



ULTRACAM

Calibration Report

Camera:	UltraCam Osprey 4.1
Serial:	434S92515X413270-f120
Laboratory Calibration Date:	Nov-30-2023
Camera Revision:	Rev04.00
Date of Report:	Dec-12-2023
Version of Report:	V01



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Venice, Italy

Photo on page 1 courtesy of Vexcel Imaging GmbH



ULTRACAM

Geometric Calibration

Camera:	UltraCam Osprey 4.1
Serial:	434S92515X413270-f120

Panchromatic Camera:	ck = 79.600 mm
Multispectral Camera:	ck = 49.750 mm
Oblique Camera:	ck = see table below

PPA Information Nadir:	X: 0.000 mm
	Y: 0.000 mm

PPA Information Oblique:	see table below
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Panchromatic Camera

Large Format Panchromatic Output Image

Image Format	long track	52.700mm	14016pixel
	cross track	77.245mm	20544pixel
Image Extent		(-26.350, -38.623)mm	(26.350, 38.623)mm
Pixel Size		3.760μm*3.760μm	
Focal Length	ck	79.600mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 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	52.700mm	8760pixel
	cross track	77.245mm	12840pixel
Image Extent		(-26.350, -38.623)mm	(26.350, 38.623)mm
Pixel Size		6.016μm*6.016μm	
Focal Length	ck	49.750mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		



Oblique Camera

Oblique Output Image

Image Format	long track cross track		39.706mm 53.181mm	10560pixel 14144pixel
Image Extent			(-19.853, -26.591)mm	(19.853, 26.591)mm
Pixel Size			3.760μm*3.760μm	
Focal Length	C4 (Backward)	ck	123.380mm	± 0.002mm
	C5 (Right)	ck	123.380mm	± 0.002mm
	C6 (Left)	ck	123.380mm	± 0.002mm
	C7 (Forward)	ck	123.380mm	± 0.002mm
Principal Point (Level 2)	C4 (Backward)	X_ppa	0.000mm	± 0.002mm
		Y_ppa	0.000mm	± 0.002mm
	C5 (Right)	X_ppa	-6.680mm	± 0.002mm
		Y_ppa	0.000mm	± 0.002mm
	C6 (Left)	X_ppa	6.680mm	± 0.002mm
		Y_ppa	0.000mm	± 0.002mm
	C7 (Forward)	X_ppa	0.000mm	± 0.002mm
		Y_ppa	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm			



Enhanced Resolution output:

NADIR Images:

Image Format	long track	52.700mm	21024pixel
	cross track	77.245mm	30816pixel
Image Extent		(-26.350, -38.623)mm	(26.350, 38.623)mm
Pixel Size		2.506666667μm*2.506666667μm	

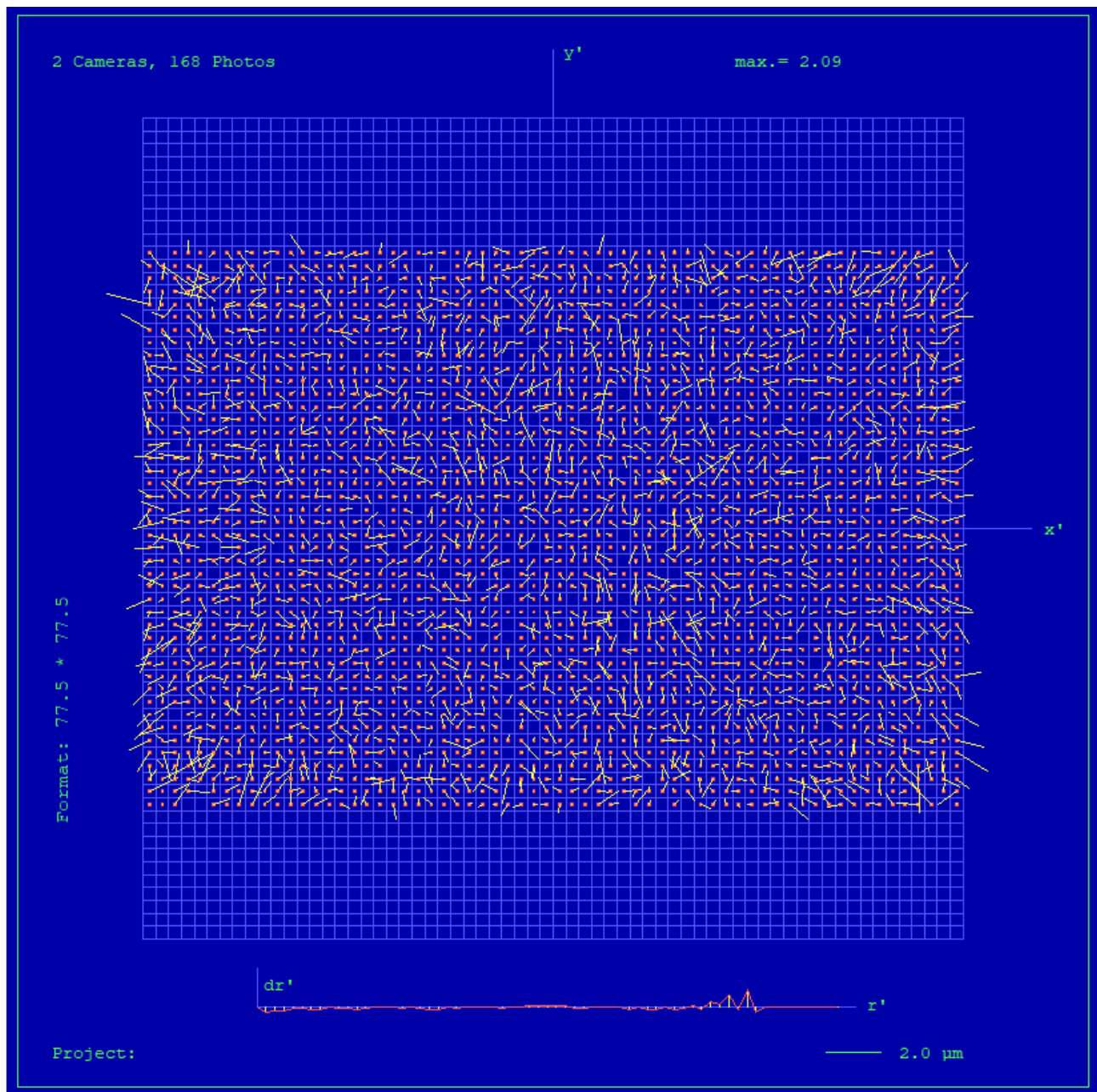
Oblique Images:

