

**VEXCEL**  
IMAGING

# ULTRACAM

## Calibration Report

**Camera:**

**UltraCam Falcon Prime**

**Serial:**

**UC-Fp-1-40616106-f100**

**Calibration Date:**

**Aug-10-2016**

**Date of Report:**

**Aug-16-2016**

**Camera Revision:**

**Rev02.00**

**Version of Report:**

**V01**



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Bahia, Brasil 2013

Photo on page 1 courtesy of Hiparc Geotecnologia, Brasil

[www.hiparc.com](http://www.hiparc.com)

UltraCam Lp, GSD25 cm, RGB



# ULTRACAM

## Geometric Calibration

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**Camera:** UltraCam Falcon Prime  
**Serial:** UC-Fp-1-40616106-f100

**Panchromatic Camera:** ck = 100.500 mm  
**Multispectral Camera:** ck = 100.500 mm

**PPA Information:** X: 0.000  
Y: 0.000

**Calibration Date:** Aug-10-2016  
**Date of Report:** Aug-16-2016  
**Camera Revision:** Rev02.00  
**Version of Report:** V01



## Panchromatic Camera

### Large Format Panchromatic Output Image

|                              |                                        |                             |                    |
|------------------------------|----------------------------------------|-----------------------------|--------------------|
| Image Format                 | long track                             | 67.860mm                    | 11310pixel         |
|                              | cross track                            | 103.860mm                   | 17310pixel         |
| Image Extent                 |                                        | (-33.930, -51.930)mm        | (33.930, 51.930)mm |
| Pixel Size                   |                                        | 6.000 $\mu$ m*6.000 $\mu$ m |                    |
| Focal Length                 | ck                                     | 100.500mm                   | $\pm$ 0.002mm      |
| Principal Point<br>(Level 2) | X_ppa                                  | 0.000mm                     | $\pm$ 0.002mm      |
|                              | Y_ppa                                  | 0.000mm                     | $\pm$ 0.002mm      |
| Lens Distortion              | Remaining Distortion less than 0.002mm |                             |                    |

