Sensor Gain Values:

| Cone_Sensor | Aperture | Minimum Gain ≥ | Maximum Gain ≤ |
|---------------|----------|-------------------|-------------------|
| 00_00 | f / 13 | 1.00 | 3,00 |
| 00_01 | f / 13 | 1.00 | 4,00 |
| 00_02 | f / 13 | 1.00 | 3,00 |
| 00_03 | f / 13 | 1.00 | 4,00 |
| 01_00 | f / 13 | 1.00 | 2,00 |
| 01_01 | f / 13 | 1.00 | 2,00 |
| 02_00 | f / 13 | 1.00 | 3,00 |
| 02_01 | f / 13 | 1.00 | 3,00 |
| 03_00 | f / 13 | 1.00 | 2,00 |
| 04_00 (red) | f / 19 | 1.00 | 5,00 |
| 05_00 (green) | f / 19 | 1.00 | 3,00 |
| 06_00 (blue) | f / 13 | 1.00 | 3,00 |
| 07_00 (NIR) | f / 19 | 1.00 | 3,00 |

Calibration of Vignetting for Aperture Setting 6

Graphical Overview of Pan Sensor Gain Values:

| | | |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

Graphical Overview of Multispectral Sensor Gain Values:

| | |
|---|---|
|  |  |
|  |  |

Calibration of Vignetting for Aperture Setting 7





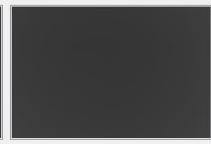


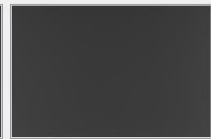

| | | | |
|----------|------------|------------------|----------|
| | PAN | R, G, NIR | B |
| Aperture | F16 | F22 | F16 |

Overview of Individual Sensor Gain Values:

| Cone_Sensor | Aperture | Minimum Gain ≥ | Maximum Gain ≤ |
|--------------------|-----------------|---------------------------|---------------------------|
| 00_00 | f / 16 | 1.00 | 3,00 |
| 00_01 | f / 16 | 1.00 | 4,00 |
| 00_02 | f / 16 | 1.00 | 3,00 |
| 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 | 3,00 |
| 02_01 | f / 16 | 1.00 | 3,00 |
| 03_00 | f / 16 | 1.00 | 2,00 |
| 04_00 (red) | f / 22 | 1.00 | 5,00 |
| 05_00 (green) | f / 22 | 1.00 | 3,00 |
| 06_00 (blue) | f / 16 | 1.00 | 3,00 |
| 07_00 (NIR) | f / 22 | 1.00 | 3,00 |

Calibration of Vignetting for Aperture Setting 7

Graphical Overview of Pan Sensor Gain Values:

| | | |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

Graphical Overview of Multispectral Sensor Gain Values:

| | |
|---|---|
|  |  |
|  |  |

Calibration of Vignetting for Aperture Setting 8



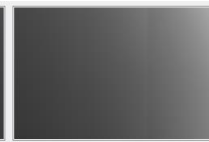
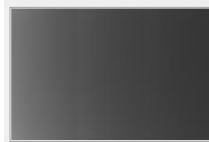
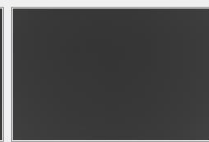
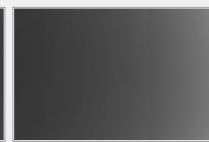

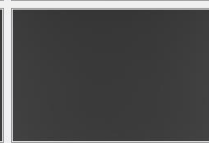

| | | | |
|----------|------------|------------------|----------|
| | PAN | R, G, NIR | B |
| Aperture | F22 | F27 | F22 |

Overview of Individual Sensor Gain Values:

| Cone_Sensor | Aperture | Minimum Gain ≥ | Maximum Gain ≤ |
|---------------|----------|-------------------|-------------------|
| 00_00 | f / 22 | 1.00 | 3,00 |
| 00_01 | f / 22 | 1.00 | 4,00 |
| 00_02 | f / 22 | 1.00 | 3,00 |
| 00_03 | f / 22 | 1.00 | 4,00 |
| 01_00 | f / 22 | 1.00 | 2,00 |
| 01_01 | f / 22 | 1.00 | 2,00 |
| 02_00 | f / 22 | 1.00 | 3,00 |
| 02_01 | f / 22 | 1.00 | 3,00 |
| 03_00 | f / 22 | 1.00 | 2,00 |
| 04_00 (red) | f / 27 | 1.00 | 5,00 |
| 05_00 (green) | f / 27 | 1.00 | 3,00 |
| 06_00 (blue) | f / 22 | 1.00 | 3,00 |
| 07_00 (NIR) | f / 27 | 1.00 | 3,00 |

