



ULTRACAM

Calibration Report



Copyright © 2018 by Vexcel Imaging GmbH, Graz - Austria.

The contents of this document may not be reproduced in any form or communicated to any third party without the prior written consent of Vexcel Imaging GmbH.

While every effort is made to ensure its correctness, Vexcel Imaging GmbH assumes no responsibility neither for errors and omissions which may occur in this document nor for damage caused by them.

Vexcel Imaging GmbH does not make a commitment to update the information and software discussed in this document.

All mentioned trademarks or registered trademarks are owned by their respective owners.

Printed in Austria at Vexcel Imaging GmbH. All rights reserved.

Bahia, Brasil 2013

Photo on page 1 courtesy of Hiparc Geotecnologia, Brasil

www.hiparc.com

UltraCam Lp, GSD25 cm, RGB



ULTRACAM

Geometric Calibration

Camera: UltraCam Xp
Serial: UC-SXp-CI-90517044

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

PPA Information: X: 0.120
Y: 0.000

Calibration Date: Dec-21-2018
Date of Report: Dec-28-2018
Camera Revision: Rev08.00
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	(33.9300, 51.930)mm
Pixel Size		6.000µm*6.000µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.120mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		

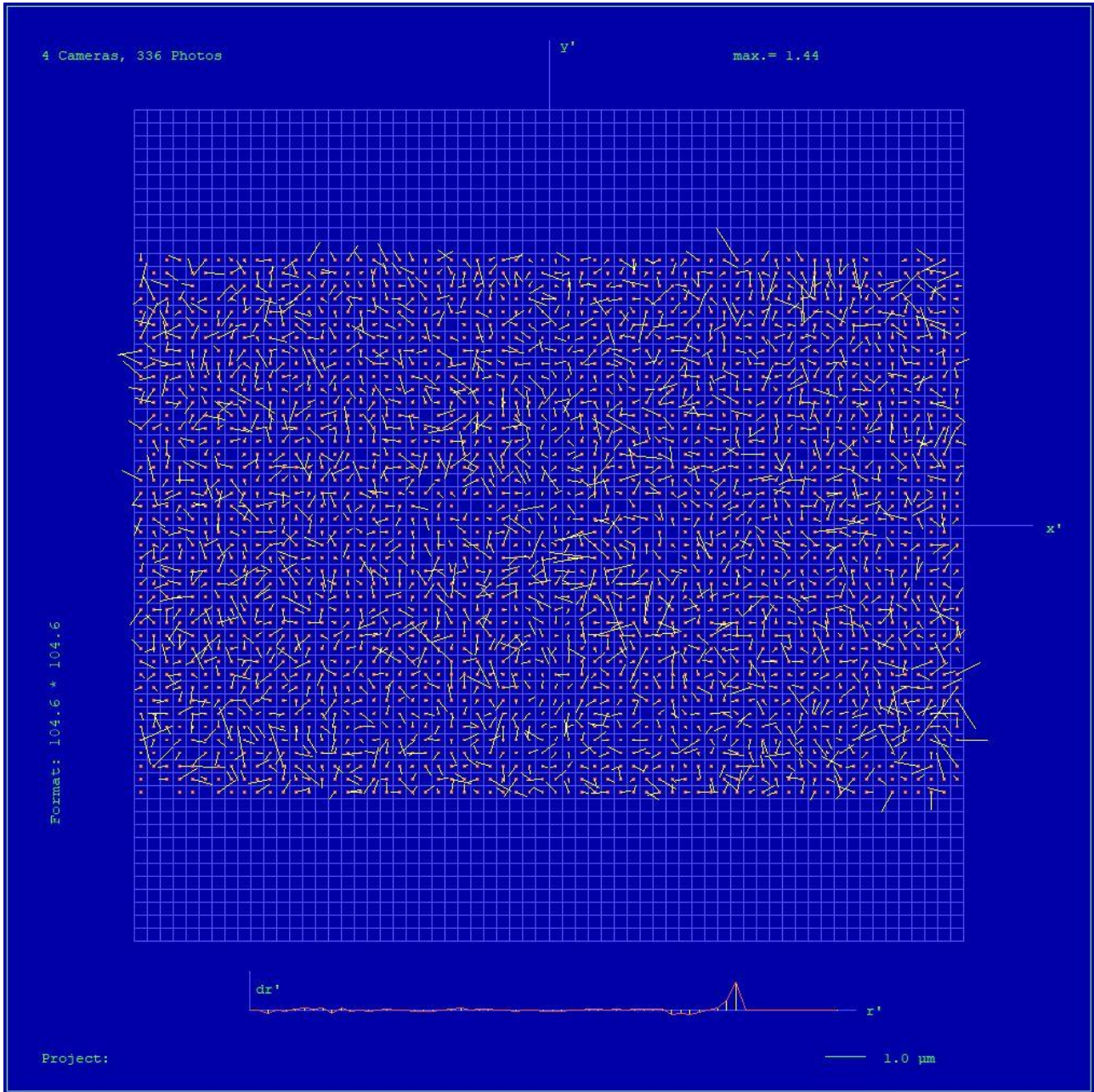
Multispectral Camera

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

Image Format	long track	67.860mm	3770pixel
	cross track	103.860mm	5770pixel
Image Extent		(-33.930, -51.930)mm	(33.930, 51.930)mm
Pixel Size		18.000µm*18.000µm	
Focal Length	ck	100.500mm	± 0.002mm
Principal Point (Level 2)	X_ppa	0.120mm	± 0.002mm
	Y_ppa	0.000mm	± 0.002mm
Lens Distortion	Remaining Distortion less than 0.002mm		



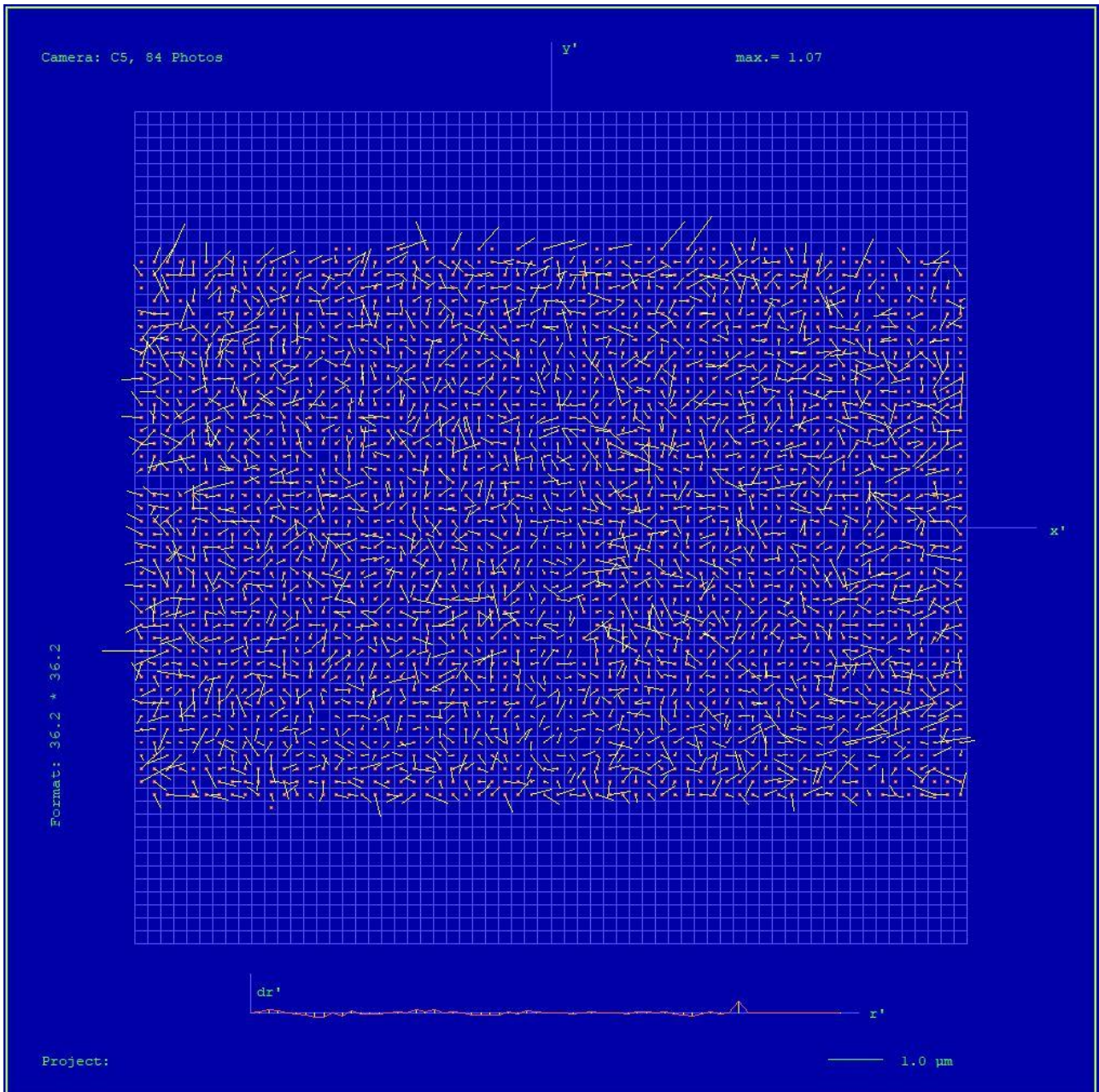
Full Panchromatic Image, Residual Error Diagram