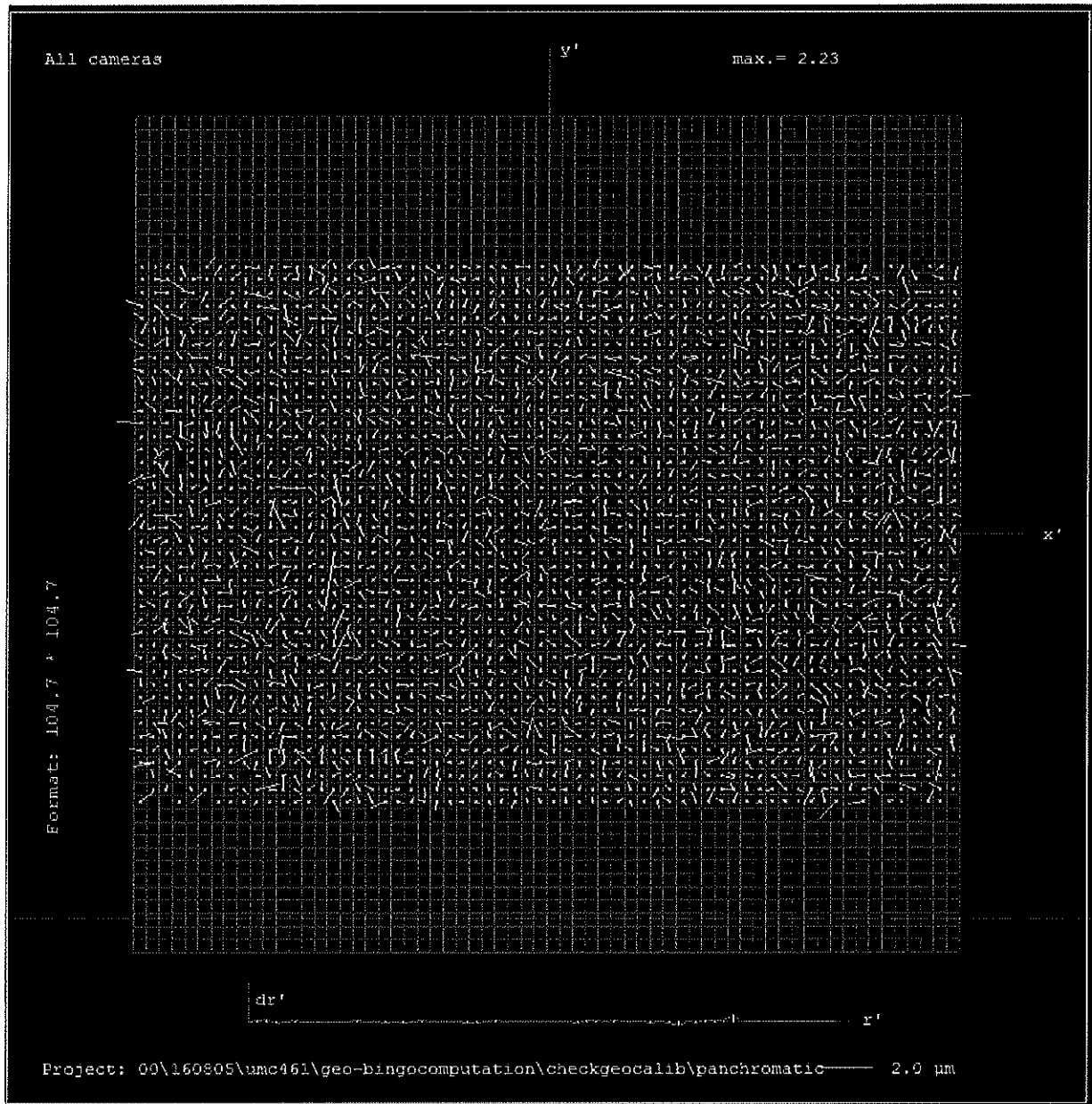
## Multispectral Camera

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

|                              |                                        |                               |                    |
|------------------------------|----------------------------------------|-------------------------------|--------------------|
| Image Format                 | long track                             | 67.860mm                      | 3770pixel          |
|                              | cross track                            | 103.860mm                     | 5770pixel          |
| Image Extent                 |                                        | (-33.930, -51.930)mm          | (33.930, 51.930)mm |
| Pixel Size                   |                                        | 18.000 $\mu$ m*18.000 $\mu$ m |                    |
| Focal Length                 | ck                                     | 100.500mm                     | $\pm$ 0.002mm      |
| Principal Point<br>(Level 2) | X_ppa                                  | 0.000mm                       | $\pm$ 0.002mm      |
|                              | Y_ppa                                  | 0.000mm                       | $\pm$ 0.002mm      |
| Lens Distortion              | Remaining Distortion less than 0.002mm |                               |                    |



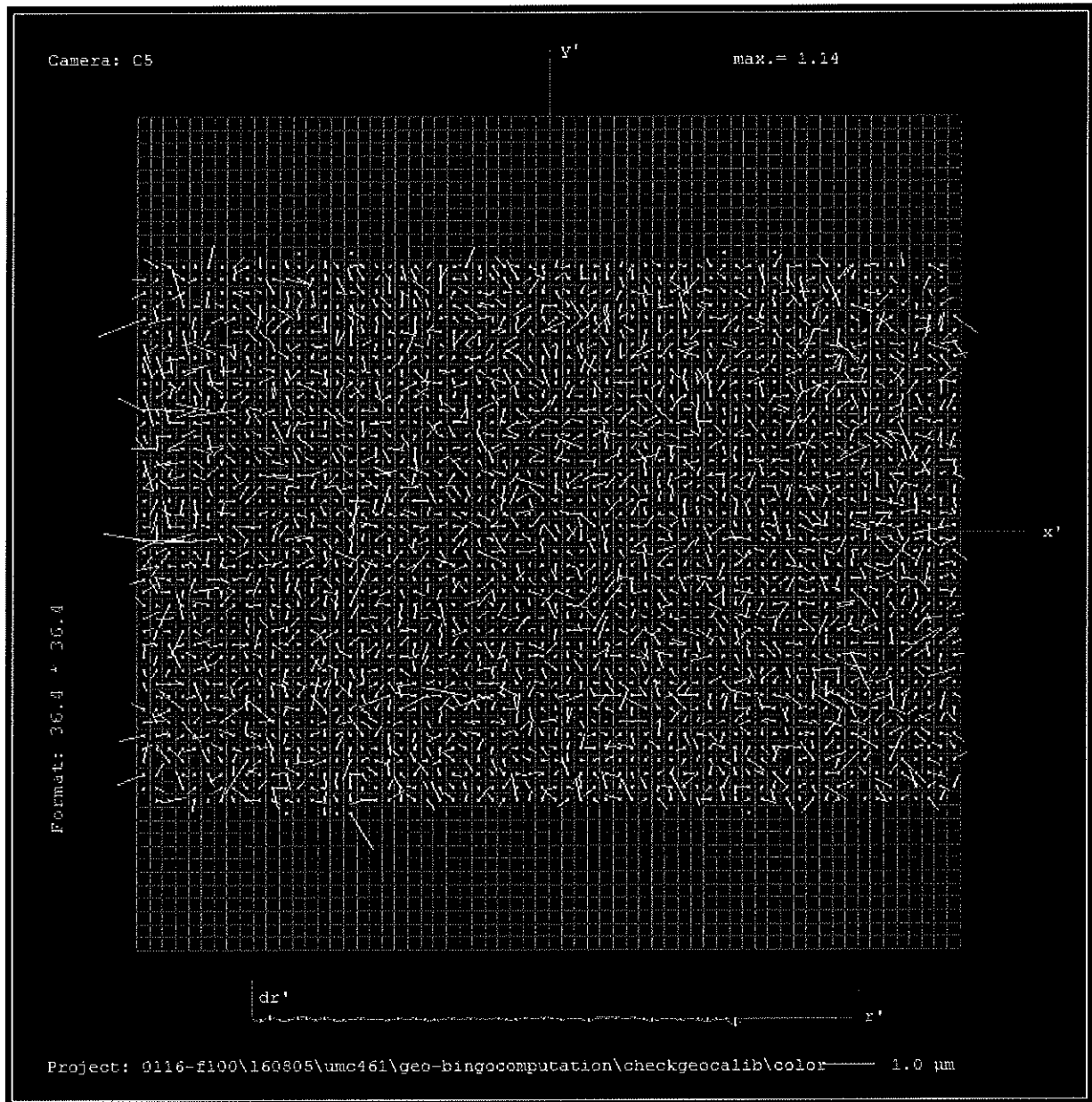
## Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): 0.60  $\mu\text{m}$



## Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): 0.50  $\mu\text{m}$



## Explanations

### 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 : >16000

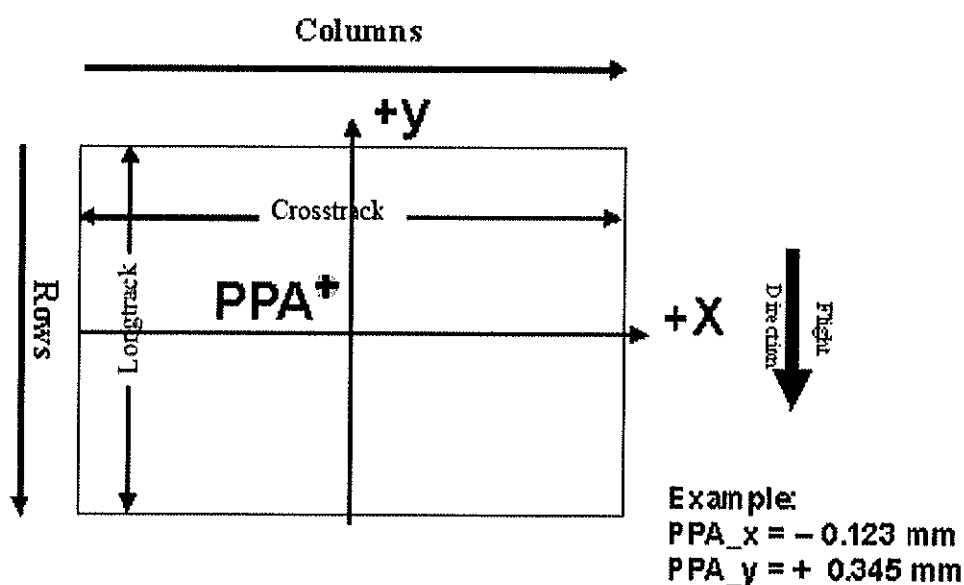
Number of point measurements for the multispectral camera : >60000

Determination of the image parameters by Least Squares Adjustment.

Software used for the adjustment: BINGO (GIP Eng. Aalen, Germany)

### Level 2 Image Coordinate System:

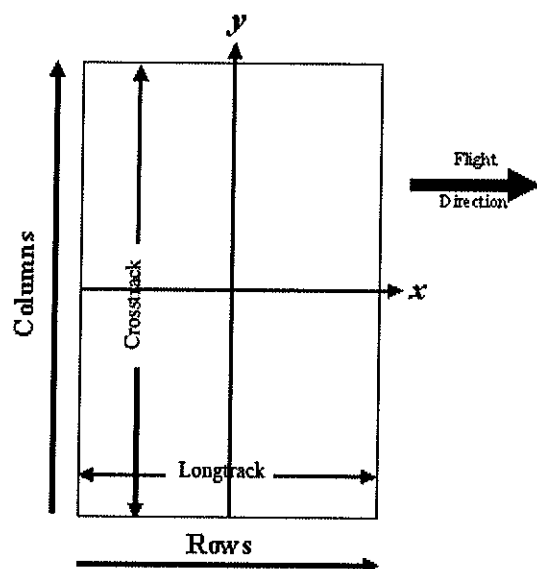
## Lvl2, Camera prop. Orientation



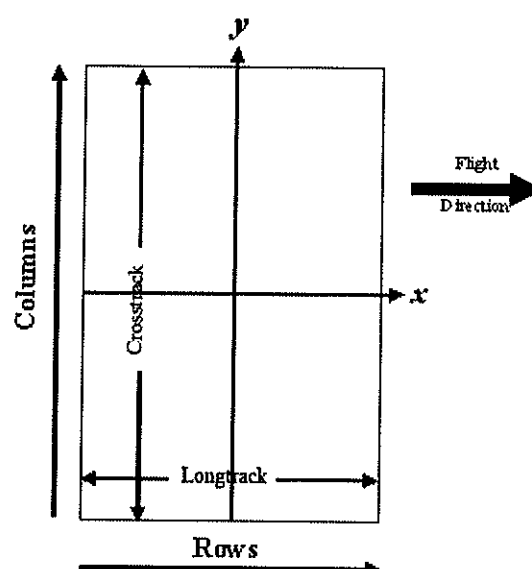
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



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



Panchromatic Image Format



Multispectral Image Format

**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 4 for high- and low resolution images.

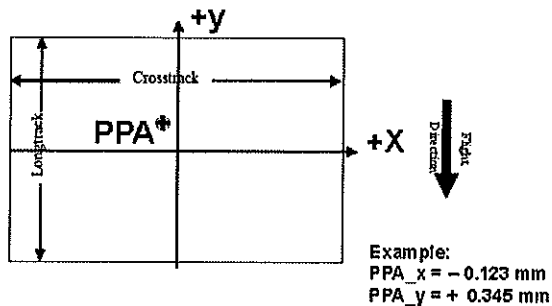
| Image Format | Clockwise Rotation (Degree) | PPA   |       |
|--------------|-----------------------------|-------|-------|
|              |                             | X     | Y     |
| Level 2      | -                           | 0.000 | 0.000 |
| Level 3      | 0                           | 0.000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



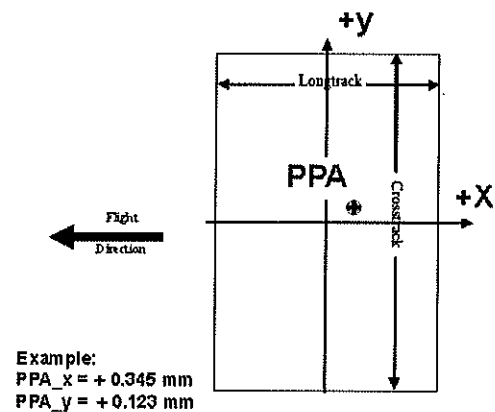


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

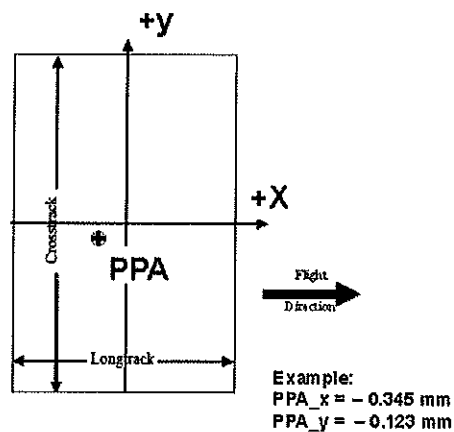
Lvl3, Rotation 0 deg clockwise



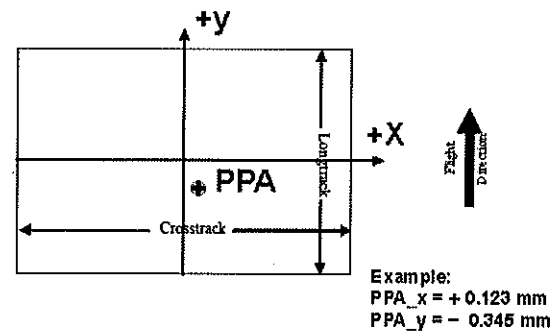
Lvl3, Rotation 90 deg clockwise



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 sagital (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