Image Format	long track	39.706mm	12210pixel
	cross track	53.181mm	16354pixel
Image Extent		(-19.853, -26.591)mm	(19.853, 26.591)mm
Pixel Size		3.251891892μm*3.251891892μm	

Other specifications, like Lens Distortion, Focal Length and Principal Point remain valid like stated on pages 4 and 5, therefore these values are not stated separately on this page.



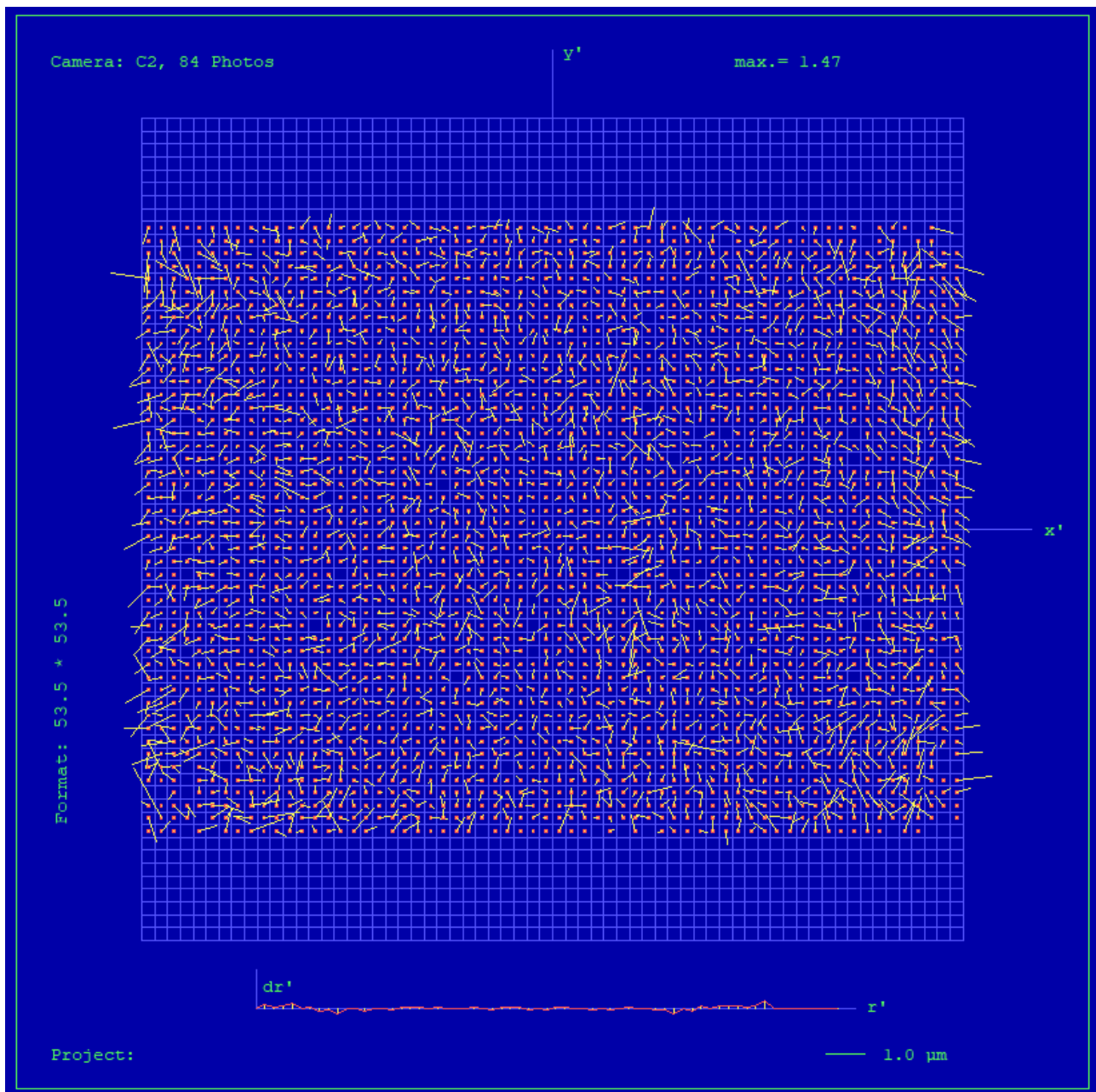
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): 0.79 μm



