AEROQUEST

MAPCON

Aerial Triangulation Report

2020 City of Nanaimo Aerial Mapping Project

Project # 200014

Date: **May 21, 2020**

City of Nanaimo,
455 Wallace Street,
Nanaimo, B.C.,
V9R 5J6

Attention: **Mr. Mark Willoughby,**

TABLE OF CONTENT

APPENDICIES

1.1 SCOPE OF PROJECT

Aeroquest Mapcon Inc. adjusted a total of 1207 digital colour images to support an aerial Triangulation accuracy (AT) of 4.0cm RMSE horizontally and vertically. An additional 112 models were created based solely on post processed airborne GPS/IMU data for images covering water. Summary of Aerial Triangulation input data, procedure and results are presented below.

1.2 PHOTOGRAPHY

Digital color images were flown at a mean photo scale of 1:8,863 to support a 4.0cm pixel size and 4.0cm AT accuracy. All images were captured by Kisik Aerial Survey of Richmond, B.C. using a Vexcel UltraCam Eagle M3 digital camera with airborne GPS and inertial measuring unit. Flights took place on April 09 and 11, 2020. All images were flown at a nominal 60% forward gain and 30% sidelap. All images were flown with < 2º off level and course. Camera calibrations report can be found in Appendix E.

1.3 GROUND CONTROL

Ground control used was surveyed by J. E. Anderson & Associates in 2016 and 2018 of Nanaimo, B.C. and by Eagle Mapping Ltd. of Port Coquitlam B.C. For 2016 Lidar control. Additional control was supplied by City of Nanaimo and existing BC Government MASCOT points.

1.3a Ground control and weights

I. **47** J.E. Anderson controls were used in final adjustment. 41 points were used as horizontal and vertical (HV) control and 6 as vertical-only. 1 point was used as HV check point in preliminary adjustment. All HV points were photo identified locations.
II. **14** Eagle controls were used in final adjustment. Of these 10 were used as horizontal/vertical control, 3 were used as vertical-only control and 1 was used as horizontal-only control. All horizontal points were at photo identified locations.
III. **21** BC Government MASCOT points were used in final adjustment. 18 were used as horizontal and vertical control and 3 as vertical-only. 20 HV points were used as check points in in preliminary adjustment. Horizontal locations were based on visible monument access covers.
IV. **55** City of Nanaimo supplied points were used in final adjustment. 54 points were used as horizontal and vertical control. One was used as vertical-only. 6 HV points were used as check points in preliminary adjustment. 51 HV points were targeted and 3 photo-identified.
V. All control points were assigned a horizontal/vertical weight of 4cm.

1.4 CONTROL DATUM

Projection – UTM zone 10
Horizontal Datum - North American 1983 (CSRS)
Vertical Datum – CGVD28
Units – Metres

1.5 PROCEDURE

All adjusted images were bridged using Vexcel's UltraMap (ver. 4.5.3) automatic tie point generation software (ATP). The ATP result was then analyzed and areas of failed correlation were densified by manual means using Intergraph's ISAT software (ver. 16.5.0). Ground control was also read in ISAT. All bridged data was then exported to GIP's BINGO (ver. 7.2) adjustment software. A preliminary adjustment with check points 'floated' was performed. Once satisfied check point residuals fell within 4cm of surveyed coordinates they were weighted and used as control in a final adjustment. The final adjustment was exported back to Intergraph's ISAT and models created. QC of the model was then done using Intergraph's ISSD module. The QC involved checks for tie to ground control, parallax and line tie accuracy. The project extent covers areas of water were some images could not be adjusted. Model setups for these images are based on post processes airborne GPS and IMU received from Kisik Aerial Surveys.

No airborne data was used in the adjustment due to the high accuracy specified and the high density of ground control.

1.6 RESULTS

Statistical results are based on the final adjustment that included check points as control. Results are based on RMSE (root/mean/square) or approximately 68% confidence interval.

Type of measurements	A priori Standard Deviation			Computed Standard Deviations		
	X	Y	Z	X	Y	Z
	Metres	Metres	Metres	Metres	Metres	Metres
Pass/tie points	2.0 microns	2.0 microns	n/a	0.9microns	0.8microns	n/a
Surveyed Control	0.04	0.04	0.04	0.029	0.027	0.022

Standard Deviations of Adjusted Terrain Coordinates

		X [m]	Y [m]	Z [m]
Total number	18,863			
Mean Precision		0.018	0.026	0.065 *

* - Mean vertical precision is high due to many 2-ray tree top points that have no weight in the adjustment. The vertical precision base on ≥ 3-ray points is 2.8cm.

Standard precision of adjusted Orientation Parameters

		X0 [m]	Y0 [m]	Z0 [m]	Omega [Deg.]	Phi [Deg.]	Kappa [Deg.]
Total number	1207						
Mean Precision		0.076	0.071	0.049	0.0058º	0.0057º	0.0018º

Image observation residuals

	X microns	Y microns
RMS value	0.9	0.8
Max residual	17.6	19.6

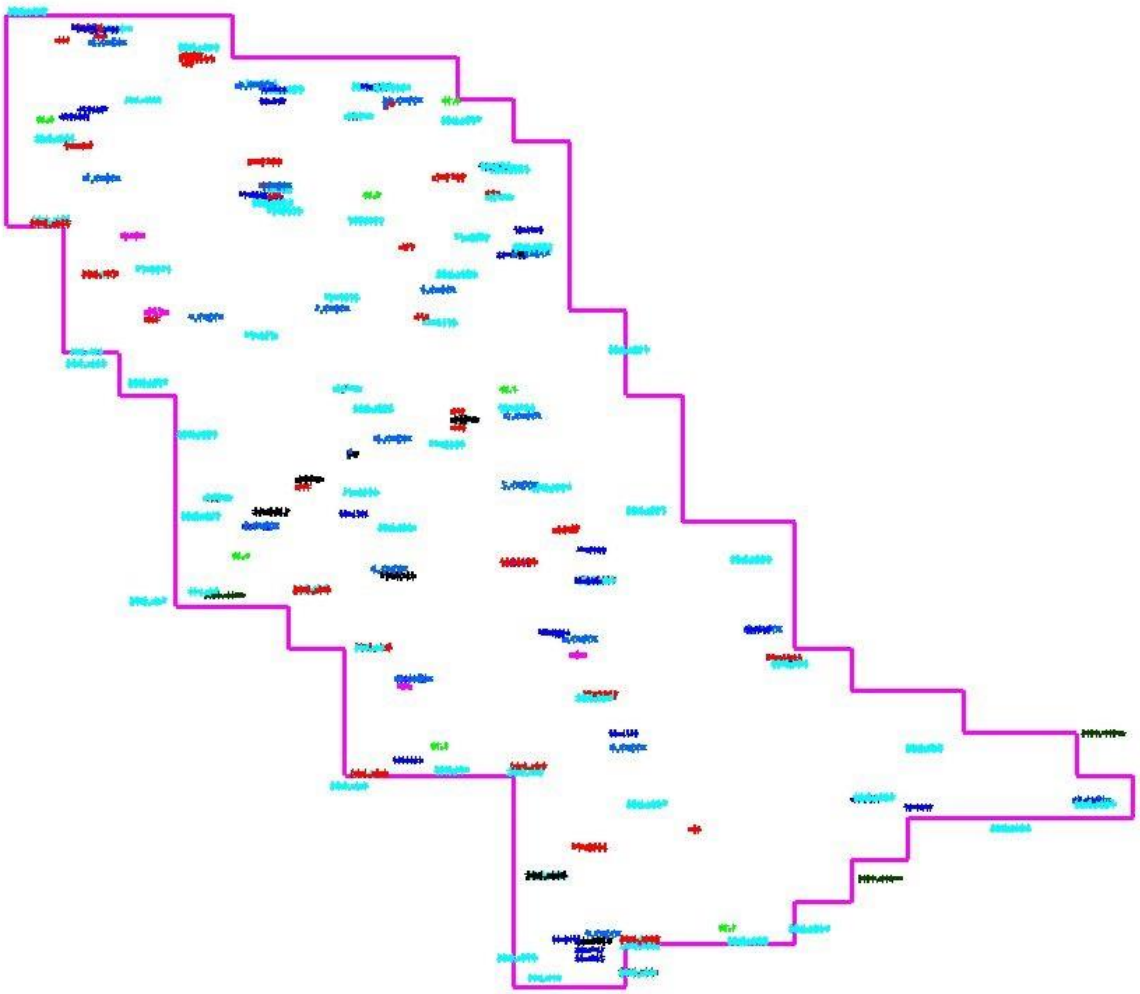
1.7 Statement of Accuracy

A total of 75,303 readings of 18,863 adjusted points were generated by the adjustment. This result is 4.0 readings per point and 15.6 point per image. The computed mean ground sample distance (GSD) for the adjusted images is 3.6cm. The mean standard deviation of ground control used is 0.038m horizontally and 0.022m vertical. The mean standard deviation of adjusted terrain points is 0.032m horizontal and 0.027m (without 2-ray points) vertical. This shows that both photography and adjustment fall within specification for 4.0cm image resolution and 8.0cm horizontal and vertical data accuracy.