Residual Error (RMS): **0.66 μm**



Green Cone (Cone 5), Residual Error Diagram



Residual Error (RMS): **0.55 μm**



Explanations

Calibration Method:

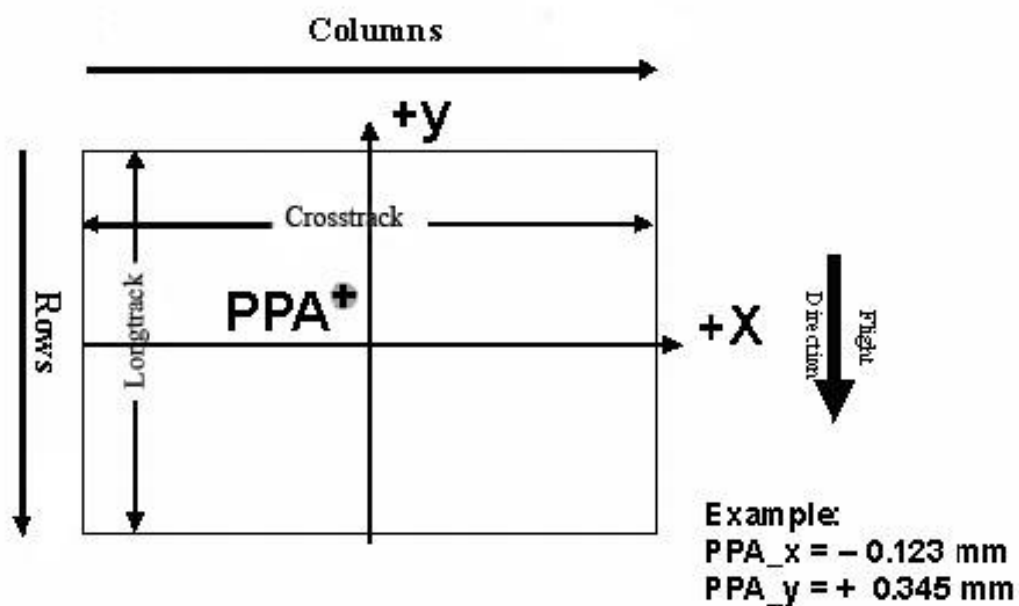
The geometric calibration is based on a set of 84 images of a defined geometry target with 394 GCPs.

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

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

Level 2 Image Coordinate System:

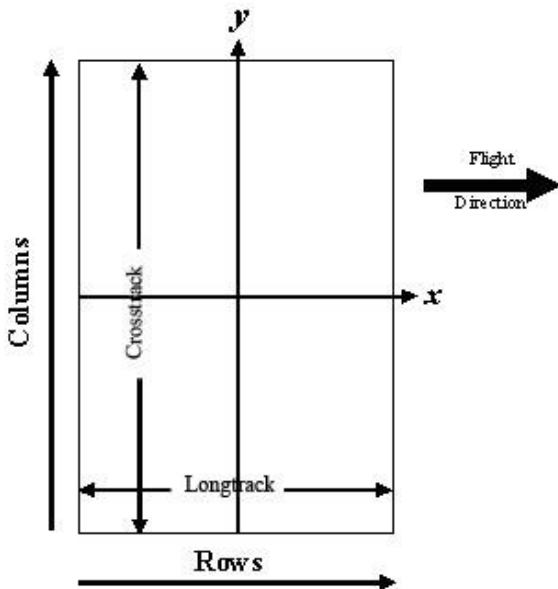
Lvl2, Camera prop. Orientation



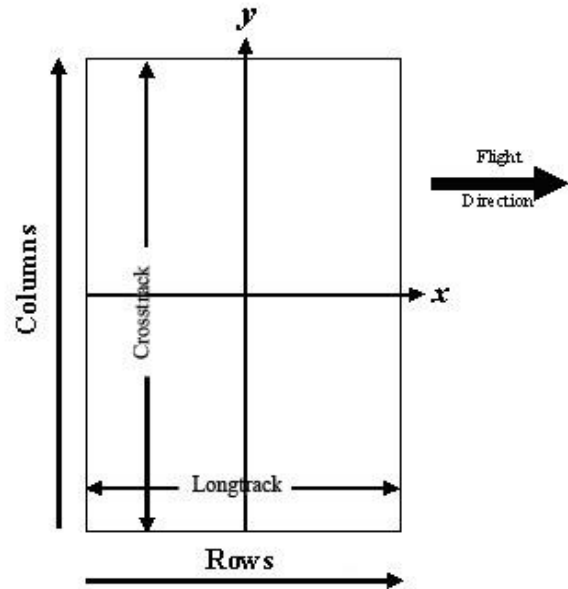
The image coordinate system of the Level 2 images is shown in the above figure. The basic image format and coordinate of the principal point in the level 2 image is given on page 4 of this report. The above figure shows the position of an example principal point at the coordinate (-0.123 / 0.345).



