Calibration Report

Short Version

Camera:	**UltraCam Falcon, S/N UC-Fp-1-50811038-f100**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Date of Calibration:	**Jan-28-2014**
Date of Report:	**Feb-25-2014**
Revision of Camera:	**Rev01**
Version of Report:	**V01**

Calibration Report

Geometric Calibration

Camera:	**UltraCam Falcon, S/N UC-Fp-1-50811038-f100**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Panchromatic Camera:	**ck = 100.500mm**
Multispectral Camera:	**ck = 100.500mm**
Date of Calibration:	**Jan-28-2014**
Date of Report:	**Feb-25-2014**
Revision of Camera:	**Rev01**
Version of Report:	**V01**

Panchromatic Camera

Large Format Panchromatic Output Image

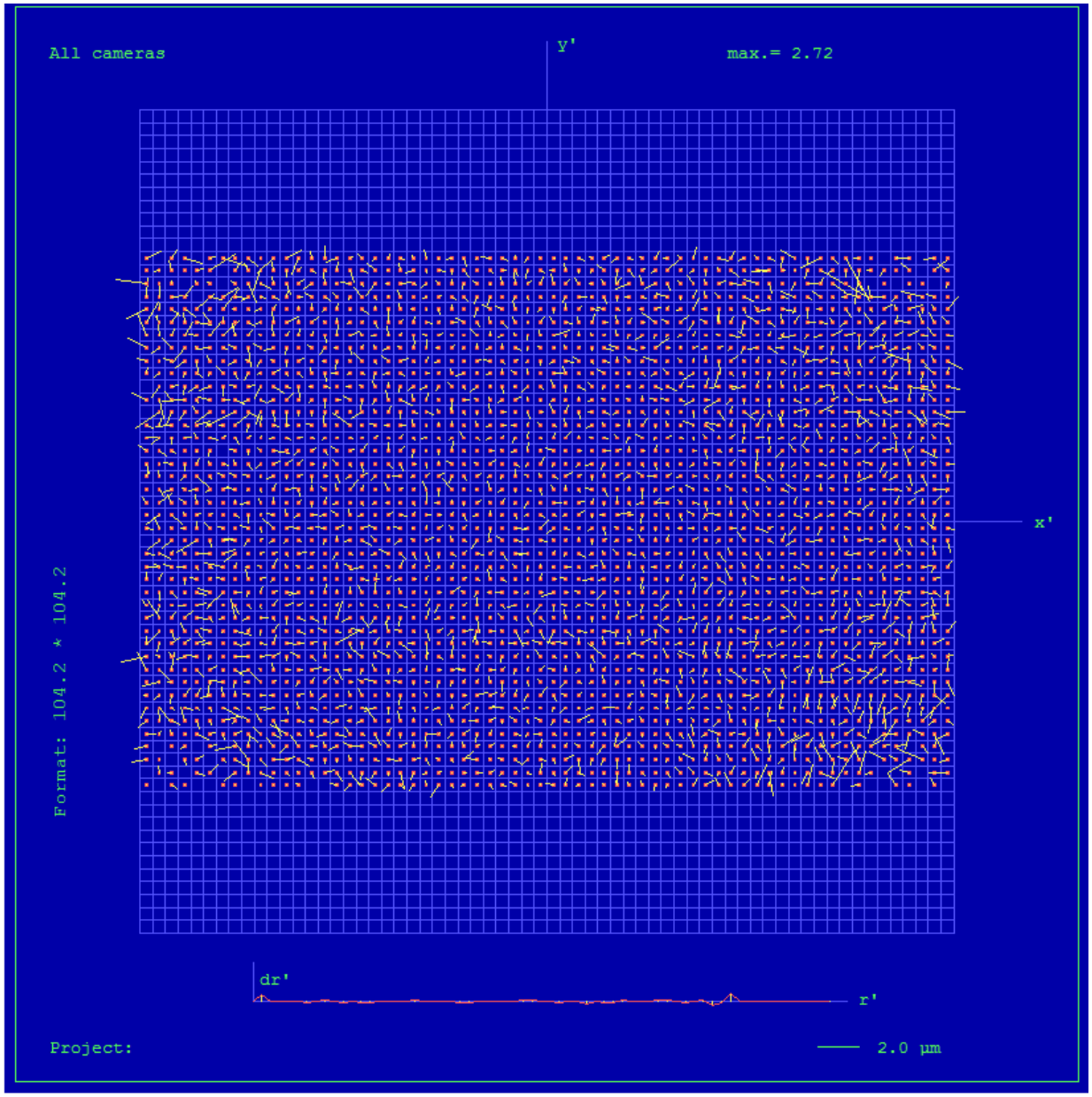
Image Format	long track	67.860mm	11310pixel
	cross track	103.860mm	17310pixel
Image Extent		(-33.93, -51.93)mm	(33.93, 51.93)mm
Pixel Size		6.000µm*6.000µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point	X_ppa	0.000 mm	± 0.002mm
(Level 2)	Y_ppa	-0.120 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Multispectral Camera