Björn E. Norman CP # R1264,
Aerial Triangulation Manager

APPENDIX A: Image Centre Layout

APPENDIX B: Ground Control Layout



APPENDIX C: CHECK POINT REPORT

Aeroquest Observations				Surveyed Observations			Differences (metre)		
read_x	read_y	read_z	POINT NAME	read_x	read_y	read_z	DD_x	DD_y	DD_Z
422965.634	5453902.787	106.176	03SG086	422965.660	5453902.788	106.190	0.026	0.001	0.014
432193.778	5445656.315	9.245	77H5084	432193.743	5445656.309	9.278	0.035	0.006	0.033
429381.806	5450244.758	3.248	77H5335	429381.817	5450244.729	3.300	0.011	0.029	0.052
423150.780	5455472.580	46.999	79H9176	423150.803	5455472.573	47.052	0.023	0.007	0.053
430361.803	5443591.126	74.016	79H9177	430361.766	5443591.072	74.071	0.037	0.054	0.055
435504.887	5444274.964	5.371	79H9348	435504.871	5444274.971	5.412	0.016	0.007	0.041
426391.868	5446880.086	160.826	82H5662	426391.868	5446880.038	160.842	0.000	0.048	0.016
430409.271	5453015.137	14.021	90H6361	430409.284	5453015.136	13.985	0.013	0.001	0.036
430934.236	5451895.221	42.829	92H0754	430934.222	5451895.186	42.875	0.014	0.035	0.046
430778.206	5445980.945	58.624	98SG039	430778.205	5445980.936	58.576	0.001	0.009	0.048
429594.015	5452817.704	164.359	13H2702V	429594.020	5452817.677	164.349	0.005	0.027	0.010
426314.453	5453096.691	169.537	14H2760V	426314.461	5453096.685	169.580	0.008	0.006	0.043
432047.815	5440920.956	97.861	79H5596V	432047.813	5440920.950	97.891	0.002	0.006	0.030
425063.620	5454914.637	71.032	79H5599V	425063.582	5454914.599	71.052	0.038	0.038	0.020
424300.183	5451184.761	101.932	79H9275V	424300.163	5451184.759	101.989	0.020	0.002	0.057
432237.343	5443640.002	43.711	79H9362V	432237.357	5443640.039	43.718	0.014	0.037	0.007
429516.287	5448075.938	70.811	77H5288HV	429516.237	5448075.977	70.857	0.050	0.039	0.046
426624.273	5452226.683	156.165	79H5539HV	426624.329	5452226.649	156.201	0.056	0.034	0.036
429965.230	5451745.833	116.993	79H5572HV	429965.212	5451745.843	117.007	0.018	0.010	0.014
426235.923	5450004.760	114.471	79H9231HV	426235.903	5450004.772	114.487	0.020	0.012	0.016
428634.281	5445738.640	211.864	79H9269HV	428634.275	5445738.638	211.810	0.006	0.002	0.054
427981.126	5447220.122	67.647	79H9280HV	427981.071	5447220.157	67.613	0.055	0.035	0.034
426253.948	5454468.105	47.936	79H9315HV	426253.949	5454468.104	47.980	0.001	0.001	0.044
427643.195	5450689.860	107.498	79H9393HV	427643.153	5450689.852	107.486	0.042	0.008	0.012
428547.930	5454410.324	27.274	83H6054HV	428547.984	5454410.310	27.285	0.054	0.014	0.011
428072.852	5452053.696	109.771	98SG022HV	428072.859	5452053.679	109.792	0.007	0.017	0.021
430848.651	5448584.331	10.623	12_CHECKHV	430848.650	5448584.328	10.577	0.001	0.003	0.046
431327.624	5447315.666	13.906	2016_1024HV	431327.634	5447315.629	13.882	0.010	0.037	0.024
						RMSE	0.027	0.025	0.036

APPENDIX D: FINAL BINGO ADJUSTMENT REPORT

PROJECT: 200014 - NANAIMO
4.0cm AT ACCURACY

2020, May 21., 6:48:20

Input Data Report:

No. of Used Points	18863
No. of Used Photos	1208
No. of Used Cameras	1
Used Points per Photo	62
Ignored Images	0
Ignored Points	49
Ignored Control Points	0

SIGMA0: 1.10

Photo Measurement Residulas (µm)

	x'	y'
RMS	0.9	0.8
MAX	17.6	19.6

Control Point Residuals (1/1000)

	X	Y	Z
RMS	29.	27.	22.
MAX	107.	84.	64.

GPS Residuals (1/1000)

	X	Y	Z
RMS	-	-	-
MAX	-	-	-

Check Point Residuals (1/1000)

	X	Y	Z
RMS	-	-	-
MAX	-	-	-

IMU Residuals (1/1000)

	Φ	Ω	K
RMS	-	-	-
MAX	-	-	-

GPS/IMU (max)

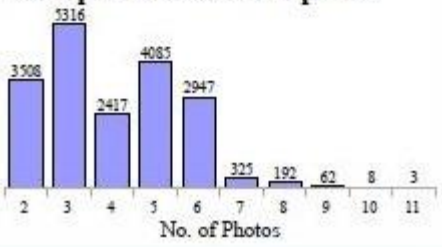
	s_X	s_Y	s_Z
Drift	-	-	-
Shift	-	-	-

Additional Parameters

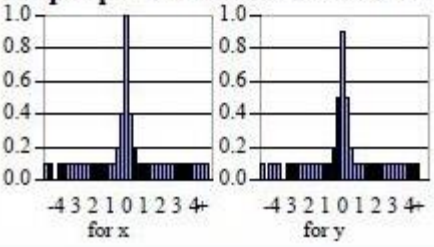
Variance-component estimation test value: s(a posteriori) / s(a priori)

Photo coordinates	0.55			
Coordinates of control points	0.79	x:0.81	y:0.74	z:0.83
Sum of all observation	0.55			