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



Panchromatic Image Format



Multispectral Image Format

Position of Principal Point in Level 3 Image

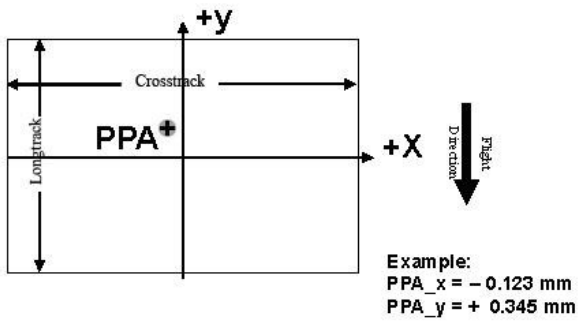
The position of the principal point in the level 3 image depends on the “rotation” setting used in UltraMap during the pan-sharpening step. The exact position relative to the image center is given in the table below as a function of the rotation setting used in UltraMap. The coordinates are specified 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	-	0.120	0.000
Level 3	0	0.120	0.000
Level 3	90	0.000	-0.120
Level 3	180	-0.120	0.000
Level 3	270	0.000	0.120

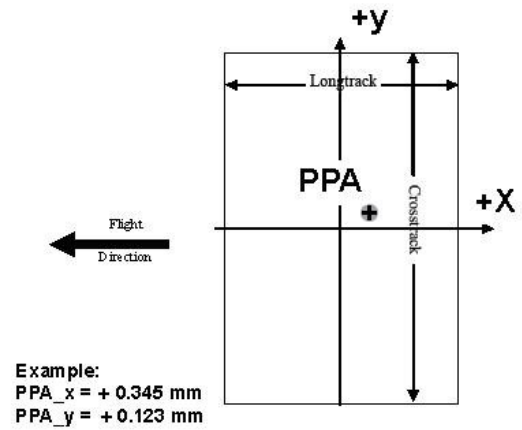


The coordinates in the figure below are only example values to illustrate the effect of image rotation on the principal point position, and do **not** correspond to the camera described in this report.

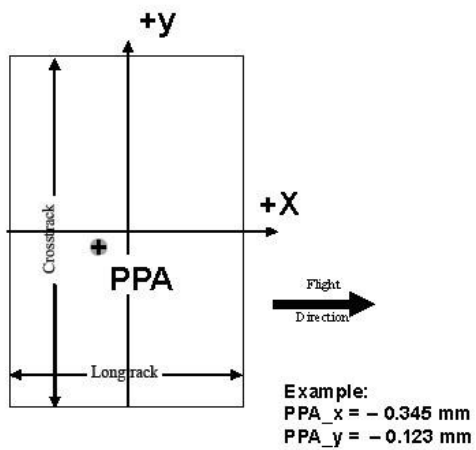
Lvl3, Rotation 0 deg clockwise



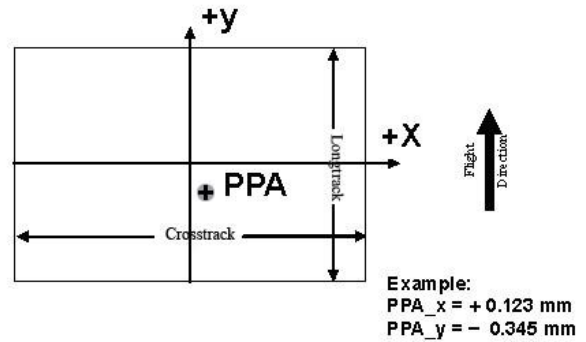
Lvl3, Rotation 90 deg clockwise



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.