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

Image Format	long track	67.860mm	3770pixel
	cross track	103.860mm	5770pixel
Image Extent		(-33.93, -51.93)mm	(33.93, 51.93)mm
Pixel Size		18.000µm*18.000µm	
Focal Length	ck	100.500mm	
Principal Point	X_ppa	0.000 mm	± 0.002mm
(Level 2)	Y_ppa	-0.120 mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

Full Pan Image, Residual Error Diagram



Residual Error (RMS): 0.97 µm

Explanations:

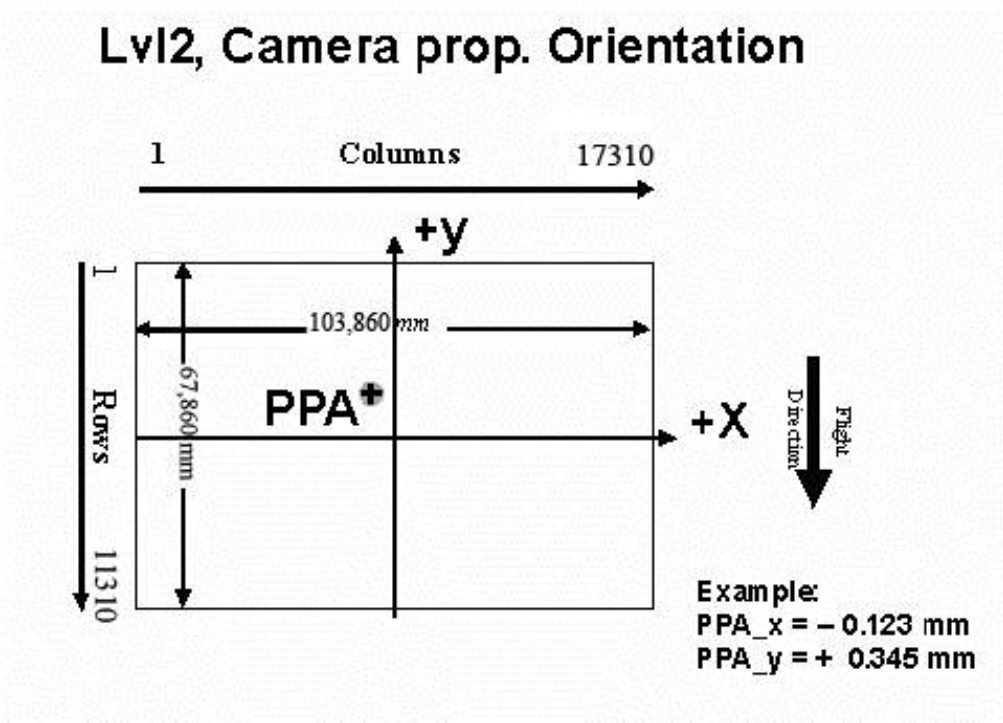
1) Calibration Method:

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 : 18490
Number of point measurements for the multispectral camera : 71567

Determination of the image parameters by Least Squares Adjustment.
Software used for the adjustment: BINGO (GIP Eng. Aalen, Germany)