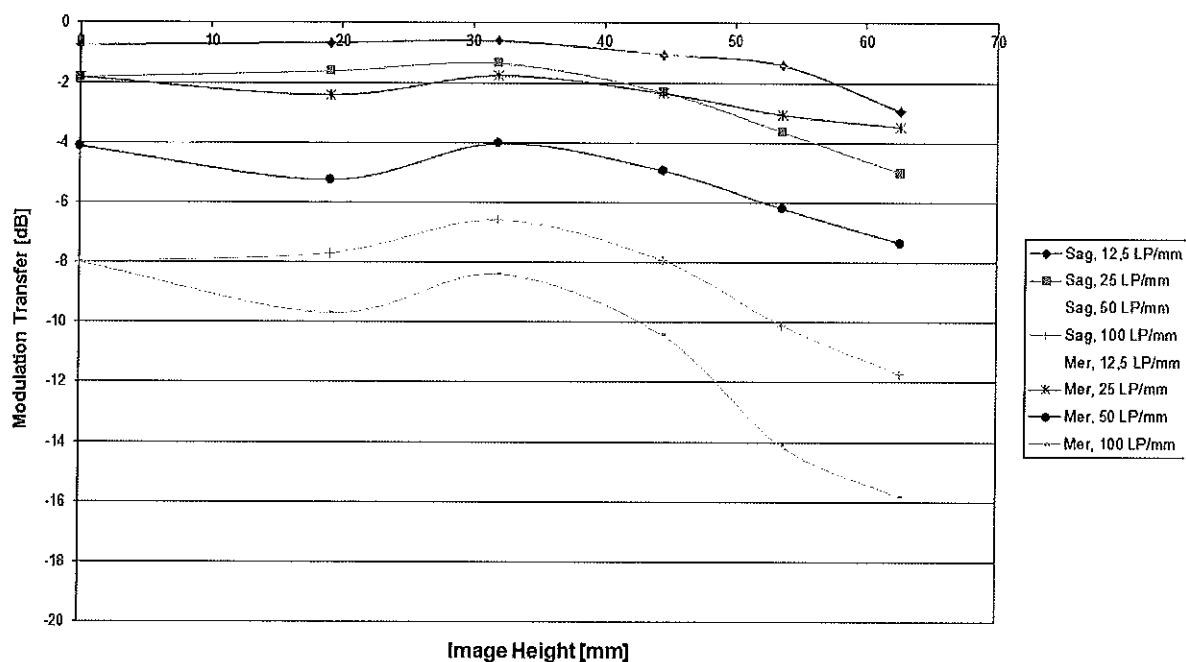
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

### Lens types

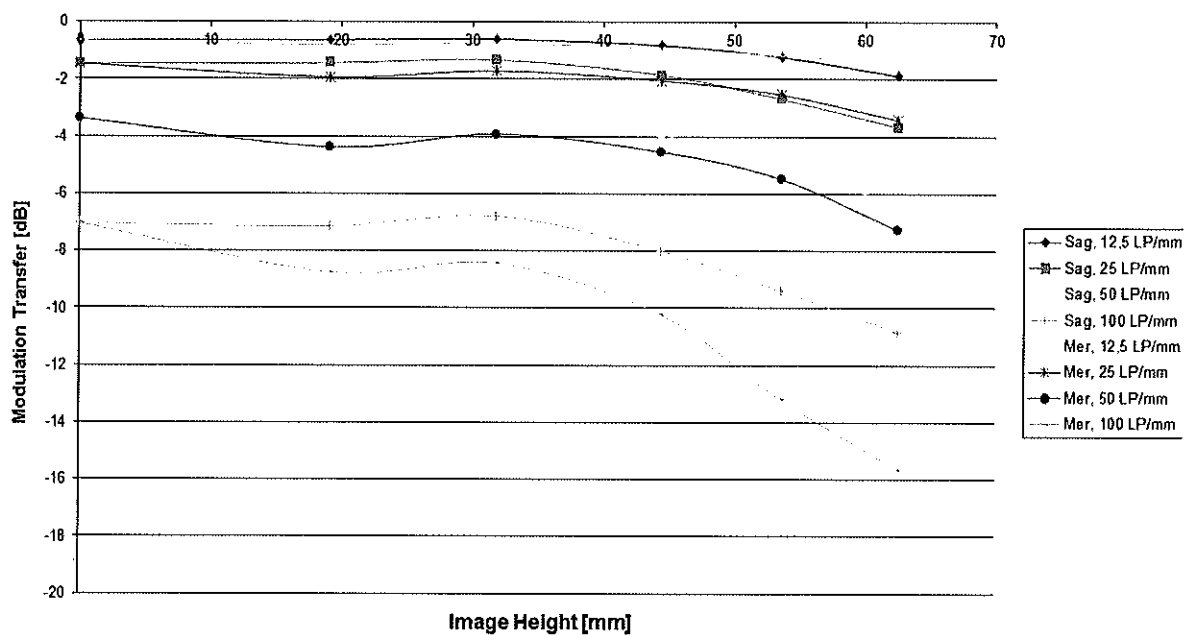
| Cone       | Lens                                                                 |
|------------|----------------------------------------------------------------------|
| C0         | Linor Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linor GmbH, Germany |
| C1         | Linor Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linor GmbH, Germany |
| C2         | Linor Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linor GmbH, Germany |
| C3         | Linor Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linor GmbH, Germany |
| C4 (RED)   | Linor Vexcel Apo-Sironar Digital HR 1:4/33mm, Linor GmbH, Germany    |
| C5 (GREEN) | Linor Vexcel Apo-Sironar Digital HR 1:4/33mm, Linor GmbH, Germany    |
| C6 (BLUE)  | Linor Vexcel Apo-Sironar Digital HR 1:4/33mm, Linor GmbH, Germany    |
| C7 (NIR)   | Linor Vexcel Apo-Sironar Digital HR 1:4/33mm, Linor GmbH, Germany    |