RGB Cone (Cone 2), Residual Error Diagram



Residual Error (RMS): **0.65 μm**



Explanations

Calibration Method:

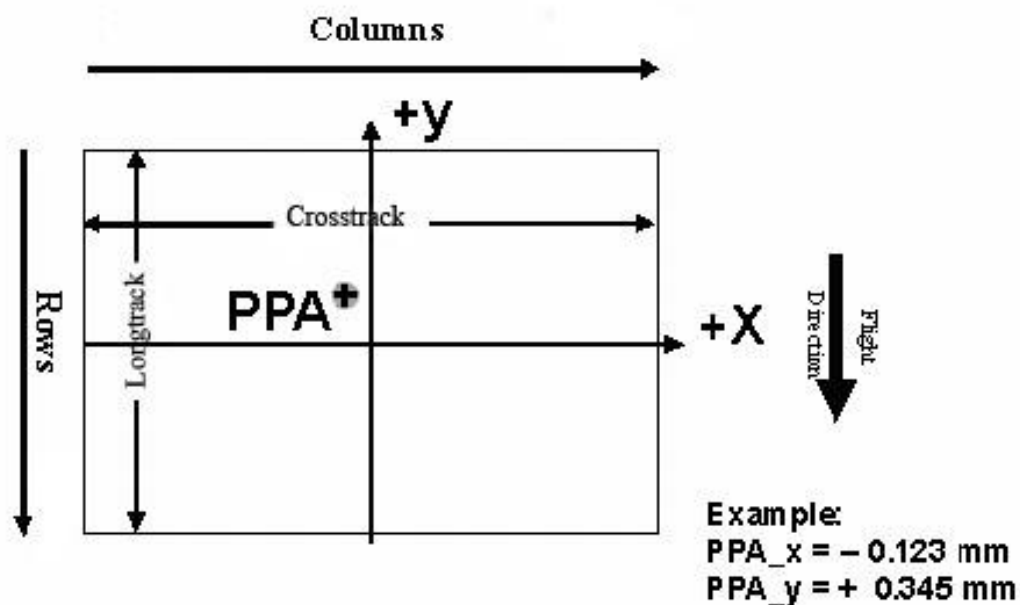
The geometric calibration is based on a set of 84 images of a defined geometry target with 394 GCPs.

Number of point measurements for the panchromatic camera :	>16000
Number of point measurements for the multispectral camera :	>60000
Number of point measurements for the oblique camera :	>9000

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

Level 2 Image Coordinate System:

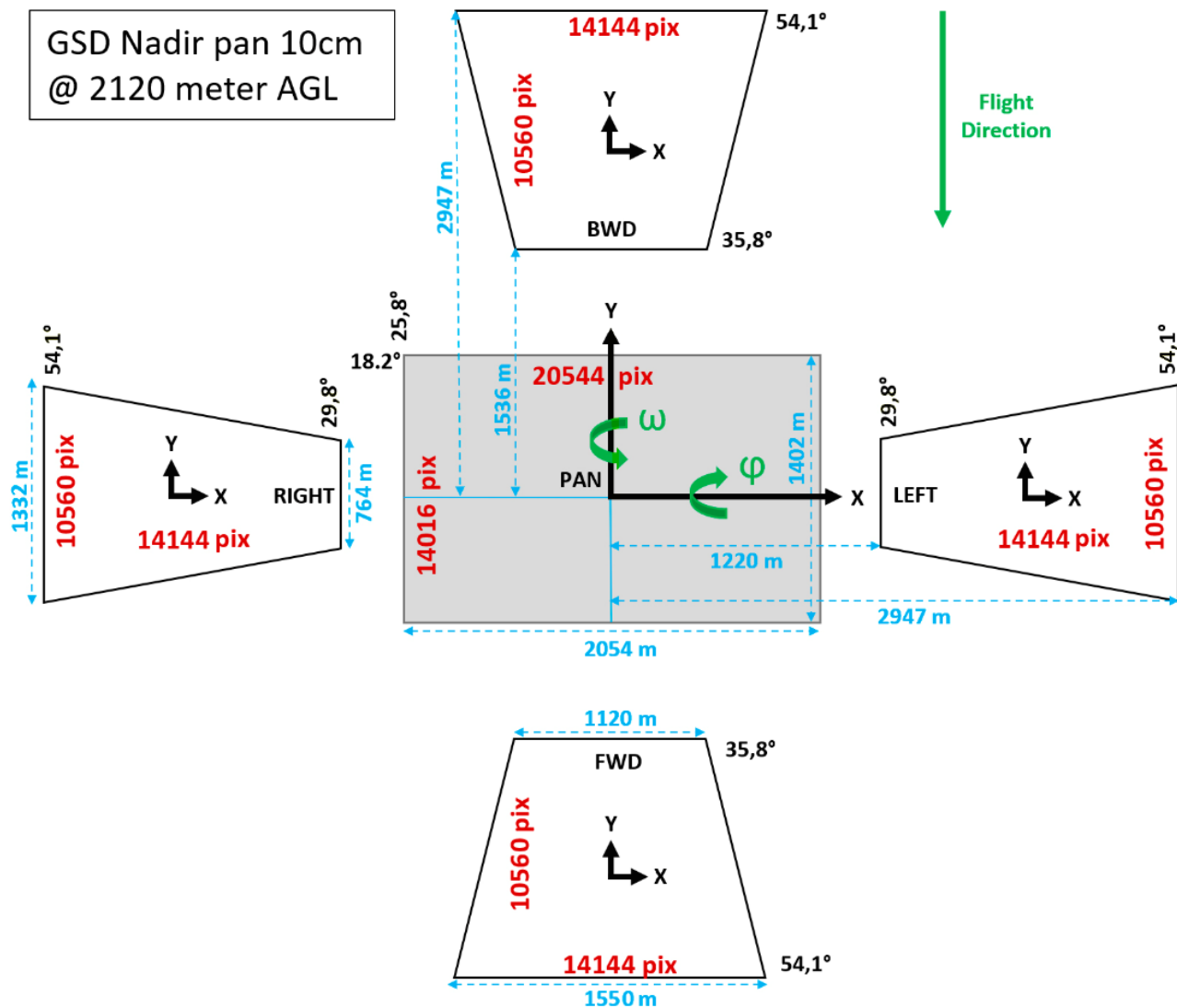
Lvl2, Camera prop. Orientation



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 4/5 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



Image Orientation Oblique Camera:





Eccentricity

Following Eccentricities are applicable for the oblique cones:

Camera	X [mm]	Y [mm]	Z [mm]	Phi [degree]	Omega [degree]	Kappa [degree]
PAN camera (C0 &C1)	0.000	0.000	0.000	0.000	0.000	0.000
RGB/I camera (C2 and C3)	0.000	0.000	0.000	0.000	0.000	0.000
C4 (Backward)	-106.765	-21.578	-7.8788	0.045	-45.005	-0.083
C5 (Right)	-115.198	-86.019	-144.939	-44.988	0.0493	-0.008
C6 (Left)	-35.585	-86.121	5.820	45.006	-0.002	-0.022
C7 (Forward)	-106.871	-100.103	-129.843	0.038	44.971	0.039



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.

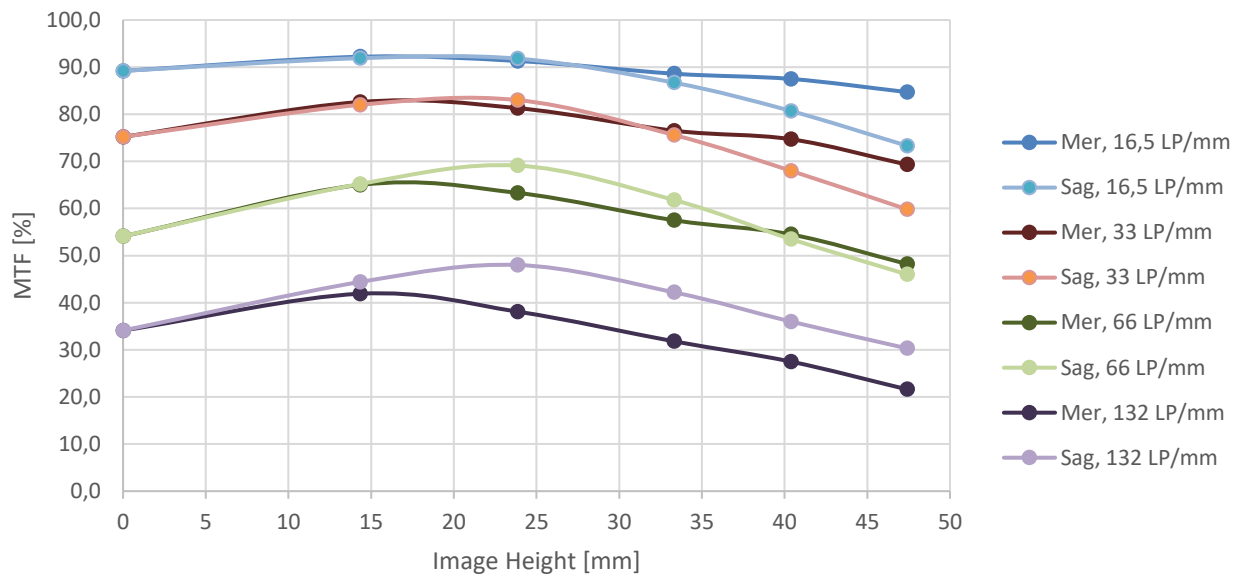
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