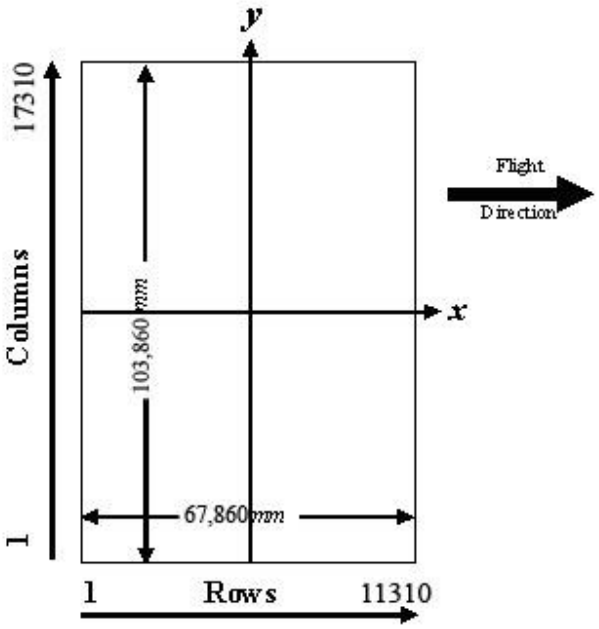
2) Level 2 Image Coordinate System: PAN 17310 pixel by 11310 pixel
MS 5770 pixel by 3770 pixel



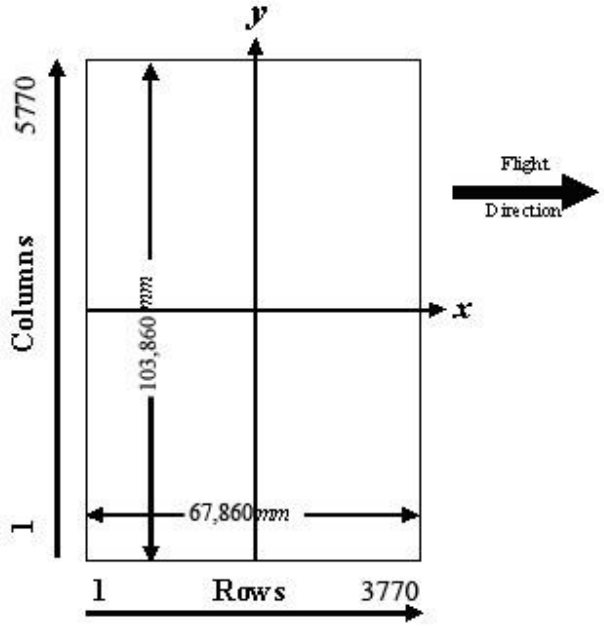
The image coordinate system of the Level 2 images is shown in the above figure. The level 2 image consists of 17310 columns and 11310 rows, which leads to a total image format of 103.860 x 67.860 mm. The coordinate of the principal point in the level 2 image is given on page 3 of this report. The above 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 17310 pixel by 11310 pixel
MS 5770 pixel by 3770 pixel



Panchromatic Image Format



Multispectral Image Format

==========

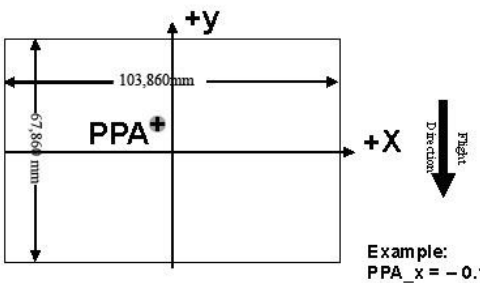
4) Position of Principal Point in Level 3 Image

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	-0.120
Level 3	0	0.000	-0.120
Level 3	90	-0.120	0.000
Level 3	180	0.000	0.120
Level 3	270	0.120	0.000

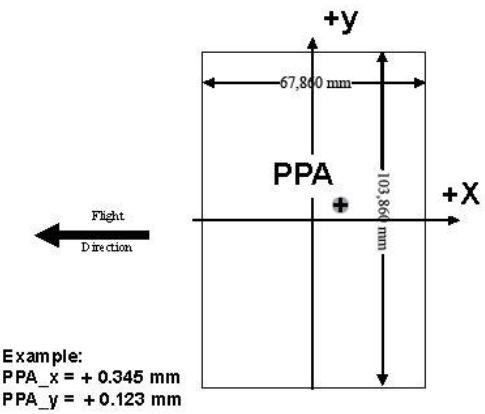
The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