### Modulation versus Image Height - Aperture f/5.6

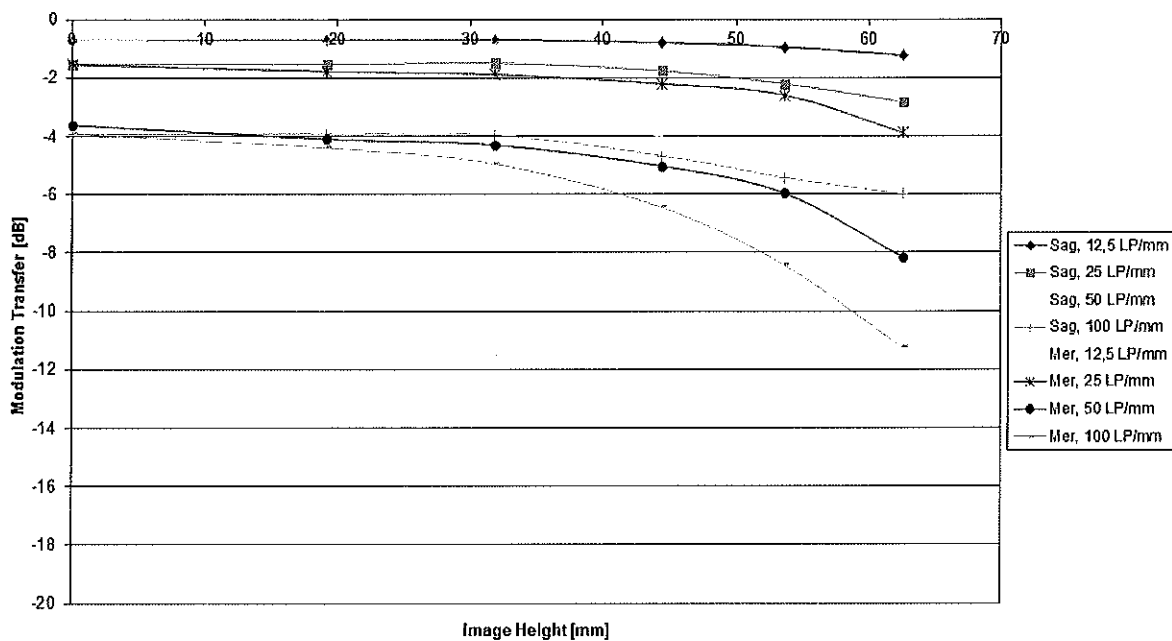


### Modulation versus Image Height - Aperture f/6.7

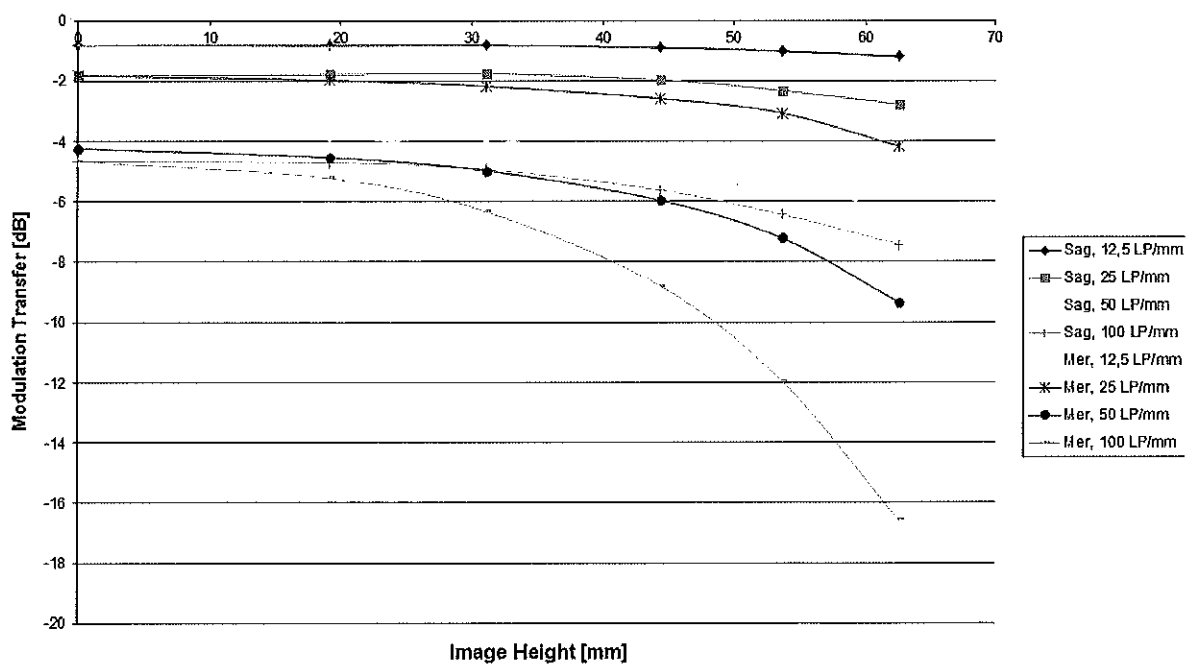




### Modulation versus Image Height - Aperture f / 8



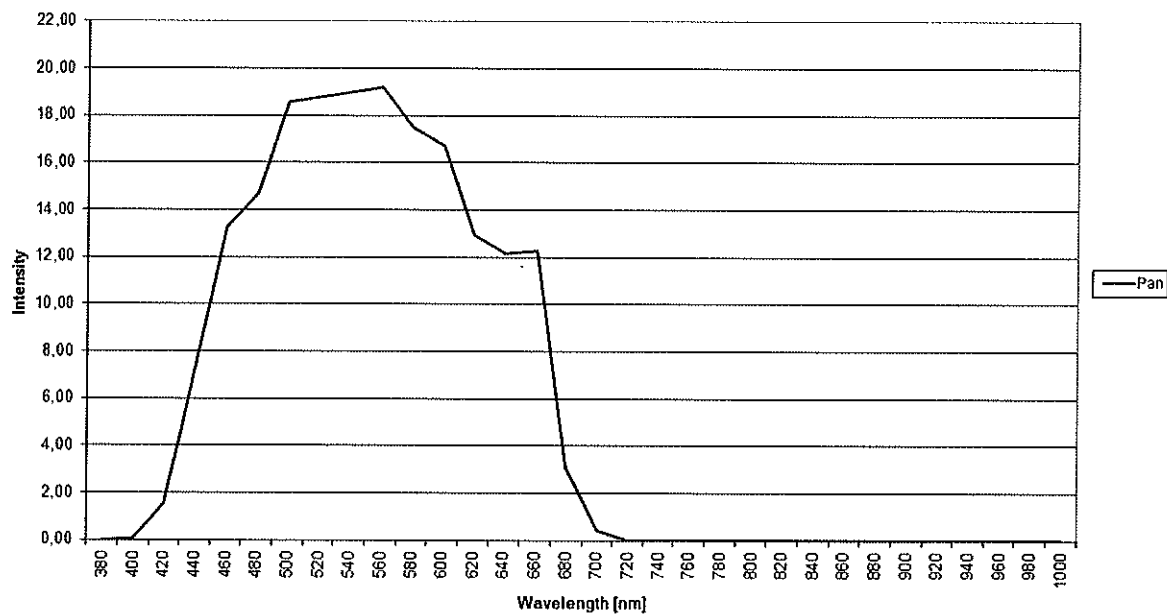
### Modulation versus Image Height - Aperture f / 9.5



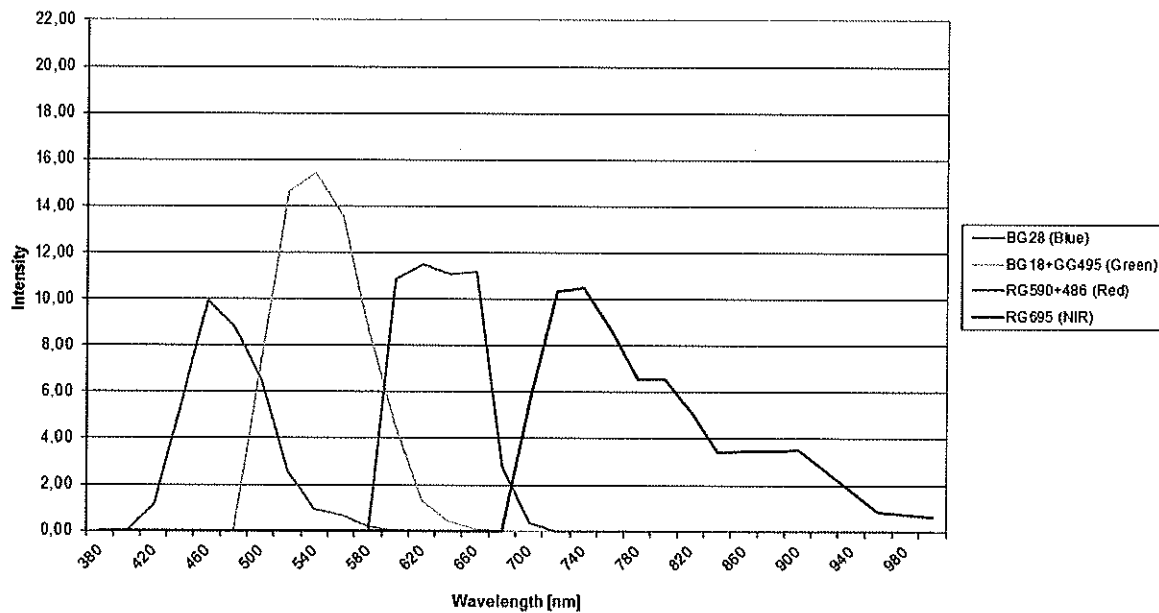


## Spectral Sensitivity

Spectral Sensitivity Vexcel UCX - Panchromatic  
with AR-106 Coating



Spektral Sensitivity Vexcel UCX - Multispectral  
with AR-106 Coating





# ULTRACAM

## Radiometric Calibration

**Camera:** UltraCam Falcon Prime  
**Serial:** UC-Fp-1-40616106-f100

|                | PAN  | R, G, NIR | B    |
|----------------|------|-----------|------|
| Used Apertures | F5.6 | F4.8      | F4.8 |