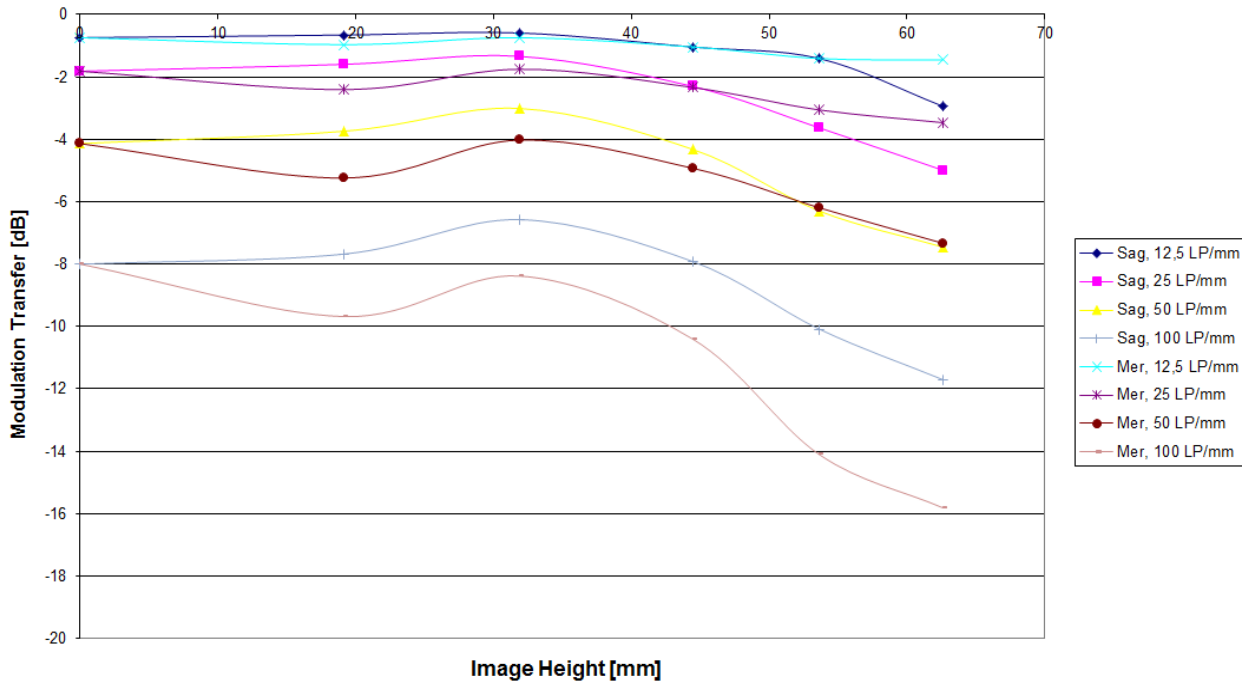
As the MTF is a function of the specific aperture size used, one set of curves is given for each aperture size.

Lens types

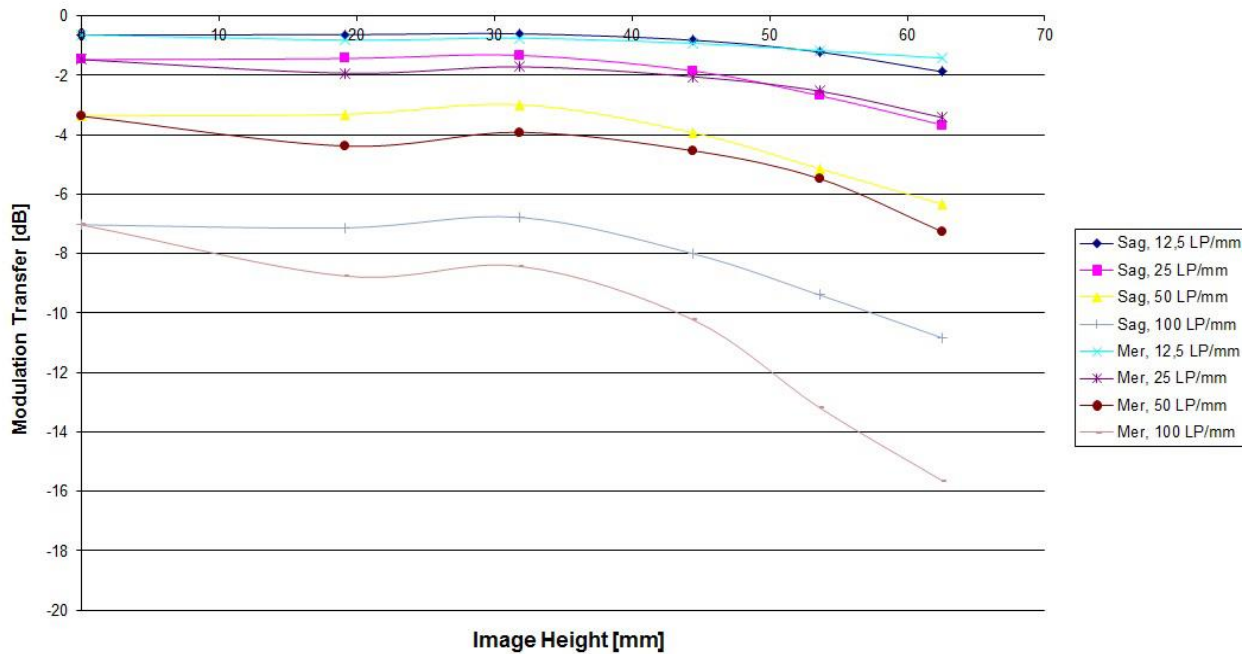
Cone	Lens
C0	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C1	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C2	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C3	Linos Vexcel Apo-Sironar Digital HR 1:5,6/100mm, Linos GmbH, Germany
C4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