Lvl3, Rotation 0 deg clockwise



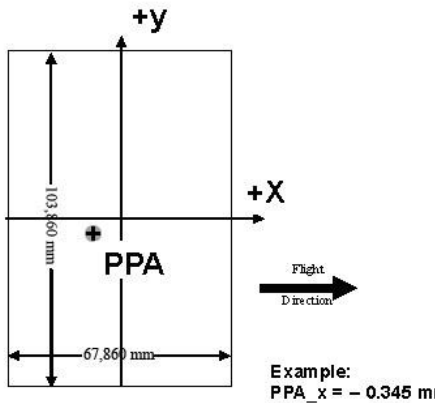
Example:
PPA_x = – 0.123 mm
PPA_y = + 0.345 mm

Lvl3, Rotation 90 deg clockwise



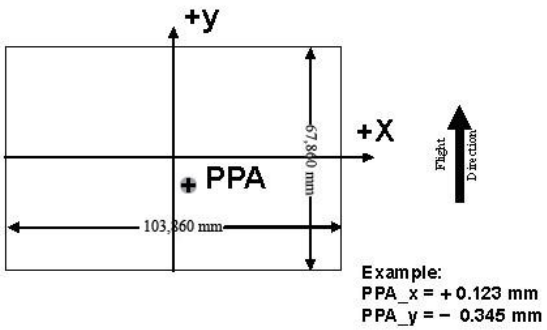
Example:
PPA_x = + 0.345 mm
PPA_y = + 0.123 mm

Lvl3, Rotation 270 deg clockwise



Example:
PPA_x = – 0.345 mm
PPA_y = – 0.123 mm

Lvl3, Rotation 180 deg clockwise



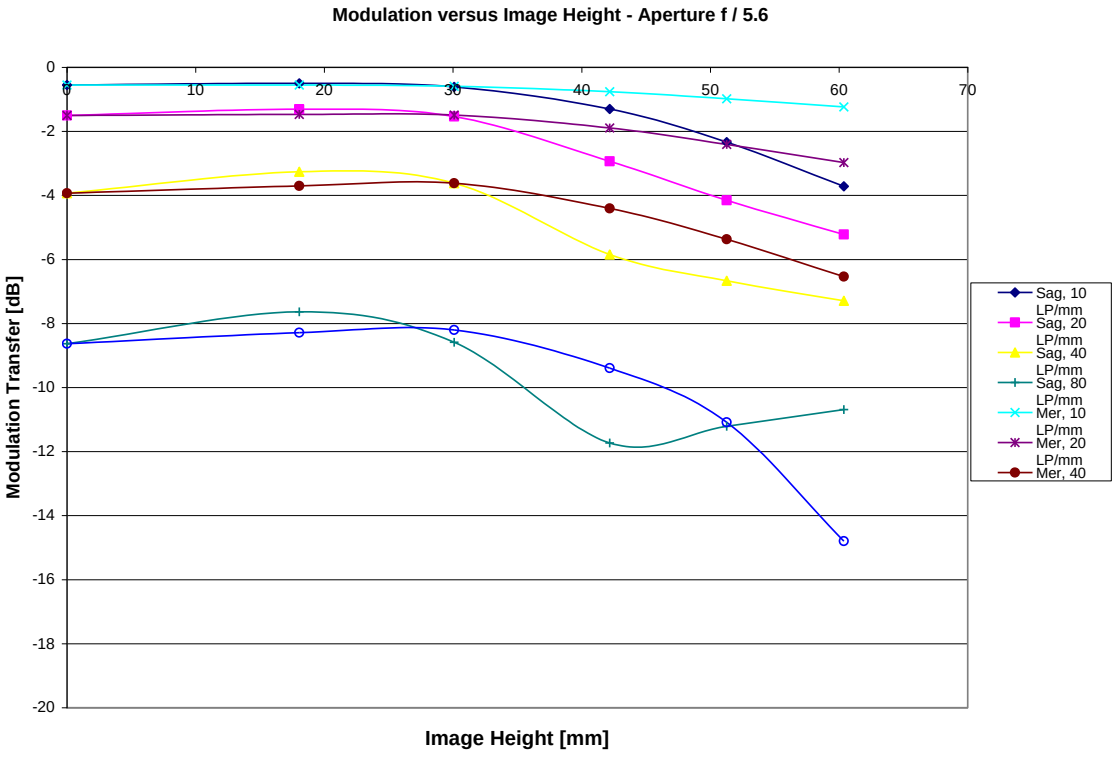
Example:
PPA_x = + 0.123 mm
PPA_y = – 0.345 mm