|                | F6.7 | F5.6      | F4.8 |
|                | F8   | F6.7      | F4.8 |
|                | F9.5 | F8        | F5.6 |
|                | F11  | F9.5      | F6.7 |
|                | F13  | F11       | F8   |
|                | F16  | F13       | F9.5 |
|                | F22  | F19       | F13  |

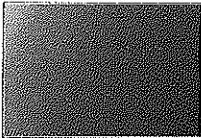
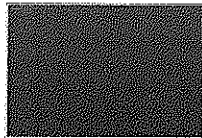
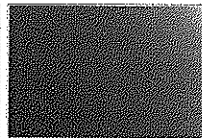
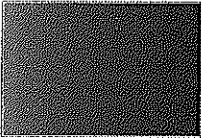
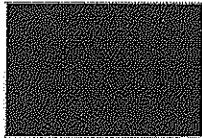
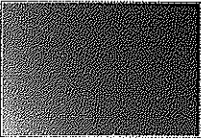
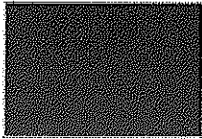
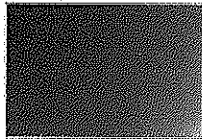
**Calibration Date:** Aug-10-2016  
**Date of Report:** Aug-16-2016  
**Camera Revision:** Rev02.00  
**Version of Report:** V01