Modulation versus Image Height - Aperture f/ 5.6

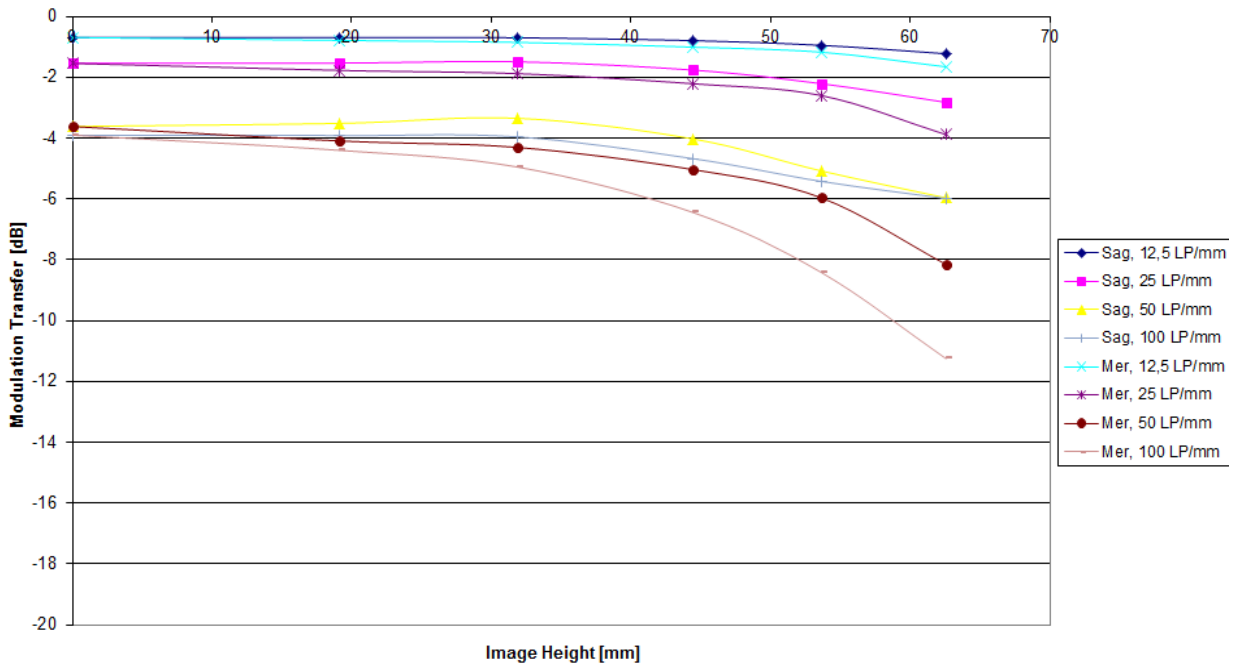


Modulation versus Image Height - Aperture f/ 6.7

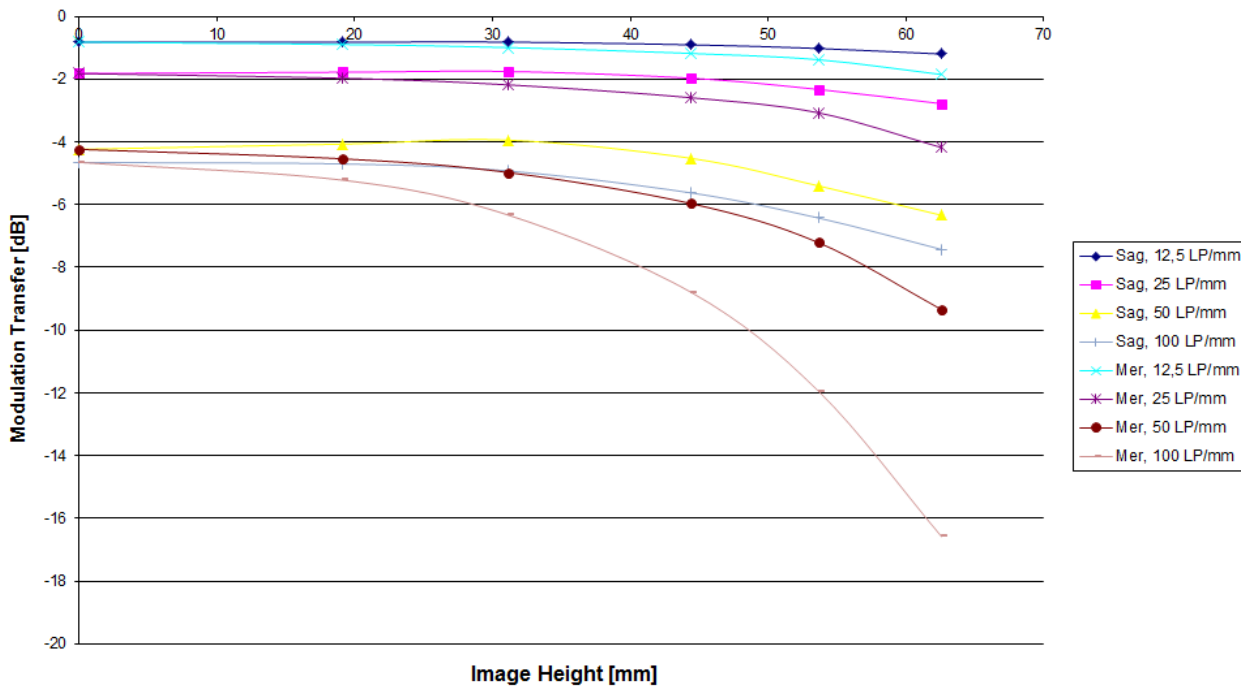