Lens Resolving Power

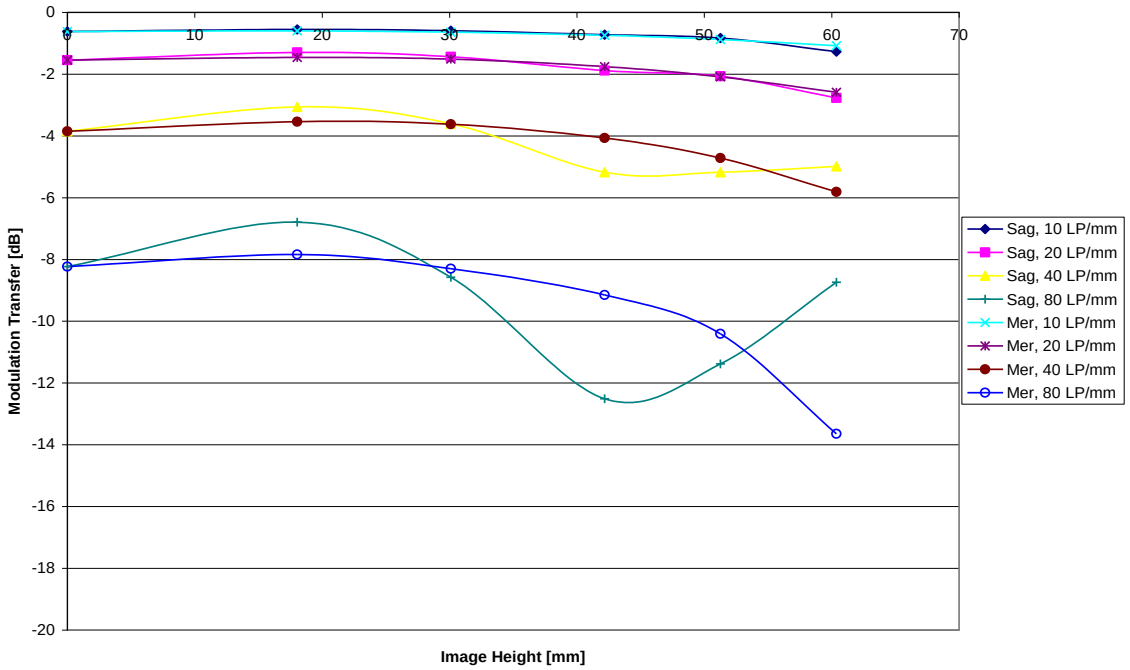
The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones.

The curves are given for the meridonial (tangential) and sagital (radial) component of signals at frequencies of 10, 20, 40 and 80 line pairs per millimeter.

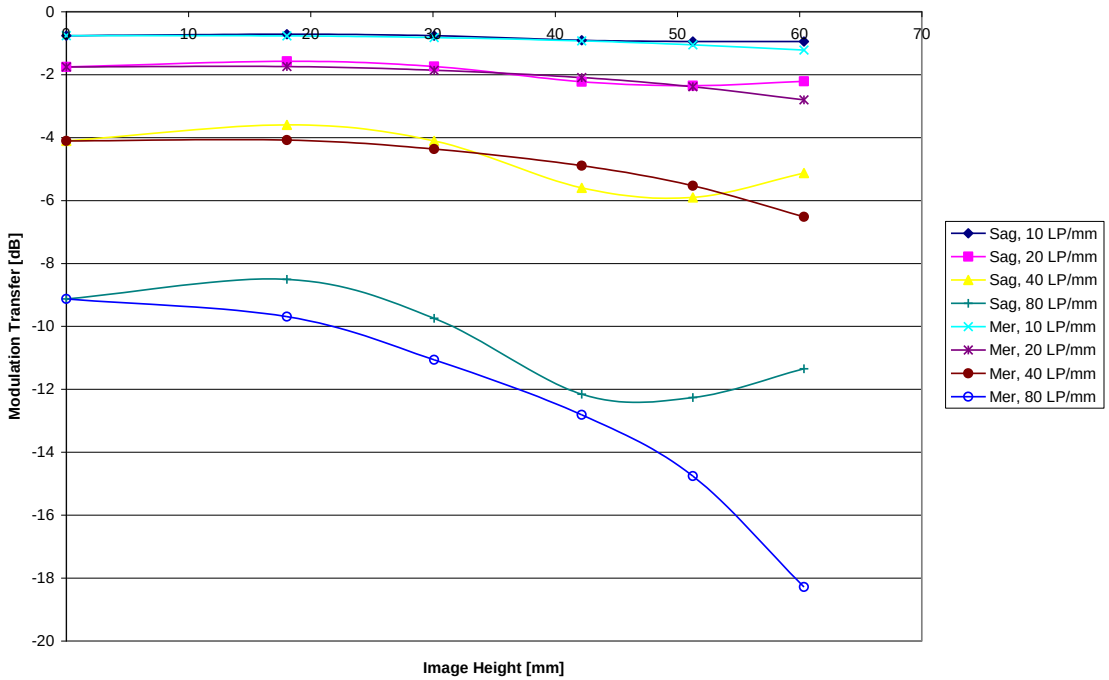
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.