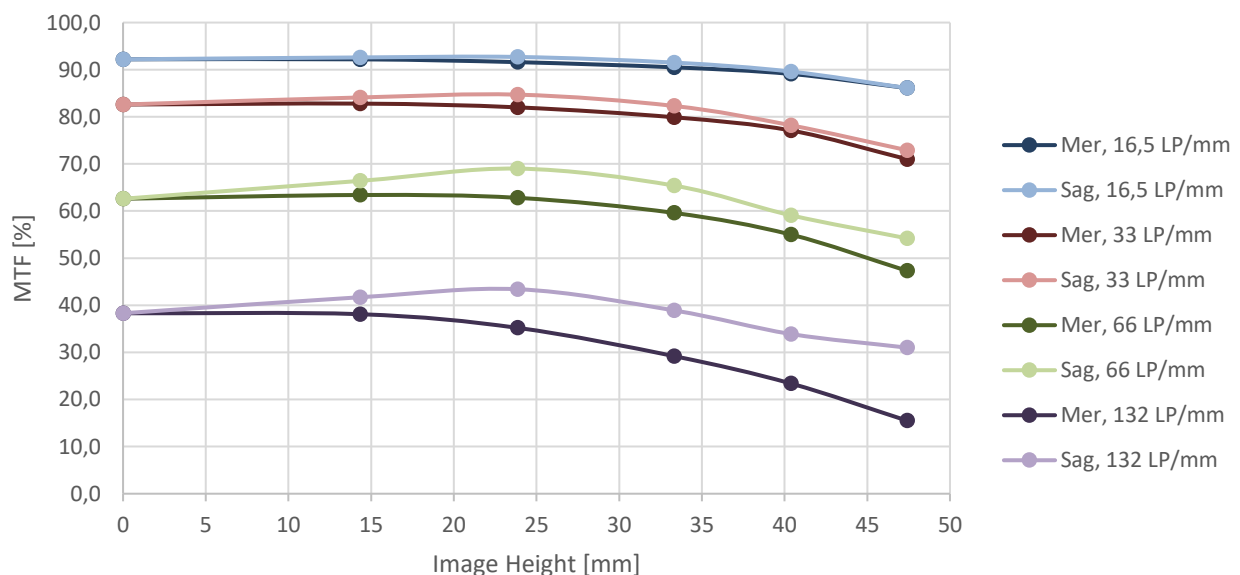
Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:4.3/80mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:4.3/80mm, Qioptic GmbH, Germany
C2 (RGB)	Qioptic Vexcel HR Digaron 1:4.2/50mm, Qioptic GmbH, Germany
C3 (NIR)	Qioptic Vexcel HR Digaron 1:4.2/50mm, Qioptic GmbH, Germany
C4 (Backward)	Qioptic Vexcel HR Digaron 1:4.2/120mm, Qioptic GmbH, Germany
C5 (Right)	Qioptic Vexcel HR Digaron 1:4.2/120mm, Qioptic GmbH, Germany
C6 (Left)	Qioptic Vexcel HR Digaron 1:4.2/120mm, Qioptic GmbH, Germany
C7 (Forward)	Qioptic Vexcel HR Digaron 1:4.2/120mm, Qioptic GmbH, Germany