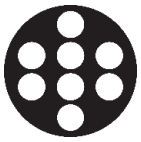
No. of points measured on photos



Freq. of photo measurement residuals



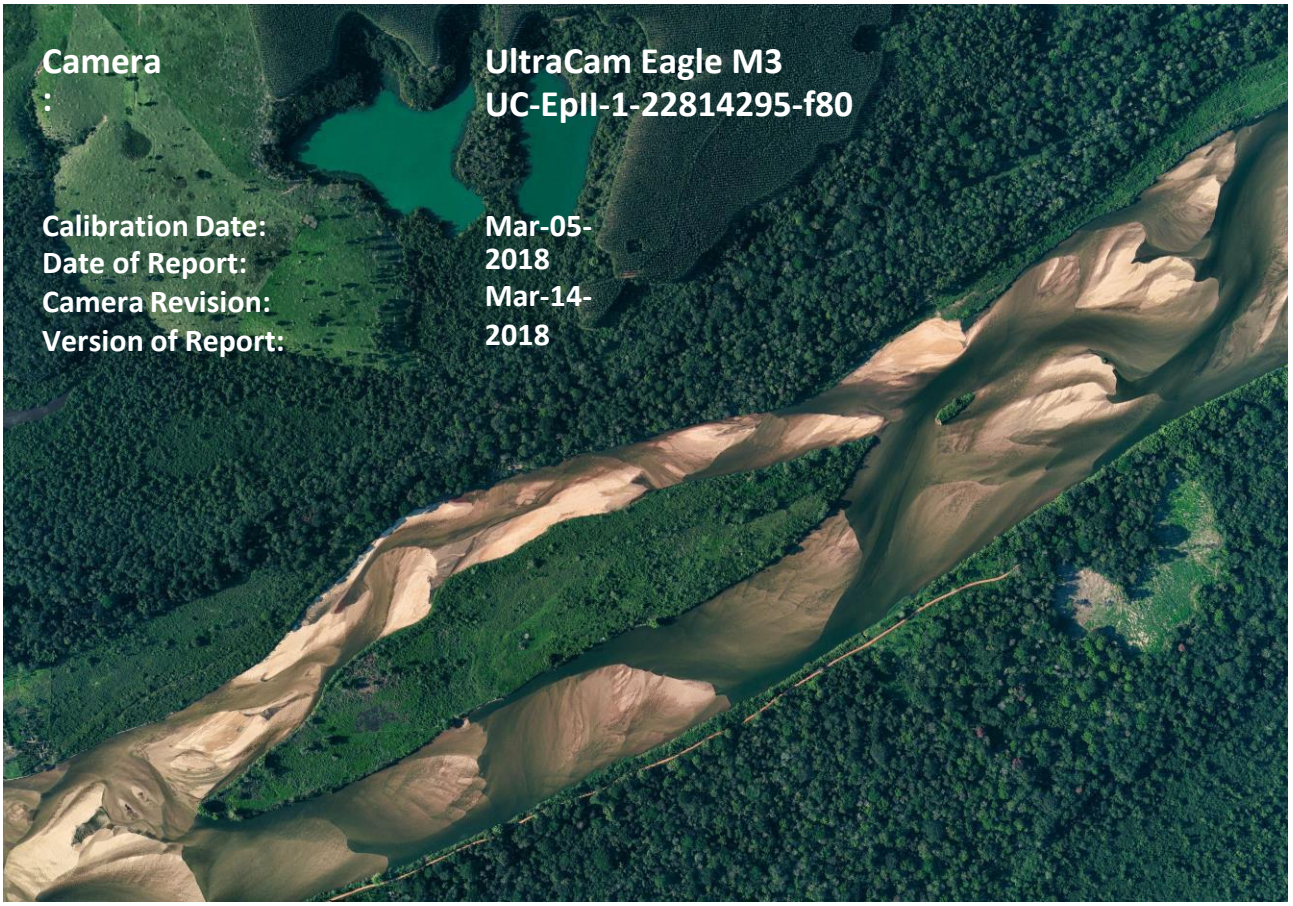
APPENDIX E: Camera Calibration Report



VEXCEL
IMAGING

ULTRACAM

Calibration Report



Camera :	**UltraCam Eagle M3 UC-EpII-1-22814295-f80**
Calibration Date:	**Mar-05-2018**
Date of Report:	**Mar-14-2018**
Camera Revision:	
Version of Report:	

Bahia, Brasil 2013

Photo on page 1 courtesy of Hiparc Geotecnologia, Brasil
www.hiparc.com
UltraCam Lp, GSD25 cm, RGB

ULTRACAM

Geometric Calibration

UltraCam Eagle M3

Serial:	**UC-EpII-1-22814295-f80**
Panchromatic Camera:	**ck = 79.800 mm**
Multispectral Camera:	**ck = 79.800 mm**
PPA Information:	**X: 0.000 mm**
	Y: 0.000 mm
Calibration Date:	**Mar-05-2018**
Date of Report:	**Mar-14-2018**
Camera Revision:	**Rev01.00**
Version of Report:	**V01**

Panchromatic Camera

Large Format Panchromatic Output Image

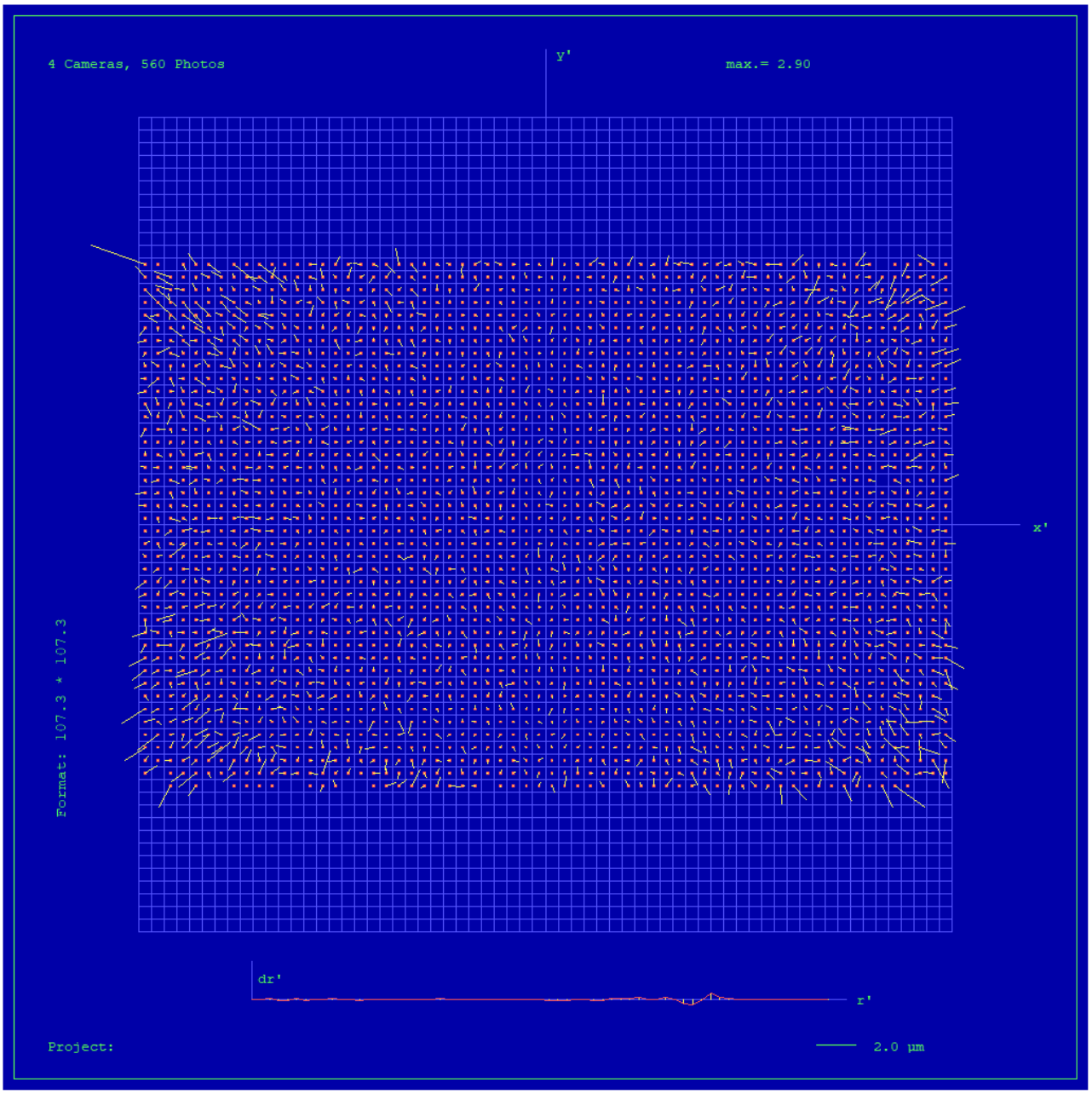
Image Format	long track cross track	68.016mm 105.840mm	17004pixel 26460pixel
Image Extent		(-34.008, -52.920)mm	(34.008, 52.920)mm
Pixel Size		4.000µm*4.000µm	
Focal Length	ck	79.800mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion		Remaining Distortion less than 0.002mm	