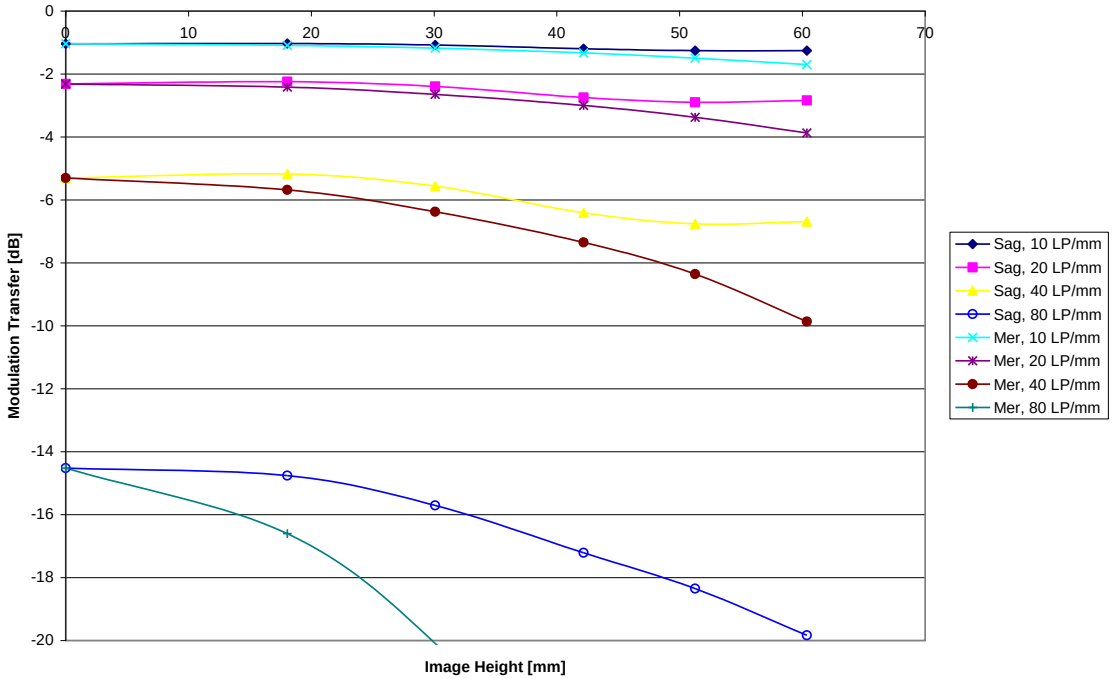
Modulation versus Image Height - Aperture f / 8