Modulation versus Image Height - Aperture f / 8



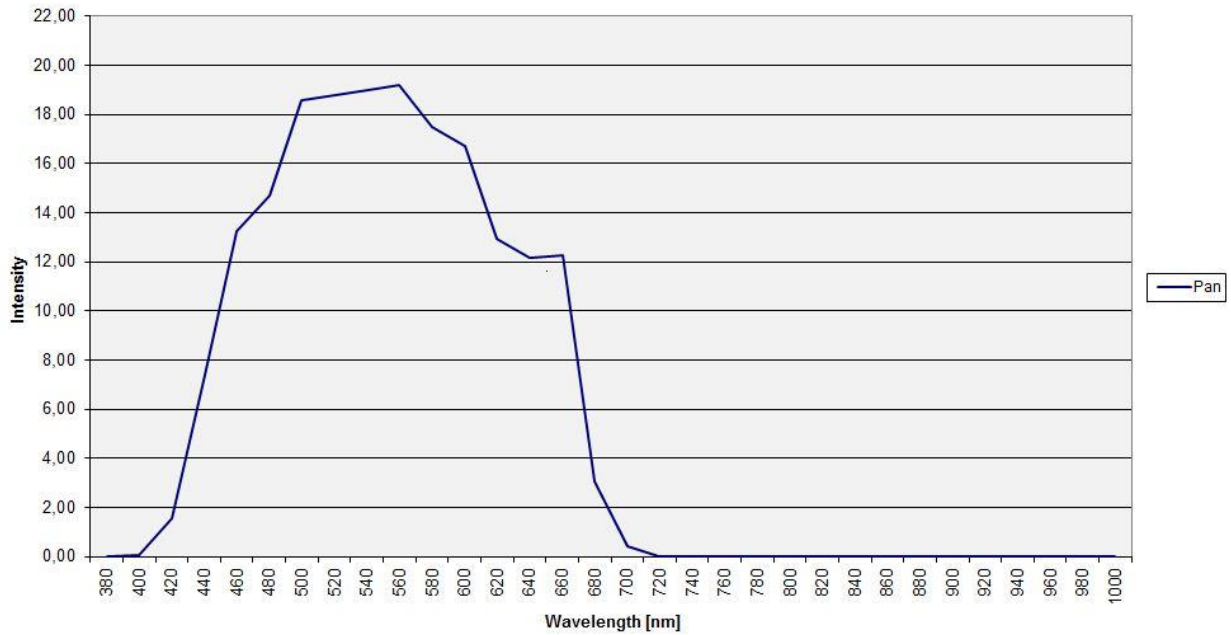
Modulation versus Image Height - Aperture f / 9.5