Multispectral Camera

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

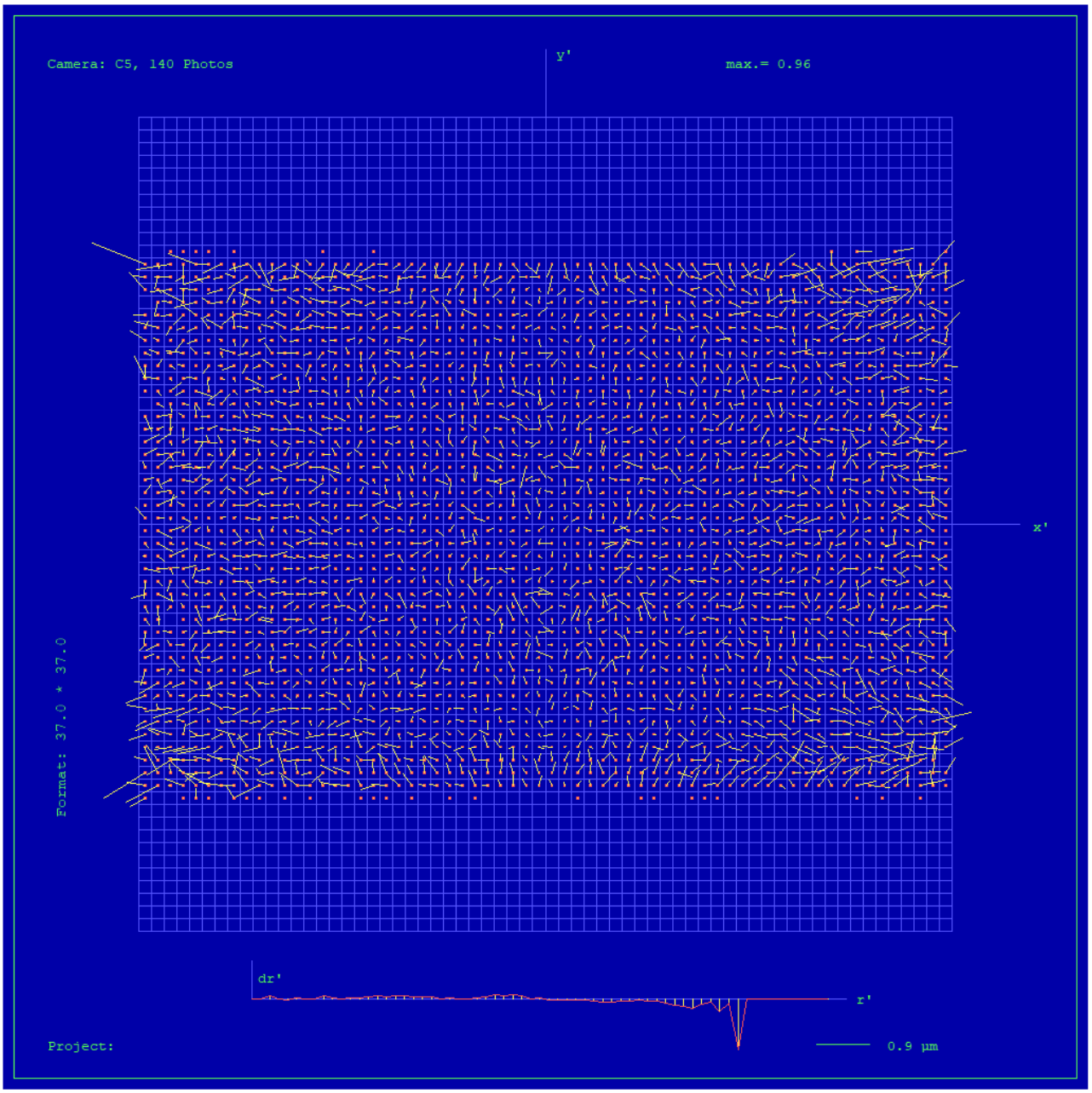
Image Format	long track cross track	68.016mm 105.840mm	5668pixel 8820pixel
Image Extent		(-34.008, -52.920)mm	(34.008, 52.920)mm
Pixel Size		12.000µm*12.000µm	
Focal Length	ck	79.800mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.000mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion		Remaining Distortion less than 0.002mm	

Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.59 µm**

Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.40 µm**

Explanations

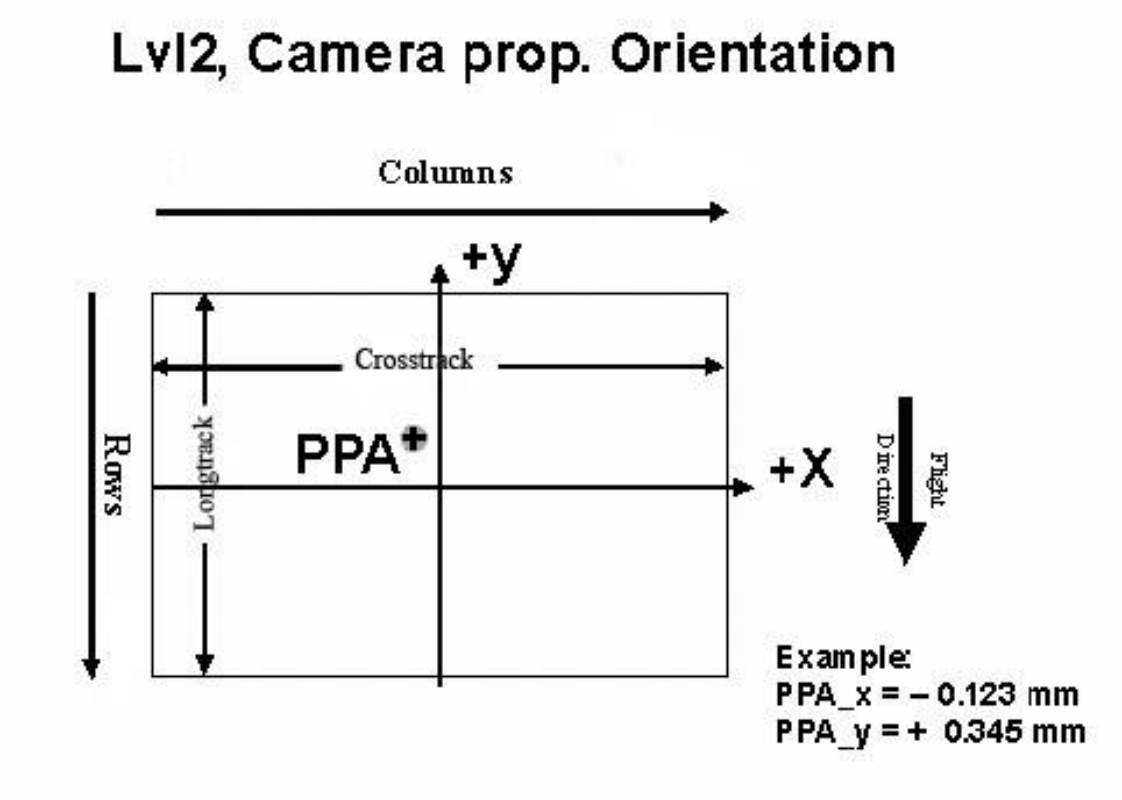
Calibration Method:

The geometric calibration is based on a set of 140 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

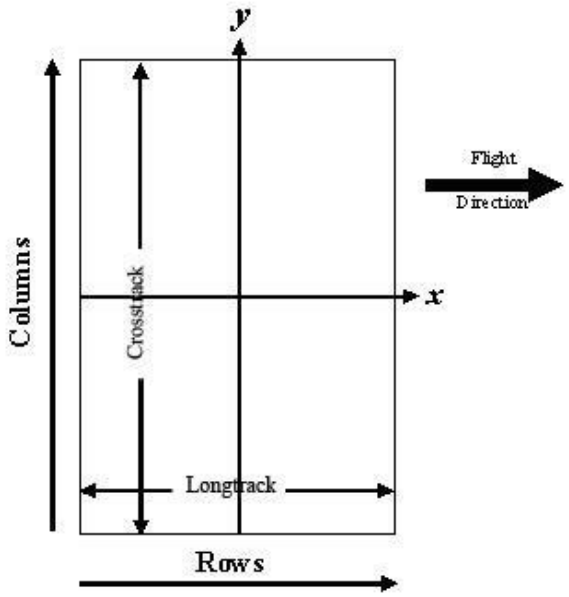
Determination of the image parameters by Least Squares Adjustment. Software used for the adjustment: BINGO (GIP Eng. Aalen, Germany)

Level 2 Image Coordinate System:

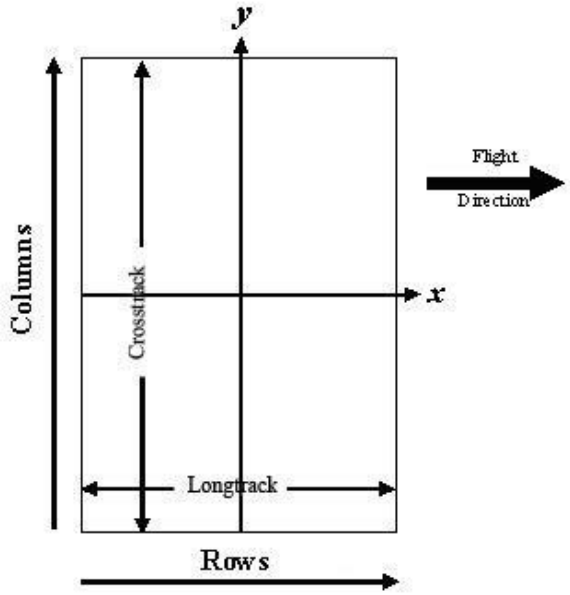


The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).