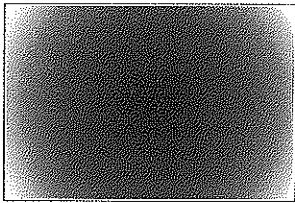
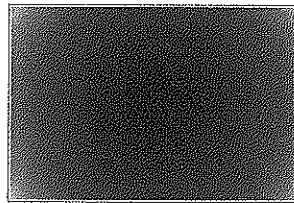
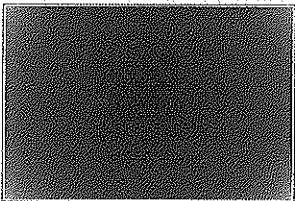
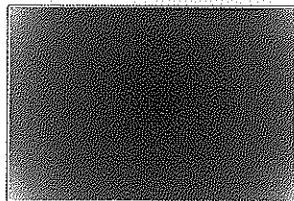
## Calibration of Vignetting for working Aperture F6.7

|          | PAN  | R, G, NIR | B    |
|----------|------|-----------|------|
| Aperture | F6.7 | F5.6      | F4.8 |

Graphical Overview of Pan Sensors:

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

Graphical Overview of Multispectral Sensors:

|                                                                                     |                                                                                     |                  |                 |
|-------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------|------------------|-----------------|
|  |  | 04_00<br>(RED)   | 06_00<br>(BLUE) |
|  |  | 05_00<br>(GREEN) | 07_00<br>(NIR)  |



## Dead Pixel Report:

| Sensor number | Anomaly type | X-Coordinate | Y-Coordinate |
|---------------|--------------|--------------|--------------|
|---------------|--------------|--------------|--------------|

### C00-00

PIXEL: 2161/3445  
PIXEL: 4157/2964  
PIXEL: 5291/2526  
PIXEL: 5891/3227  
PIXEL: 5822/ 382  
PIXEL: 5822/ 383

### C00-01

PIXEL: 37/ 596  
PIXEL: 151/3338  
PIXEL: 2745/1964  
PIXEL: 3337/3489  
PIXEL: 5552/3346  
PIXEL: 5962/ 72  
PIXEL: 1163/1220  
PIXEL: 5889/3889  
PIXEL: 5930/3858  
PIXEL: 232/3264

### C00-02

PIXEL: 629/ 355  
PIXEL: 2785/2260  
PIXEL: 62/3665  
PIXEL: 3198/3021  
PIXEL: 295/3856

### C00-03

PIXEL: 1115/2392  
PIXEL: 1365/1993  
PIXEL: 3483/ 365  
PIXEL: 3958/ 74  
PIXEL: 5040/2208  
PIXEL: 5224/1837  
PIXEL: 5265/2014  
PIXEL: 5435/2499  
PIXEL: 2762/2241  
PIXEL: 2763/2241



**C01-00**

PIXEL: 1313/3108  
PIXEL: 3862/2397  
PIXEL: 4893/ 869  
PIXEL: 3870/3965  
PIXEL: 5376/1680  
PIXEL: 5376/1681  
PIXEL: 5376/1682

**C01-01**

PIXEL: 381/1667  
PIXEL: 4689/1356  
PIXEL: 239/3923

**C02-00**

PIXEL: 4674/3468  
PIXEL: 258/2879  
PIXEL: 204/3808  
PIXEL: 55/3925  
PIXEL: 247/ 93

**C02-01**

PIXEL: 551/1756  
PIXEL: 1631/1193  
PIXEL: 3938/1915  
PIXEL: 4371/1444  
PIXEL: 4513/1825  
PIXEL: 97/3950

**C03-00**

PIXEL: 673/ 50  
PIXEL: 3672/ 861  
PIXEL: 4972/2827  
PIXEL: 3814/3489  
COLUMN: 1006/1243

**C04-00**

PIXEL: 2051/3391  
PIXEL: 3085/2815  
PIXEL: 4856/2297  
PIXEL: 5511/2155  
PIXEL: 5511/2156  
PIXEL: 5512/2154  
PIXEL: 5512/2155  
PIXEL: 5512/2156

**C05-00**



PIXEL: 645/2326  
PIXEL: 4528/2800  
PIXEL: 4709/3613  
PIXEL: 118/ 60  
PIXEL: 695/1405  
PIXEL: 695/1406  
PIXEL: 5845/1343  
PIXEL: 6016/ 49  
PIXEL: 6016/ 50  
PIXEL: 5974/ 189  
PIXEL: 2276/ 112  
PIXEL: 2276/ 113  
PIXEL: 117/ 61  
PIXEL: 581/ 50

## **C06-00**

PIXEL: 1304/3429  
PIXEL: 1596/2725  
PIXEL: 2772/1355  
PIXEL: 4696/2092  
PIXEL: 5117/1898  
PIXEL: 54/3874  
PIXEL: 86/3983  
PIXEL: 37/3978  
PIXEL: 117/3861  
PIXEL: 4464/ 85  
PIXEL: 5895/3857

## **C07-00**

PIXEL: 349/ 668  
PIXEL: 1827/ 347  
PIXEL: 5333/1288  
PIXEL: 130/3795  
PIXEL: 131/3794  
PIXEL: 131/3795  
PIXEL: 1100/3903  
PIXEL: 2788/2755