Calibration of Vignetting for Aperture Setting 8

Graphical Overview of Pan Sensor Gain Values:

| | | |
|---|---|---|
|  |  |  |
|  |  |  |
|  |  |  |

Graphical Overview of Multispectral Sensor Gain Values:

| | |
|---|---|
|  |  |
|  |  |

Defective Pixel Report:

| Sensor | | |
|--------------|---|---|
| Anomaly Type | X | Y |

C00-00

PIXEL: 3078/2134
PIXEL: 3177/4031
PIXEL: 121/ 54
PIXEL: 6357/ 726
PIXEL: 6644/3931
PIXEL: 6645/3931
PIXEL: 6904/ 78

C00-01

PIXEL: 2744/ 304
PIXEL: 736/3304
PIXEL: 1903/4412
PIXEL: 6951/4331
PIXEL: 1904/4412

C00-02

PIXEL: 37/3731
PIXEL: 4267/ 936
PIXEL: 474/ 56
PIXEL: 1036/3926
PIXEL: 1292/3591
PIXEL: 3401/2613
PIXEL: 475/ 56
PIXEL: 473/ 57
PIXEL: 475/ 55
PIXEL: 1291/3591
PIXEL: 3401/2614

C00-03

PIXEL: 1366/2778
PIXEL: 4731/ 603
PIXEL: 5477/2692
PIXEL: 1409/ 265
PIXEL: 1434/ 235
PIXEL: 1435/ 235
PIXEL: 1474/2729
PIXEL: 1474/2730
PIXEL: 1475/2729
PIXEL: 3974/1754
PIXEL: 5846/1515
PIXEL: 6398/4409

UltraCamEagle, Serial Number UC-Eagle-1-60814437-f80

C01-00

PIXEL: 684/4089
PIXEL: 5809/3016
PIXEL: 707/3589
PIXEL: 708/3589
PIXEL: 3302/ 196
PIXEL: 3302/ 197
PIXEL: 4078/4259
PIXEL: 4079/4259
PIXEL: 4079/4260
PIXEL: 5517/3197
PIXEL: 5618/3865

C01-01

PIXEL: 5208/3782
PIXEL: 5410/2805
PIXEL: 6562/3460
PIXEL: 1089/2454
PIXEL: 1587/3002
PIXEL: 5608/1284
PIXEL: 6742/ 228
PIXEL: 1088/2454
PIXEL: 1089/2453
PIXEL: 5608/1285

C02-00

PIXEL: 2029/4305
PIXEL: 4724/ 226

C02-01

PIXEL: 682/4562
PIXEL: 1864/1413
PIXEL: 2199/1582
PIXEL: 6818/ 69
PIXEL: 6945/ 208
PIXEL: 6946/ 209
PIXEL: 6945/ 209
PIXEL: 6818/ 68
PIXEL: 6819/ 69

C03-00

PIXEL: 620/3430
PIXEL: 1702/2008
PIXEL: 1948/ 668
PIXEL: 3333/1181
PIXEL: 4633/2808
PIXEL: 6810/ 86
PIXEL: 6811/ 86

C04-00

PIXEL: 5366/ 736
PIXEL: 691/4403
PIXEL: 691/4404
PIXEL: 691/4405
PIXEL: 692/4403
PIXEL: 692/4404
PIXEL: 1336/1214
PIXEL: 1336/1215
PIXEL: 1337/1214

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C05-00

PIXEL: 2717/ 996
PIXEL: 3138/1220
PIXEL: 6931/4261

C06-00

PIXEL: 1360/2476
PIXEL: 2235/2353
PIXEL: 2431/ 191
PIXEL: 4314/2479
PIXEL: 5965/1202

C07-00

PIXEL: 1711/2428
PIXEL: 114/ 550
PIXEL: 114/ 551
PIXEL: 2858/3732
PIXEL: 5534/3159
PIXEL: 6501/ 388
PIXEL: 6509/ 503
PIXEL: 6638/4359
PIXEL: 6654/ 610
PIXEL: 6502/ 387
PIXEL: 6533/ 365

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-1-60914437-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: Apr-28-2015
Date of Report: May-06-2015
Revision of Camera: Rev01.00
Version of Report: V01

Calibration of Shutter Release Times:

The shutter release times measured during the calibration describe the time from the moment when the electrical current through the shutter is turned off by the electronics, until the shutter is mechanically closed.

This time is relevant for the exposure control and needs to be known before image recording can take place.