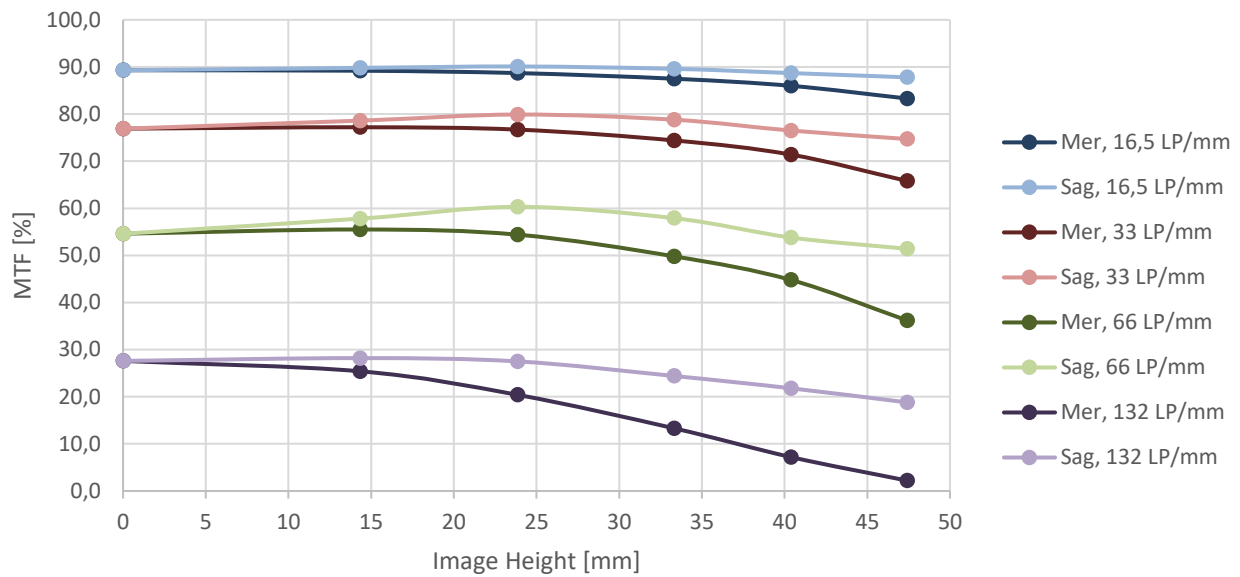
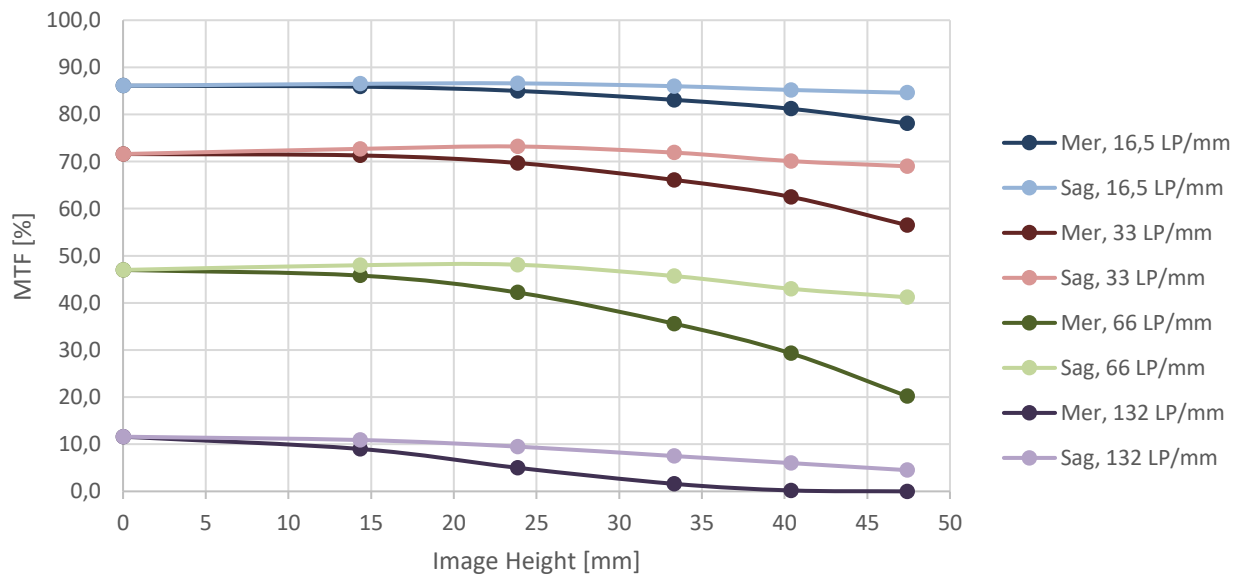