## **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.



# **ULTRACAM**

## **Shutter Calibration**

---

**Camera:** UltraCam Falcon Prime  
**Serial:** UC-Fp-1-40616106-f100

**Panchromatic Camera:** 4 \* Prontor Magnetic 0 HS  
Prontor-Werk Alfred Gauthier GmbH, Germany

**Multispectral Camera:** 4 \* Prontor Magnetic 0 HS  
Prontor-Werk Alfred Gauthier GmbH, Germany

**Calibration Date:** Aug-10-2016  
**Date of Report:** Aug-16-2016  
**Camera Revision:** Rev02.00  
**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<br>F5.6<br>[ms] | SRT<br>F6.7<br>[ms] | SRT<br>F8<br>[ms] | SRT<br>F9.5<br>[ms] | SRT<br>F11<br>[ms] | SRT<br>F13<br>[ms] | SRT<br>F16<br>[ms] | SRT<br>F22<br>[ms] | Measurement<br>Tolerance [ms] |
|---------------|--------------------|---------------------|---------------------|-------------------|---------------------|--------------------|--------------------|--------------------|--------------------|-------------------------------|
| C0<br>(Pan)   | 12 23 55 19        | 6.67                | 6.80                | 6.94              | 7.17                | 7.36               | 7.57               | 7.69               | 7.79               | +/- 0.2                       |
| C1<br>(Pan)   | 12 22 11 11        | 6.31                | 6.45                | 6.61              | 6.83                | 7.02               | 7.20               | 7.31               | 7.36               | +/- 0.2                       |
| C2<br>(Pan)   | 12 22 11 03        | 6.81                | 6.94                | 6.97              | 7.13                | 7.29               | 7.48               | 7.62               | 7.81               | +/- 0.2                       |
| C3<br>(Pan)   | 12 22 11 14        | 6.80                | 6.91                | 7.19              | 7.44                | 7.67               | 7.89               | 8.03               | 8.05               | +/- 0.2                       |
| C4<br>(Red)   | 12 21 89 94        | 7.16                | 7.29                | 7.52              | 7.63                | 7.77               | 7.85               | 7.89               | 7.97               | +/- 0.2                       |
| C5<br>(Green) | 12 21 89 90        | 6.73                | 6.74                | 6.93              | 7.07                | 7.28               | 7.34               | 7.34               | 7.42               | +/- 0.2                       |
| C6<br>(Blue)  | 12 21 89 92        | 6.59                | 6.59                | 6.62              | 6.69                | 6.89               | 7.06               | 7.25               | 7.35               | +/- 0.2                       |
| C7<br>(NIR)   | 12 23 11 80        | 7.36                | 7.61                | 7.69              | 7.81                | 7.85               | 7.93               | 8.04               | 8.04               | +/- 0.2                       |



# **ULTRACAM**

## Electronics and Sensor Calibration

---

**Camera:** UltraCam Falcon Prime  
**Serial:** UC-Fp-1-40616106-f100

**Panchromatic Camera:** 9 \* FTF6040-M Area CCD Sensor by DALSA  
**Multispectral Camera:** 4 \* FTF6040-M Area CCD Sensor by DALSA

**Calibration Date:** Aug-10-2016  
**Date of Report:** Aug-16-2016  
**Camera Revision:** Rev02.00  
**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         | FTF6040-M   | 157 701/025          | 22.5            |
| 00_01         | FTF6040-M   | 157 701/017          | 22.50           |
| 00_02         | FTF6040-M   | 157 701/007          | 22.50           |
| 00_03         | FTF6040-M   | 157 701/011          | 22.50           |
| 01_00         | FTF6040-M   | 157 701/014          | 22.50           |
| 01_01         | FTF6040-M   | 157 701/018          | 22.50           |
| 02_00         | FTF6040-M   | 157 701/027          | 22.50           |
| 02_01         | FTF6040-M   | 157 701/030          | 22.50           |
| 03_00         | FTF6040-M   | 157 701/028          | 22.50           |
| 04_00 (red)   | FTF6040-M   | 157 701/035          | 22.30           |
| 05_00 (green) | FTF6040-M   | 155 293/073          | 21.80           |
| 06_00 (blue)  | FTF6040-M   | 155 293/077          | 22.50           |
| 07_00 (NIR)   | FTF6040-M   | 155 293/092          | 22.50           |



## 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         | FTF6040-M   | 157 701/025          | 13550                    |
| 00_01         | FTF6040-M   | 157 701/017          | 13490                    |
| 00_02         | FTF6040-M   | 157 701/007          | 13980                    |
| 00_03         | FTF6040-M   | 157 701/011          | 13700                    |
| 01_00         | FTF6040-M   | 157 701/014          | 13750                    |
| 01_01         | FTF6040-M   | 157 701/018          | 14010                    |
| 02_00         | FTF6040-M   | 157 701/027          | 14630                    |
| 02_01         | FTF6040-M   | 157 701/030          | 13440                    |
| 03_00         | FTF6040-M   | 157 701/028          | 13660                    |
| 04_00 (red)   | FTF6040-M   | 157 701/035          | 13720                    |
| 05_00 (green) | FTF6040-M   | 155 293/073          | 12460                    |
| 06_00 (blue)  | FTF6040-M   | 155 293/077          | 12730                    |
| 07_00 (NIR)   | FTF6040-M   | 155 293/092          | 12640                    |





# ULTRACAM

## Summary

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|                           |                              |
|---------------------------|------------------------------|
| <b>Camera:</b>            | <b>UltraCam Falcon Prime</b> |
| <b>Serial:</b>            | <b>UC-Fp-1-40616106-f100</b> |
| <b>Calibration Date:</b>  | <b>Aug-10-2016</b>           |
| <b>Date of Report:</b>    | <b>Aug-16-2016</b>           |
| <b>Camera Revision:</b>   | <b>Rev02.00</b>              |
| <b>Version of Report:</b> | <b>V01</b>                   |

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

- Geometric Calibration
- Radiometric Calibration
- Shutter Calibration
- Sensor and Electronics Calibration

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

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