| Cone Number | Lens Serial Number | SRT F5.6 [ms] | SRT F6.7 [ms] | SRT F8 [ms] | SRT F9.5 [ms] | SRT F11 [ms] | SRT F13 [ms] | SRT F16 [ms] | SRT F22 [ms] | Measurement Tolerance [ms] |
|---------------------|--------------------|---------------|---------------|-------------|---------------|--------------|--------------|--------------|--------------|----------------------------|
| C0 (Pan 4CCD) | 12 13 59 53 | 6.65 | 6.84 | 7.10 | 7.30 | 7.45 | 7.62 | 7.68 | 7.89 | +/- 0.2 |
| C1 (Pan 2CCD V) | 12 13 59 55 | 6.23 | 6.33 | 6.63 | 6.77 | 6.98 | 7.05 | 7.14 | 7.32 | +/- 0.2 |
| C2 (Pan 2CCD H) | 12 10 10 00 | 6.44 | 6.58 | 6.81 | 6.99 | 7.15 | 7.34 | 7.44 | 7.58 | +/- 0.2 |
| C3 (Pan Central) | 12 13 59 66 | 6.28 | 6.35 | 6.64 | 6.84 | 6.97 | 7.12 | 7.19 | 7.44 | +/- 0.2 |
| C4 (Red) | 12 11 00 21 | 7.40 | 7.46 | 7.50 | 7.61 | 7.73 | 7.73 | 7.67 | 7.98 | +/- 0.2 |
| C5 (Green) | 12 11 00 63 | 7.28 | 7.34 | 7.46 | 7.60 | 7.70 | 7.70 | 7.72 | 7.88 | +/- 0.2 |
| C6 (Blue) | 12 11 00 74 | 6.85 | 6.85 | 6.84 | 6.92 | 7.10 | 7.19 | 7.31 | 7.39 | +/- 0.2 |
| C7 (NIR) | 12 11 00 15 | 7.03 | 7.10 | 7.19 | 7.21 | 7.32 | 7.47 | 7.47 | 7.44 | +/- 0.2 |

Calibration Report

Electronics and Sensor Calibration



Camera: UltraCam Eagle, S/N UC-Eagle-1-60914437-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: Apr-28-2015
Date of Report: May-06-2015
Revision of Camera: Rev01.00
Version of Report: V01

Calibration of Negative Substrate Voltage (VNS):

For optimum performance of the DALSA CCD sensors, the negative substrate voltage is adjusted to a value specified by DALSA.

This voltage value is measured to achieve the best anti-blooming performance possible for each particular sensor.

| Cone_Sensor | Sensor Type | Sensor Serial Number | VNS Voltage [V] |
|---------------|-------------|----------------------|-----------------|
| 00_00 | FTF7046-M | 16 0474/137 | 24.40 |
| 00_01 | FTF7046-M | 16 0872/029 | 24.20 |
| 00_02 | FTF7046-M | 16 0872/013 | 23.80 |
| 00_03 | FTF7046-M | 16 0872/041 | 24.00 |
| 01_00 | FTF7046-M | 16 0872/011 | 24.00 |
| 01_01 | FTF7046-M | 16 0782/038 | 23.80 |
| 02_00 | FTF7046-M | 16 0872/034 | 24.00 |
| 02_01 | FTF7046-M | 16 0474/134 | 24.20 |
| 03_00 | FTF7046-M | 16 0872/015 | 24.00 |
| 04_00 (red) | FTF7046-M | 16 0474/125 | 24.00 |
| 05_00 (green) | FTF7046-M | 16 0474/139 | 24.00 |
| 06_00 (blue) | FTF7046-M | 16 0474/120 | 23.80 |
| 07_00 (NIR) | FTF7046-M | 16 0474/123 | 23.80 |

Calibration of Intensity Threshold for Exposure Control:

Each CCD sensor and electronics module varies slightly in global sensitivity and intensity scale.

Therefore the maximum possible intensity of each sensor needs to be measured to evaluate the sensitivity behavior of the CCD and electronics.

This value is used as a threshold for the exposure control dialogue shown in the in-flight user interface of the Eagle.

| Cone_Sensor | Sensor Type | Sensor Serial Number | Intensity Threshold [DN] |
|---------------|-------------|----------------------|--------------------------|
| 00_00 | FTF7046-M | 16 0474/137 | 12950 |
| 00_01 | FTF7046-M | 16 0872/029 | 12640 |
| 00_02 | FTF7046-M | 16 0872/013 | 12670 |
| 00_03 | FTF7046-M | 16 0872/041 | 12450 |
| 01_00 | FTF7046-M | 16 0872/011 | 12700 |
| 01_01 | FTF7046-M | 16 0782/038 | 12830 |
| 02_00 | FTF7046-M | 16 0872/034 | 12780 |
| 02_01 | FTF7046-M | 16 0474/134 | 13390 |
| 03_00 | FTF7046-M | 16 0872/015 | 12240 |
| 04_00 (red) | FTF7046-M | 16 0474/125 | 12900 |
| 05_00 (green) | FTF7046-M | 16 0474/139 | 12870 |
| 06_00 (blue) | FTF7046-M | 16 0474/120 | 13100 |
| 07_00 (NIR) | FTF7046-M | 16 0474/123 | 12740 |

Calibration Report

Summary





Camera: UltraCam Eagle, S/N UC-Eagle-1-60914437-f80
Manufacturer: Vexcel Imaging GmbH, A-8010 Graz, Austria
Date of Calibration: Apr-28-2015
Date of Report: May-06-2015
Revision of Camera: Rev01.00
Version of Report: V01

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

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

This equipment is operating fully within specification as defined by Vexcel Imaging GmbH.


Dr. Michael Gruber
Chief Scientist, Photogrammetry
Vexcel Imaging GmbH


Ing. Peter Prassl
Senior Calibration Engineer
Vexcel Imaging GmbH