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



Panchromatic Image Format



Multispectral Image Format

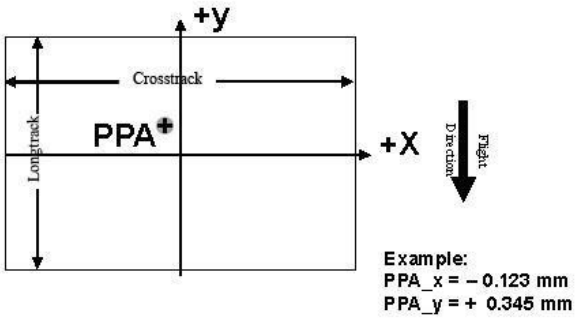
Position of Principal Point in Level 3 Image

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 coor- dinate 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

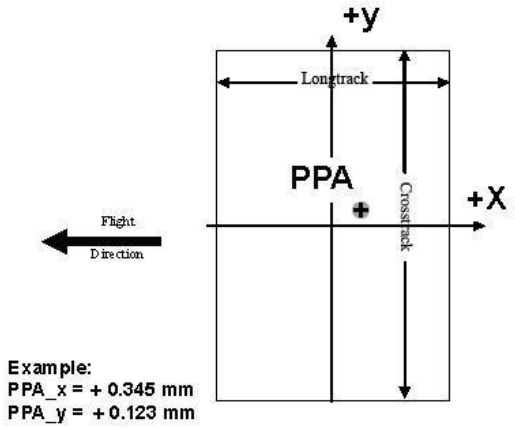
*The coordinates in the figure below are only example values to illustrate the effect of image rota- tion on the principal point position, and do **not** correspond to the camera described in this report.*

Lvl3, Rotation 0 deg clockwise



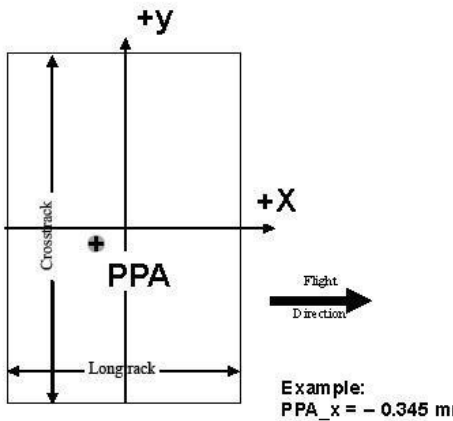
Example:
PPA_x = – 0.123 mm
PPA_y = + 0.345 mm

Lvl3, Rotation 90 deg clockwise



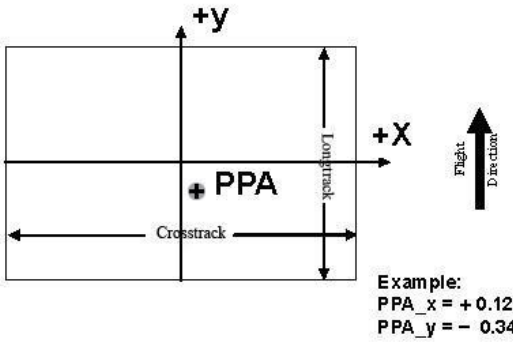
Example:
PPA_x = + 0.345 mm
PPA_y = + 0.123 mm

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

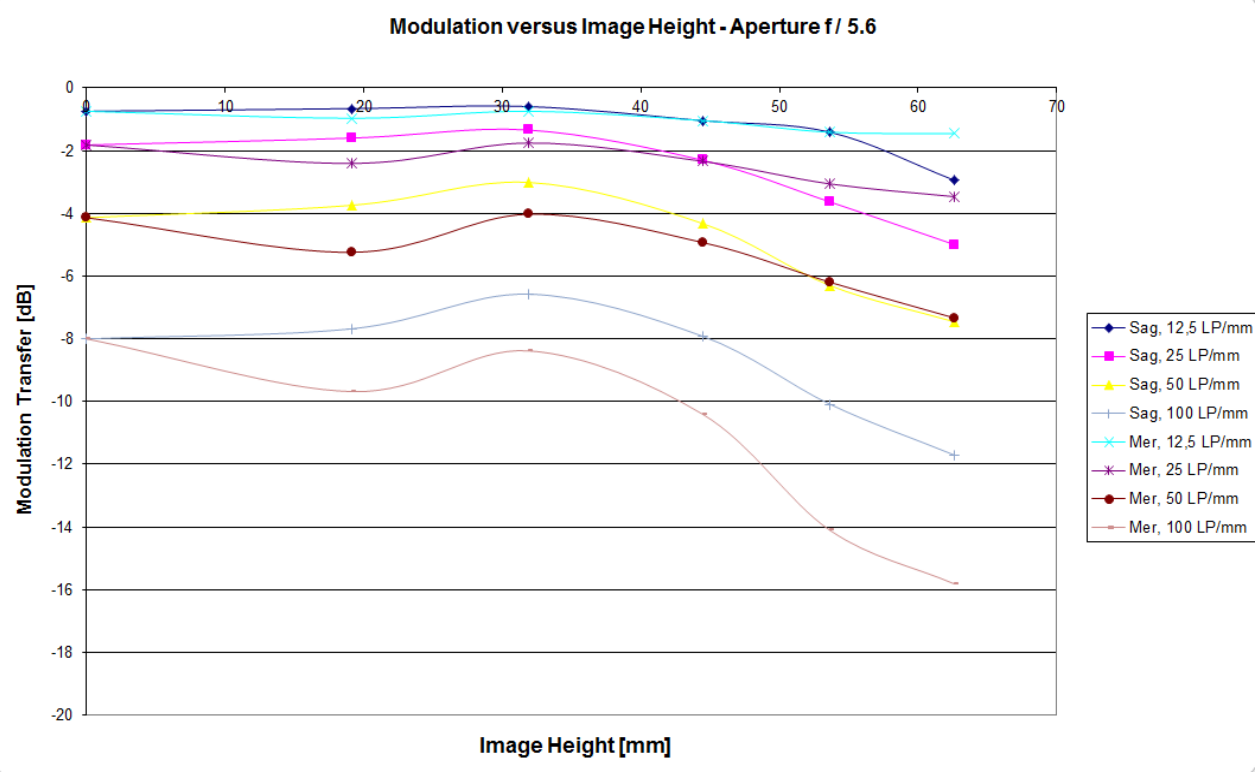
Lens Resolving Power

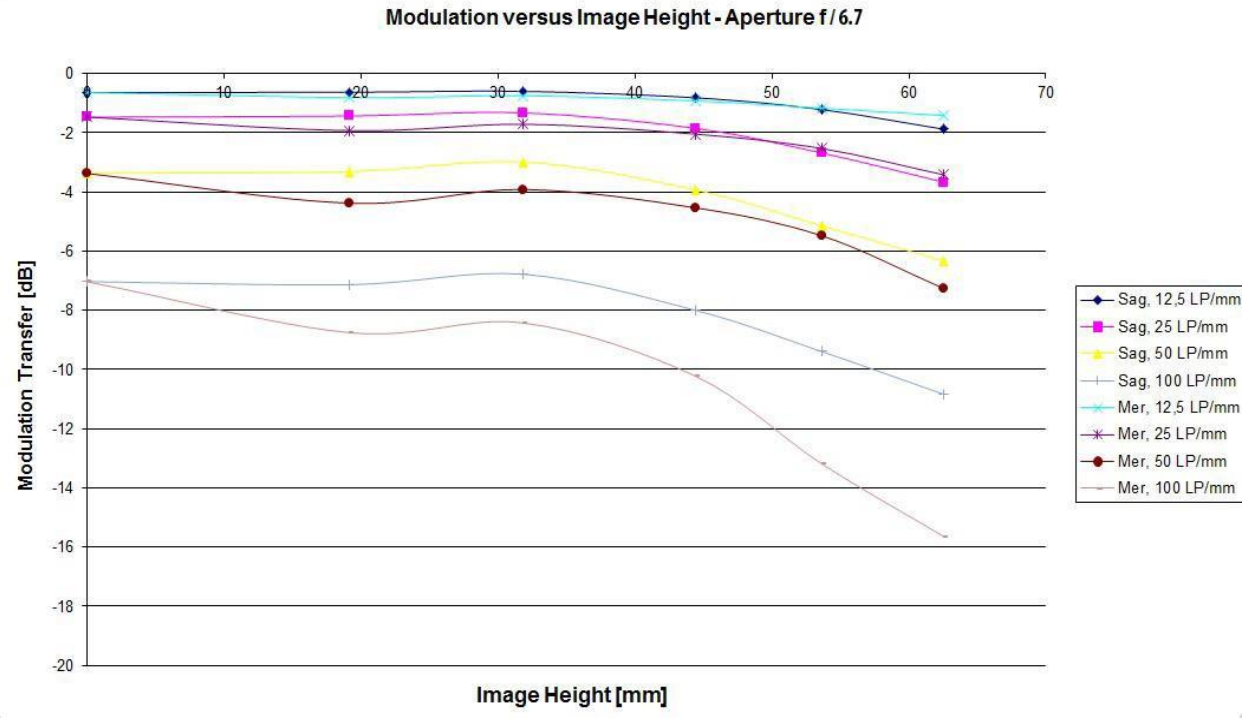
The following curves show the development of the modulation transfer function across different image heights of the panchromatic cones.
Please note that these values have been calculated and can vary up to 10% with optics from pro- duction (especially at high LP's).