Modulation versus Image Height - Aperture f / 4.0



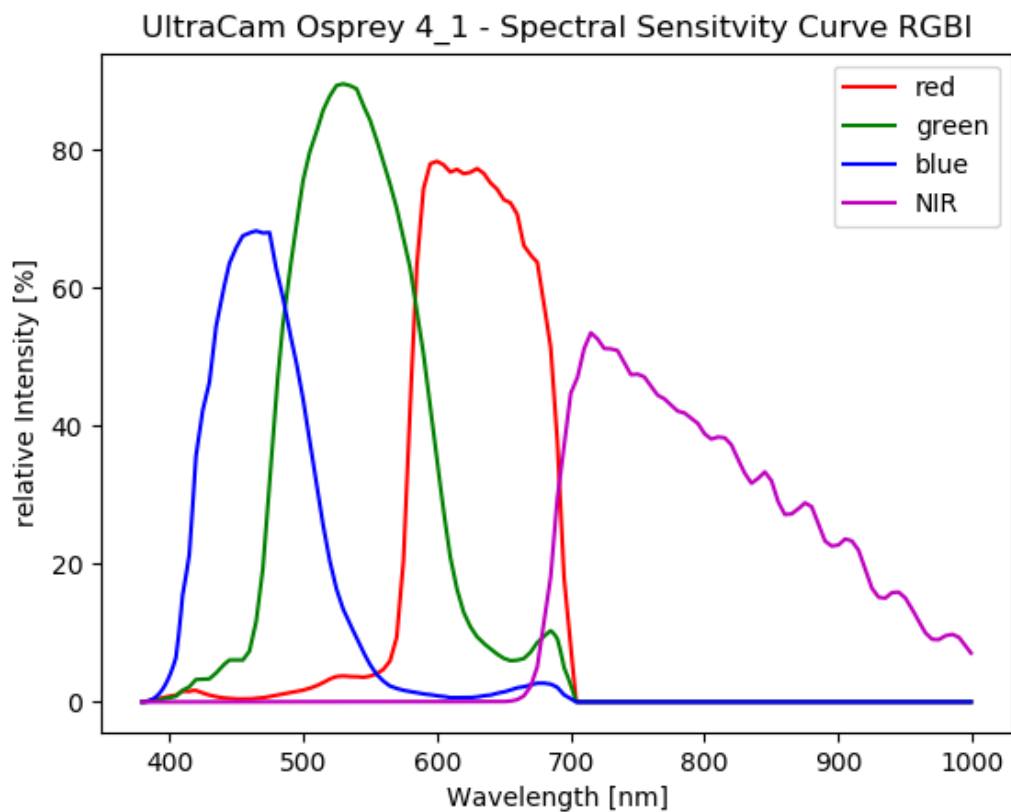
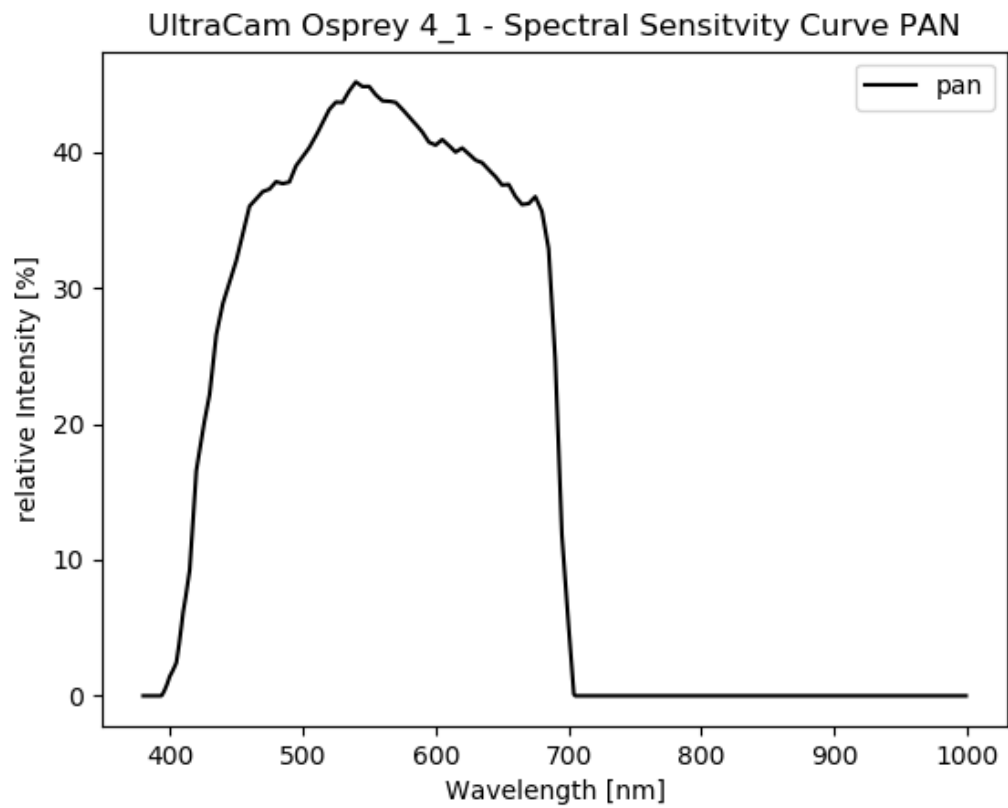
Modulation versus Image Height - Aperture f / 5.6



**Modulation versus Image Height - Aperture f / 8****Modulation versus Image Height - Aperture f / 11**



Spectral Sensitivity





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Radiometric Calibration

Camera: UltraCam Osprey 4.1
Serial: 434S92515X413270-f120

Used Apertures	PAN	RGB, NIR	Oblique
	4.8	F4.0	F4.0
	F5.6	F4.8	F4.8
	F6.7	F5.6	F5.6
	F8	F6.7	F6.7
	F9.5	F8	F8
	F11	F9.5	F9.5
	F13	F11	F11
	F19	F16	F16
	F27	F22	F22

Dead Pixel Report: see Appendix I



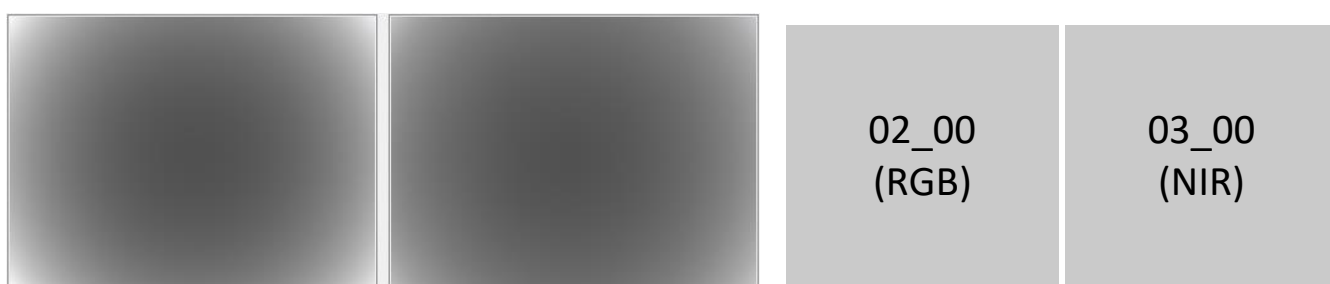
Calibration of Vignetting for working Aperture F4

	PAN	RGB, NIR	Oblique
Aperture	F4.8	F4.0	F4.0

Graphical Overview of Pan Sensor Gain Values:



Graphical Overview of Multispectral Sensor Gain Values:



Graphical Overview of Oblique Sensor Gain Values:





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 CMOS 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.