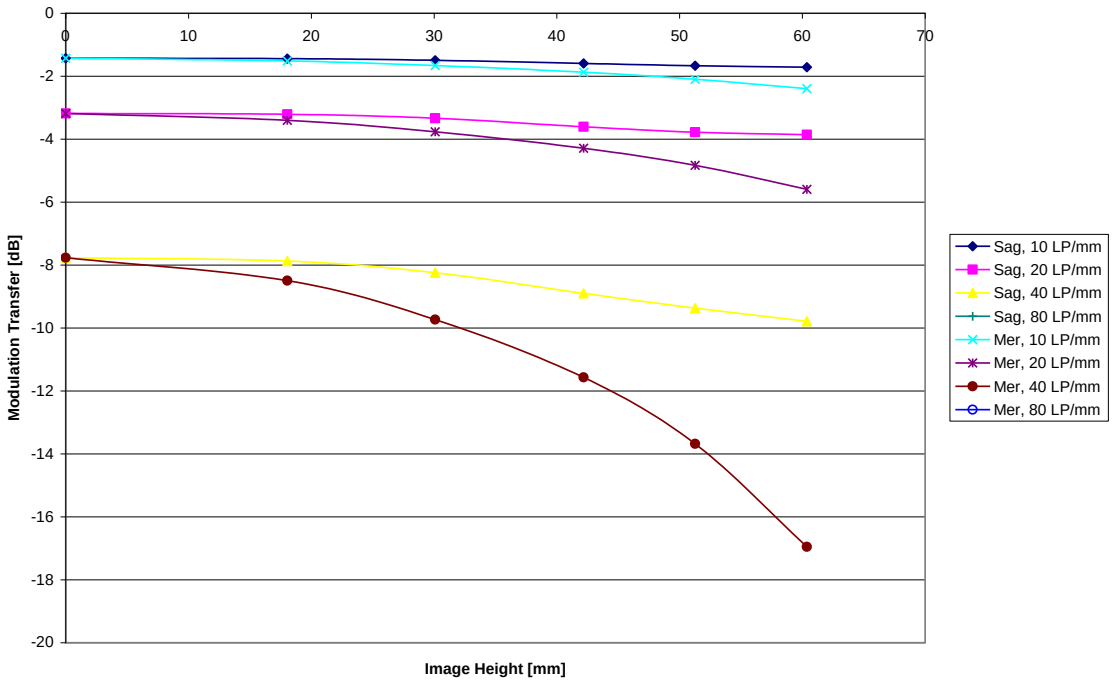
Modulation versus Image Height - Aperture f / 11



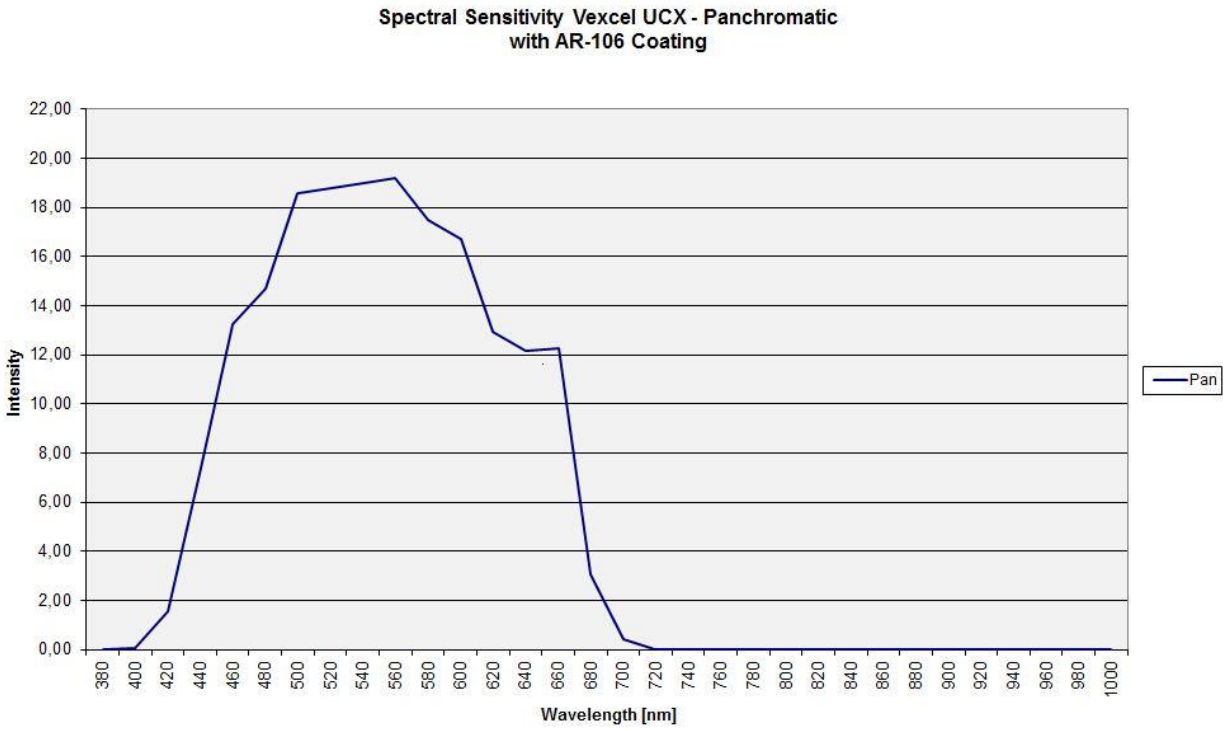
Modulation versus Image Height - Aperture f / 16