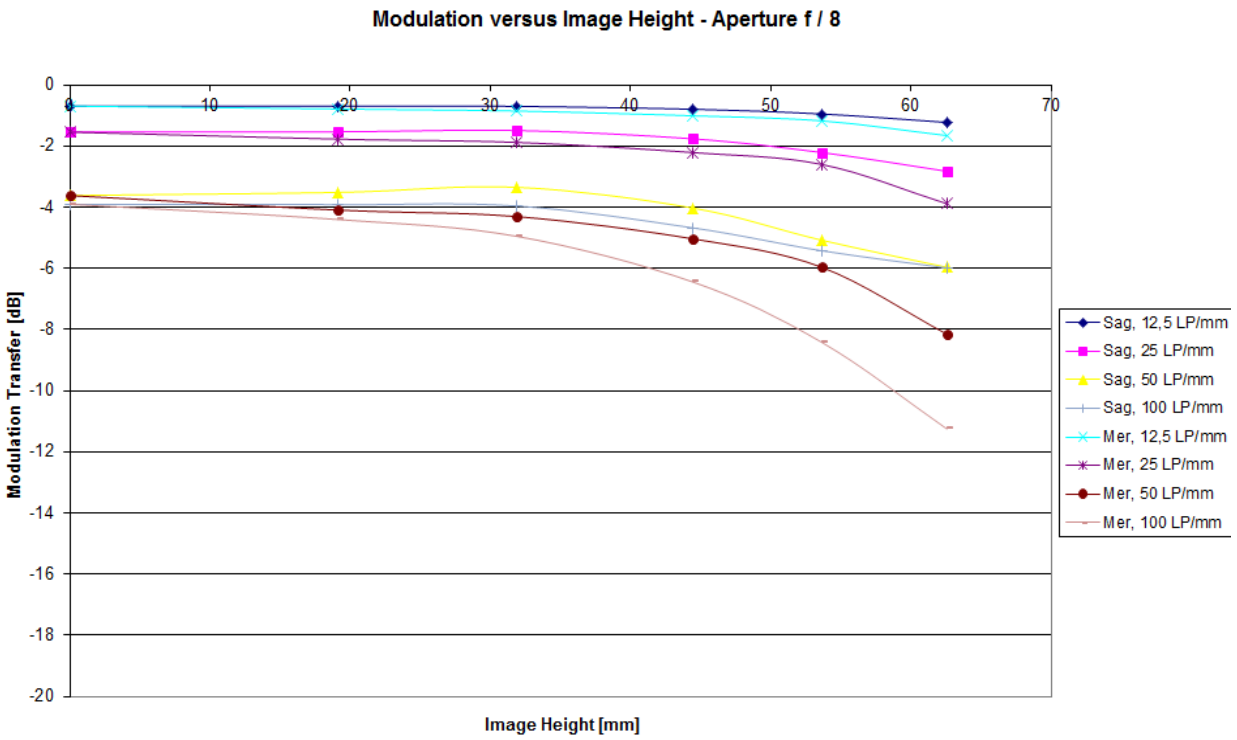
The curves are given for the meridonial (tangential) and sagital (radial) component of signals at frequencies of 12.5, 25, 50 and 100 line pairs per millimeter.

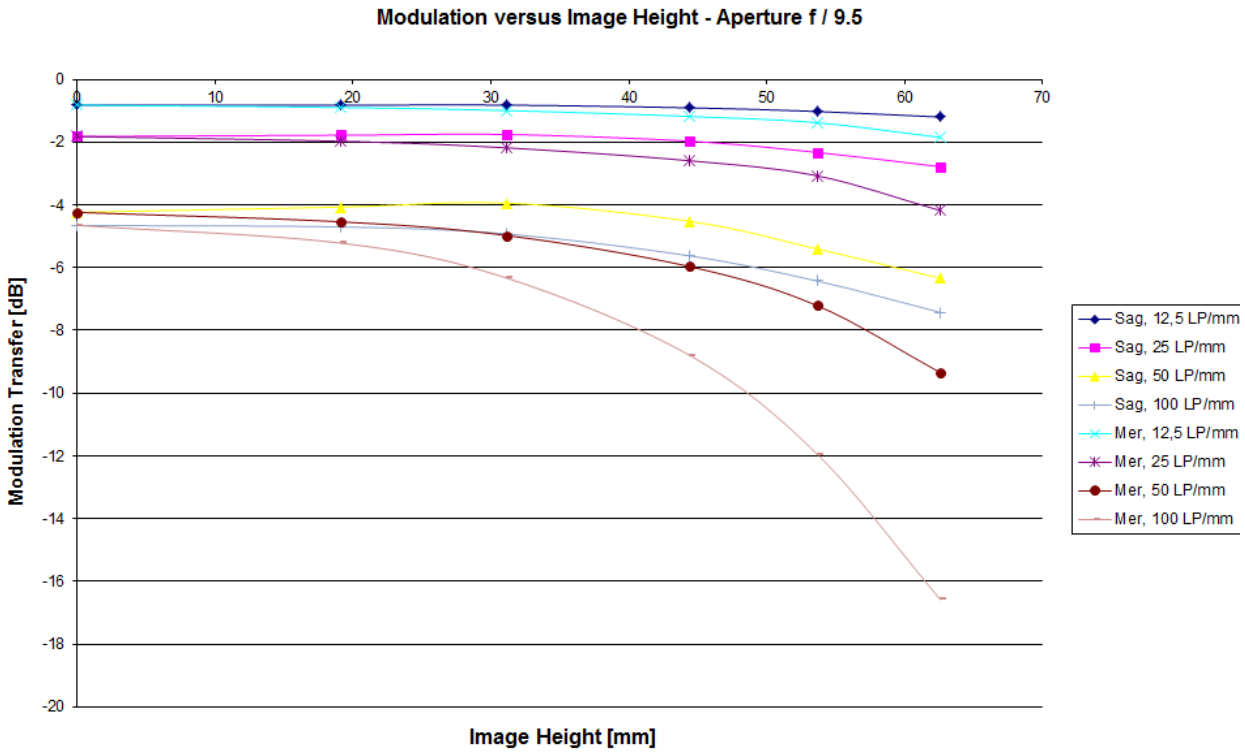
As the MTF is a function of the specific aperture size used, one set of curves is given for each aper- ture size.

Cone	Lens
C0 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C1 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C2 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C3 (PAN)	Qioptic Vexcel HR Digaron 1:5,6/80mm, Qioptic GmbH, Germany
C4 (RED)	Qioptic Vexcel HR Digaron 1:4/27mm, Qioptic GmbH, Germany
C5 (GREEN)	Qioptic Vexcel HR Digaron 1:4/27mm, Qioptic GmbH, Germany
C6 (BLUE)	Qioptic Vexcel HR Digaron 1:4/27mm, Qioptic GmbH, Germany
C7 (NIR)	Qioptic Vexcel HR Digaron 1:4/27mm, Qioptic GmbH, Germany