ULTRACAM

Shutter Calibration

Camera: UltraCam Osprey 4.1
Serial: 434S92515X413270-f120

Panchromatic Camera: 2 * Prontor Magnetic 0 HS
Prontor-Werk Alfred Gauthier GmbH, Germany

Multispectral Camera: 2 * Prontor Magnetic 0 HS
Prontor-Werk Alfred Gauthier GmbH, Germany

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



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.

Currently used SRT values (operation values):

Cone Number	Lens Serial Number	SRT F4.0 [ms]	SRT F4.8 [ms]	SRT F5.6 [ms]	SRT F6.7 [ms]	SRT F8 [ms]	SRT F9.5 [ms]	SRT F11 [ms]	SRT F16 [ms]	SRT F22 [ms]	Measurement Tolerance [ms]
C0 (Pan)	12 59 18 20	6.66	6.98	7.31	7.63	7.87	8.05	8.20	8.48	8.58	+/- 0.2
C1 (Pan)	12 59 18 27	6.66	6.96	7.35	7.64	7.88	8.07	8.20	8.46	8.60	+/- 0.2
C2 (RGB)	12 58 25 91	7.26	7.42	7.77	8.01	8.30	8.44	8.57	8.78	9.02	+/- 0.2
C3 (NIR)	12 58 25 81	7.18	7.38	7.71	8.01	8.19	8.38	8.52	8.77	8.88	+/- 0.2
C4 (Backward)	12 58 62 94	5.70	6.03	6.60	6.98	7.29	7.52	7.69	7.98	8.19	+/- 0.2
C5 (Right)	12 58 62 90	6.01	6.24	6.87	7.23	7.59	7.85	8.05	8.35	8.52	+/- 0.2
C6 (Left)	12 66 48 93	5.08	5.37	5.89	6.26	6.56	6.76	6.96	7.25	7.46	+/- 0.2
C7 (Forward)	12 58 62 76	5.95	6.29	6.91	7.30	7.65	7.88	8.05	8.40	8.61	+/- 0.2



ULTRACAM

Electronics and Sensor Calibration

Camera: UltraCam Osprey 4.1
Serial: 434S92515X413270-f120

Panchromatic Camera: 2 * IMX411-ALR-M CMOS Sensor by SONY
Multispectral Camera: 1 * IMX411-AQR-C CMOS Sensor by SONY
1 * IMX411-ALR-M CMOS Sensor by SONY
Oblique Camera: 4 * IMX411-AQR-C CMOS Sensor by SONY



Calibration of Intensity Threshold for Exposure Control:

Each CMOS 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 CMOS and electronics.

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

Currently used Threshold values (operation values):

Cone_Sensor	Sensor Type	Sensor Serial Number	Intensity Threshold [DN]
00_00 (PAN)	IMX411-ALR-M	00001B282525	16130
01_00 (PAN)	IMX411-ALR-M	00001B2844C6	16130
02_00 (RGB)	IMX411-AQR-C	00001CCB732B	16130
03_00 (NIR)	IMX411-ALR-M	00001B284D83	16100
04_00 (Backward)	IMX411-AQR-C	00001B284F6A	16130
05_00 (Right)	IMX411-AQR-C	00001B283707	16130
06_00 (Left)	IMX411-AQR-C	0000128D4311	16130
07_00 (Forward)	IMX411-AQR-C	00001B28682E	16130



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Summary

Camera:	UltraCam Osprey 4.1
Serial:	434S92515X413270-f120

Laboratory Calibration Date:	Nov-30-2023
Camera Revision:	Rev04.00

Date of Report:	Dev-12-2023
Version of Report:	V01

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.

Dr. Michael Gruber
Chief Scientist, Photogrammetry
Vexcel Imaging GmbH

Dipl. Ing. (FH) Helmut Jauk
Senior Project Engineer R&D
Vexcel Imaging GmbH



Appendix I

Dead Pixel Report:

Cone_Sensor	Dead Pixel Count
00_00 (PAN)	595
01_00 (PAN)	620
02_00 (RGB)	659
03_00 (NIR)	616
04_00 (Backward)	523
05_00 (Right)	736
06_00 (Left)	508
07_00 (Forward)	757



Appendix II

Calibration and Modification Dates

Type of Calibration	Laboratory Calibration Date	Modification Date	Modification Reason
Geometric Calibration	Nov-30-2023		
Radiometric Calibration	Nov-30-2023		
Shutter Calibration	Nov-30-2023		
Electronics and Sensor Calibration	Nov-30-2023		

Note: The above-mentioned Laboratory Calibration Dates represent the dates the camera was calibrated in one of our calibration labs for a full Laboratory Calibration. The Modification date represents a date on which the calibration has been modified due to a calibration enhancement or part exchange. It is an additional information and does not replace the Laboratory Calibration date in any way. With the Modification Reason, always the last modification to the calibration is highlighted.