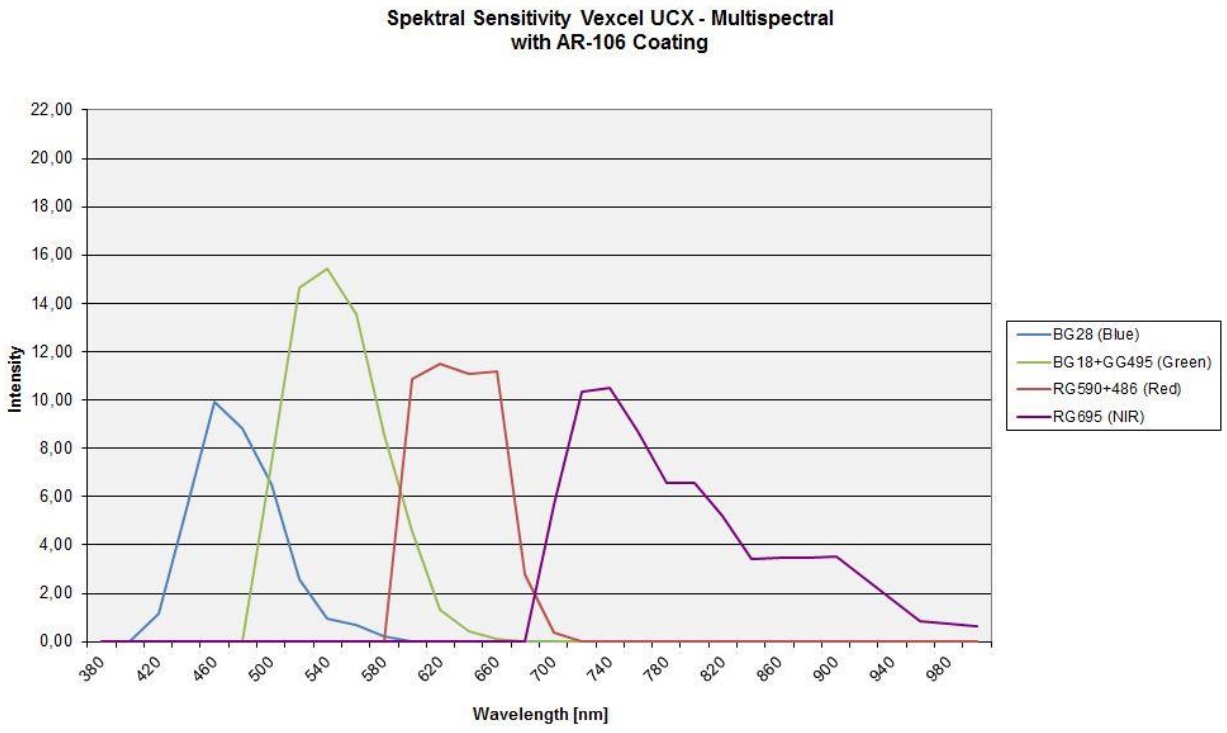


Modulation versus Image Height - Aperture f / 22



Spectral Sensitivity





Calibration Report

Radiometric Calibration

Camera: **UltraCam Falcon, S/N UC-Fp-1-50811038-f100**

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

	PAN	R, G, NIR	B
Aperture	F5.6	F4.8	F4.0
	F6.7	F5.6	F4.0
	F8	F6.7	F4.8
	F9.5	F8	F5.6
	F11	F9.5	F6.7
	F13	F11	F8
	F16	F13	F9.5
	F22	F19	F13

Date of Calibration: **Jan-28-2014**
Date of Report: **Feb-25-2014**
Revision of Camera: **Rev01**
Version of Report: **V01**

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 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

Summary

Camera:	**UltraCam Falcon, S/N UC-Fp-1-50811038-f100**
Manufacturer:	**Vexcel Imaging GmbH, A-8010 Graz, Austria**
Date of Calibration:	**Jan-28-2014**
Date of Report:	**Feb-25-2014**
Revision of Camera:	**Rev01**
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