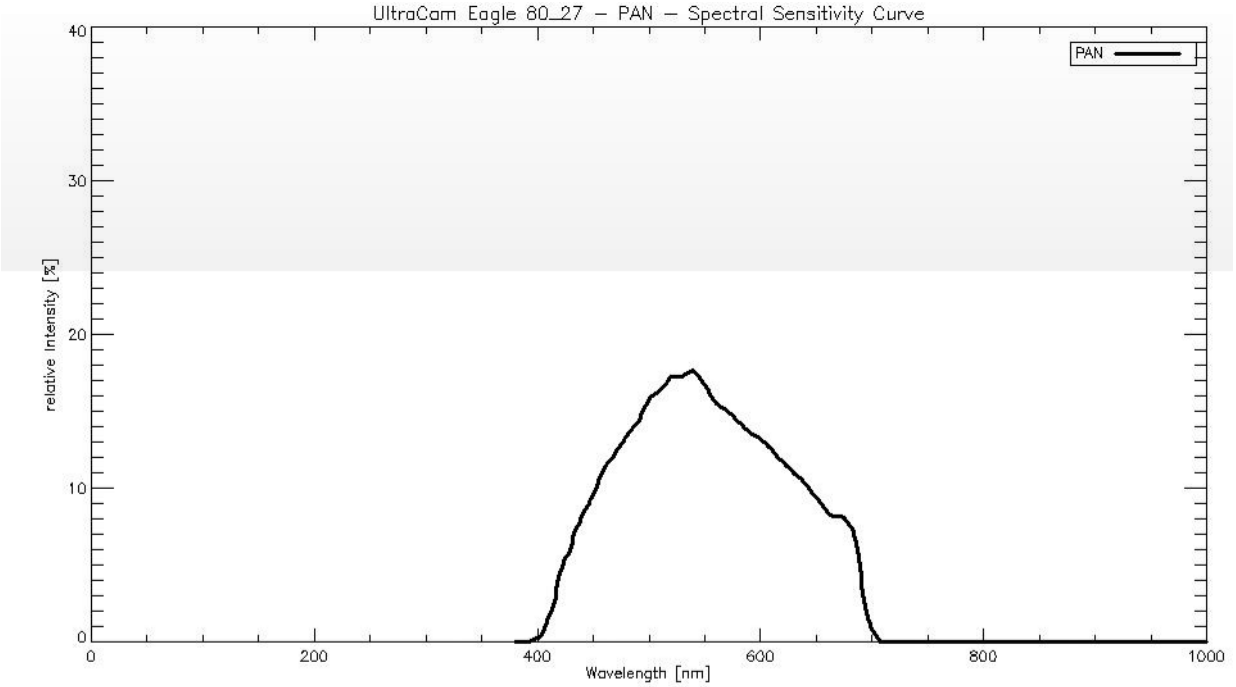

Modulation versus Image Height - Aperture f / 5.6
Modulation Transfer [dB]
Image Height [mm]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm

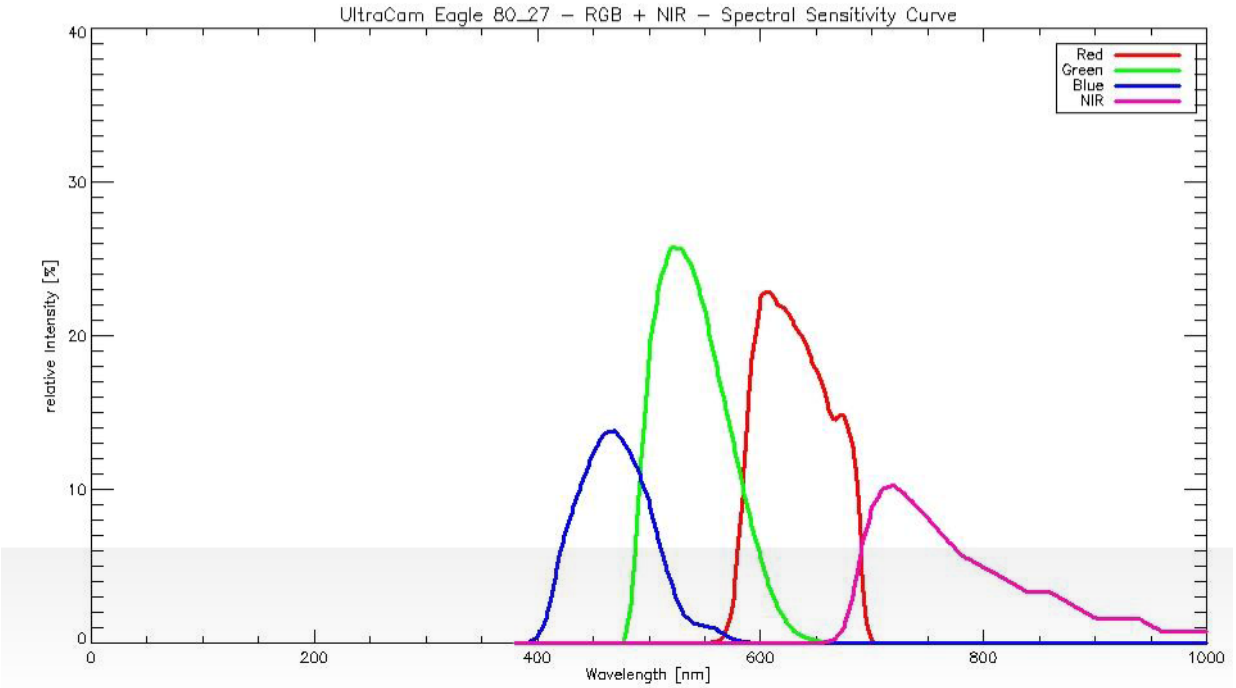

Modulation versus Image Height - Aperture f / 6.7
Modulation Transfer [dB]
Image Height [mm]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm


Modulation versus Image Height - Aperture f / 8
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm


Modulation versus Image Height - Aperture f / 9.5
Modulation Transfer [dB]
0
-2
-4
-6
-8
-10
-12
-14
-16
-18
-20
0
10
20
30
40
50
60
70
Image Height [mm]
Sag, 12,5 LP/mm
Sag, 25 LP/mm
Sag, 50 LP/mm
Sag, 100 LP/mm
Mer, 12,5 LP/mm
Mer, 25 LP/mm
Mer, 50 LP/mm
Mer, 100 LP/mm

Spectral Sensitivity





ULTRACAM

Radiometric Calibration

Camera: **UltraCam Eagle M3**

Serial: **UC-EpII-1-22814295-f80**

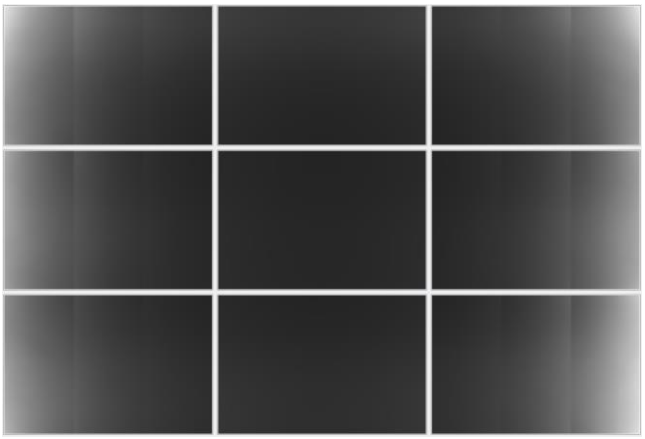
	PAN	R, G, NIR	B
Used Apertures	F5.6	F4.8	F4.8
	F6.7	F5.4	F4.8
	F8	F6.7	F4.8
	F9.5	F8	F5.6
	F11	F9.5	F6.7
	F13	F11	F8
	F16	F13	F9.5
	F22	F19	F13

Calibration Date: **Mar-05-2018**
Date of Report: **Mar-14-2018**
Camera Revision: **Rev01.00**
Version of Report: **V01**

Calibration of Vignetting for working Aperture F6.7

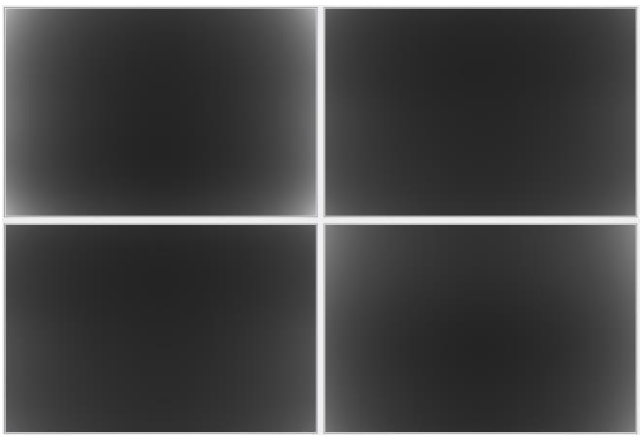
	PAN	R, G, NIR	B
Aperture	F6.7	F5.4	F4.8

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 (RED)	06_00 (BLUE)
05_00 (GREEN)	07_00 (NIR)

Dead Pixel Report:

Sensor number		
Anomaly type	X-Coordinate	Y-Coordinate

C00-00

PIXEL: 2012/2086
PIXEL: 2995/4121
PIXEL: 3017/5995
PIXEL: 3273/4862
PIXEL: 4142/3640
PIXEL: 4506/3788
PIXEL: 5202/4295
PIXEL: 6172/4428
PIXEL: 6929/4851
PIXEL: 8819/5789
PIXEL: 8886/2299
PIXEL: 895/ 115
PIXEL: 6348/5475

C00-01

PIXEL: 39/4202
PIXEL: 622/2212
PIXEL: 4619/5711
PIXEL: 5323/5511
PIXEL: 5365/3326
PIXEL: 5603/ 522
PIXEL: 8505/6012
PIXEL: 6058/2164
PIXEL: 8149/ 549
PIXEL: 8928/2347

C00-02

PIXEL: 6031/4132
PIXEL: 6684/1922
PIXEL: 6691/1918
PIXEL: 8000/2581
PIXEL: 8025/2374
PIXEL: 8062/2398
PIXEL: 436/2329
PIXEL: 436/2330
PIXEL: 1810/3625
PIXEL: 1811/3624
PIXEL: 2947/4225
PIXEL: 5388/3623
PIXEL: 6271/ 542
PIXEL: 7016/2253
PIXEL: 8164/3033

C00-03

PIXEL: 196/1707
PIXEL: 957/4364
PIXEL: 1150/2773
PIXEL: 2917/5334
PIXEL: 3125/5532
PIXEL: 3578/4899
PIXEL: 3598/ 995
PIXEL: 4759/3499
PIXEL: 5165/1345
PIXEL: 5984/1830
PIXEL: 6374/ 558
PIXEL: 7348/3315
PIXEL: 8710/5221
PIXEL: 1319/2446
PIXEL: 6125/ 334
PIXEL: 7029/4701
PIXEL: 7030/4701
PIXEL: 7509/4011
PIXEL: 7653/4099
PIXEL: 7943/5876
PIXEL: 8859/5414
PIXEL: 8924/ 315
PIXEL: 8934/4282

C01-00

PIXEL: 34/5205
PIXEL: 623/5056
PIXEL: 2077/4604
PIXEL: 5538/3480
PIXEL: 6694/4633
PIXEL: 8546/4486
PIXEL: 1105/4468
PIXEL: 1818/4180
PIXEL: 2639/1595
PIXEL: 7999/3587
PIXEL: 8514/3714
PIXEL: 8515/3713
COLUMN: 202/2280

C01-01

PIXEL: 806/ 627
PIXEL: 512/2955
PIXEL: 4816/5945
COLUMN: 8425/3508

C02-00

PIXEL: 5256/ 762
PIXEL: 7380/4587

PIXEL: 7896/ 237
PIXEL: 1349/5372
PIXEL: 2252/3211
PIXEL: 6729/4800
PIXEL: 7727/6000

C02-01

PIXEL: 1128/5067
PIXEL: 4012/2401
PIXEL: 4468/3804
PIXEL: 4468/4136
PIXEL: 4478/1924
PIXEL: 4481/1603
PIXEL: 4482/1522
PIXEL: 4484/1618
PIXEL: 5288/2069
PIXEL: 7495/2996
PIXEL: 4482/1603
PIXEL: 4483/1581
PIXEL: 4482/1560
PIXEL: 4483/1635

C03-00

PIXEL: 6663/1379
PIXEL: 7490/ 489
PIXEL: 8135/3073
PIXEL: 8970/1418
PIXEL: 948/ 558
PIXEL: 1151/ 715
PIXEL: 1152/ 715
PIXEL: 1152/ 716
PIXEL: 1210/2807
PIXEL: 4234/4781
PIXEL: 4235/4781
PIXEL: 4309/5101
PIXEL: 4724/5709
PIXEL: 5196/1640
PIXEL: 5196/1641
PIXEL: 8228/4295
PIXEL: 8432/1356
PIXEL: 8433/1356
PIXEL: 8569/2796
PIXEL: 8569/2797
PIXEL: 8636/4358

C04-00

PIXEL: 6439/1402
PIXEL: 7473/5455
PIXEL: 6947/2768

PIXEL: 8489/1729
PIXEL: 8971/4604

C05-00

PIXEL: 7261/5257
PIXEL: 7506/3758
PIXEL: 7669/4197
PIXEL: 176/2094
PIXEL: 185/ 371
PIXEL: 318/2666
PIXEL: 746/3265
PIXEL: 746/3266
PIXEL: 924/4132
PIXEL: 1003/1167
PIXEL: 1308/2767
PIXEL: 1893/4882
PIXEL: 2245/3125
PIXEL: 2280/5550
PIXEL: 2280/5551
PIXEL: 2402/1452
PIXEL: 4280/ 158
PIXEL: 4361/4586
PIXEL: 6287/1643
PIXEL: 6287/1644
PIXEL: 6288/1643
PIXEL: 6288/1644

C06-00

PIXEL: 1964/1188
PIXEL: 3155/ 111
PIXEL: 7797/ 524
PIXEL: 4232/5750
PIXEL: 6362/3366
PIXEL: 6362/3367
PIXEL: 7472/5079

C07-00

PIXEL: 2475/ 434

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 correspond- ing 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 set- ting, 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 dur- ing 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 pix- els are treated differently during post processing, since their behavior can affect not only single pixel values but whole columns.

ULTRACAM

Shutter Calibration

UltraCam Eagle M3

Serial:	**UC-EpII-1-22814295-f80**
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:	**Mar-05-2018**
Date of Report:	**Mar-14-2018**
Camera Revision:	**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)	12 12 19 79	6.51	6.6	6.89	7.08	7.28	7.41	7.5	7.82	+/- 0.2
C1 (Pan)	12 15 61 10	6.02	6.18	6.45	6.62	6.8	6.99	7.03	7.26	+/- 0.2
C2 (Pan)	12 12 19 85	6.66	6.86	7.11	7.31	7.45	7.61	7.63	7.92	+/- 0.2
C3 (Pan)	12 12 19 97	6.64	6.64	6.98	7.23	7.32	7.52	7.53	7.86	+/- 0.2
C4 (Red)	12 12 05 92	7.10	7.10	7.23	7.35	7.35	7.38	7.41	7.60	+/- 0.2
C5 (Green)	12 12 06 35	7.19	7.19	7.31	7.34	7.48	7.63	7.63	7.69	+/- 0.2
C6 (Blue)	12 11 00 49	7.21	7.21	7.21	7.22	7.37	7.65	7.65	7.88	+/- 0.2
C7 (NIR)	12 11 00 40	7.36	7.39	7.52	7.57	7.64	7.68	7.73	7.93	+/- 0.2

ULTRACAM

Electronics and Sensor Calibration

UltraCam Eagle M3

Serial:	**UC-EpII-1-22814295-f80**
Panchromatic Camera:	**9 * FTF9060-M Area CCD Sensor by DALSA**
Multispectral Camera:	**4 * FTF9060-M Area CCD Sensor by DALSA**
Calibration Date:	**Mar-05-2018**
Date of Report:	**Mar-14-2018**
Camera Revision:	**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]	VOG Voltage [V]
00_00	FTF9060-M	18 3918/053	22.40	6.67
00_01	FTF9060-M	18 3918/065	23.00	6.22
00_02	FTF9060-M	18 3918/062	22.60	6.65
00_03	FTF9060-M	18 3918/059	23.00	6.02
01_00	FTF9060-M	18 3918/036	22.60	6.74
01_01	FTF9060-M	18 3918/031	22.40	6.28
02_00	FTF9060-M	18 3918/049	22.40	6.10
02_01	FTF9060-M	18 3918/025	22.60	6.59
03_00	FTF9060-M	18 3918/002	22.80	6.70
04_00 (red)	FTF9060-M	18 3918/011	22.60	7.25
05_00 (green)	FTF9060-M	18 3918/040	22.40	6.54
06_00 (blue)	FTF9060-M	18 4458/029	22.40	7.15
07_00 (NIR)	FTF9060-M	18 3918/067	22.80	6.57

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 inter- face of the Eagle.

Cone_Sensor	Sensor Type	Sensor Serial Number	Intensity Threshold [DN]	
			Tap 1	Tap2
00_00	FTF9060-M	18 3918/053	14200	13410
00_01	FTF9060-M	18 3918/065	13860	12860
00_02	FTF9060-M	18 3918/062	13880	13040
00_03	FTF9060-M	18 3918/059	13580	12590
01_00	FTF9060-M	18 3918/036	14020	13090
01_01	FTF9060-M	18 3918/031	13940	13290
02_00	FTF9060-M	18 3918/049	14000	13120
02_01	FTF9060-M	18 3918/025	13890	12930
03_00	FTF9060-M	18 3918/002	14140	13170
04_00 (red)	FTF9060-M	18 3918/011	13090	11910
05_00 (green)	FTF9060-M	18 3918/040	14400	13610
06_00 (blue)	FTF9060-M	18 4458/029	12950	12150
07_00 (NIR)	FTF9060-M	18 3918/067	13910	13150

ULTRACAM

Summary

era: **UltraCam Eagle M3**

Serial: **UC-EpII-1-22814295-f80**

Calibration Date:	**Mar-05-2018**
Date of Report:	**Mar-14-2018**
Camera Revision:	**Rev01.00**
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