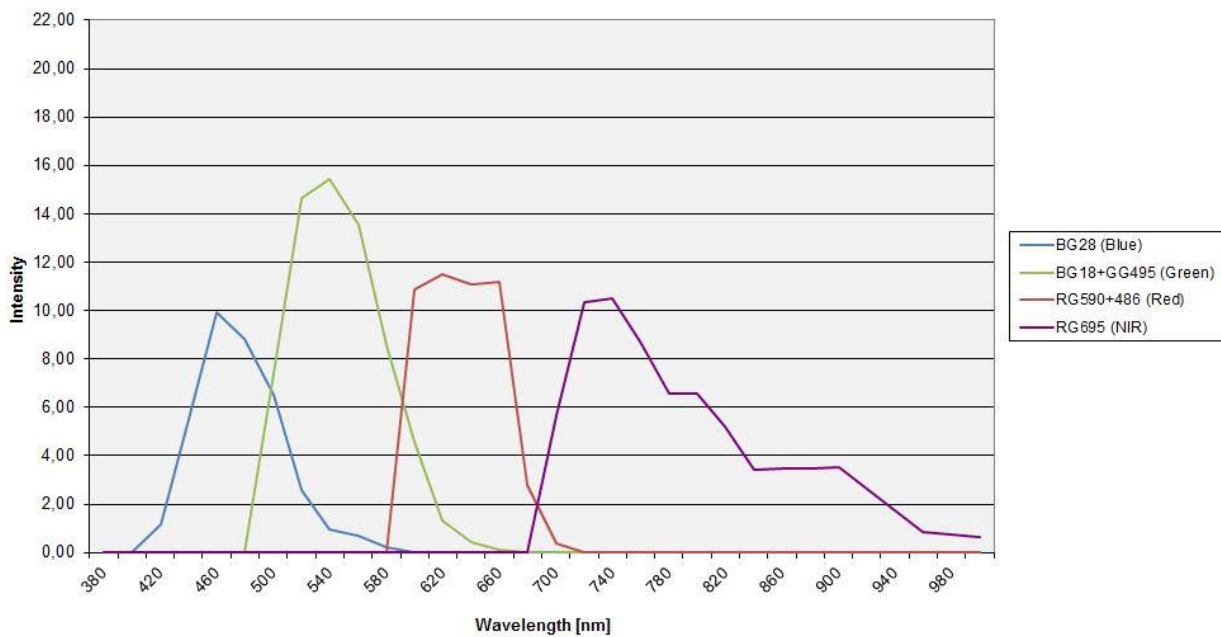


Spectral Sensitivity

Spectral Sensitivity Vexcel UCX - Panchromatic with AR-106 Coating



Spektral Sensitivity Vexcel UCX - Multispectral with AR-106 Coating





ULTRACAM

Radiometric Calibration

Camera: UltraCam Xp
Serial: UC-SXp-CI-90517044

	PAN	R, G, NIR	B
Used Apertures	F5.6	F4	F2.8
	F8	F5.6	F4
	F11	F8	F5.6
	F16	F11	F8
	F22	F16	F11

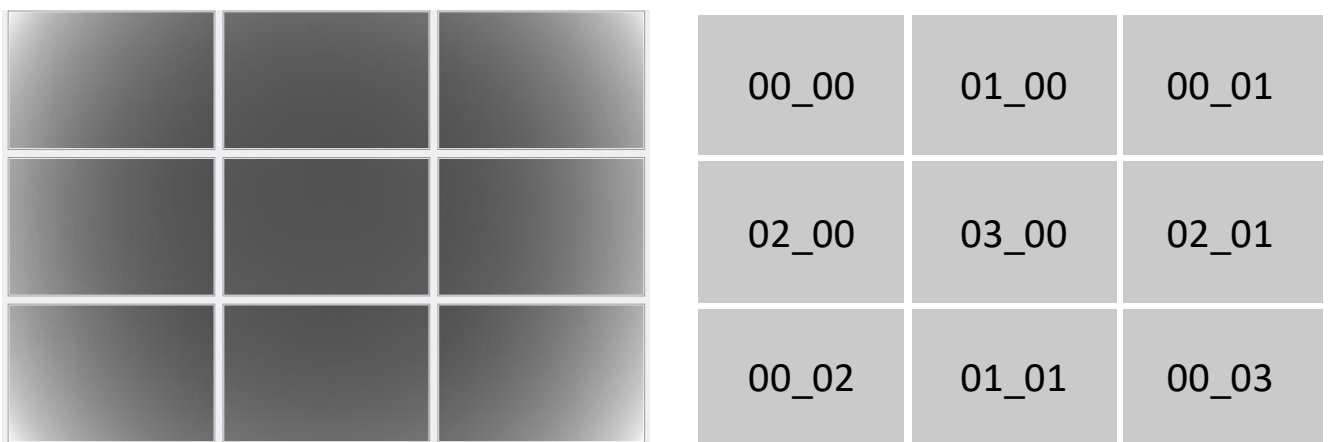
Calibration Date: Dec-21-2018
Date of Report: Dec-28-2018
Camera Revision: Rev08.00
Version of Report: V01



Calibration of Vignetting for working Aperture F8

	PAN	R, G, NIR	B
Aperture	F8	F5.6	F4

Graphical Overview of Pan Sensors:



Graphical Overview of Multispectral Sensors:





Dead Pixel Report:

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

C00-00

- PIXEL: 159/3174
- PIXEL: 223/ 925
- PIXEL: 240/1571
- PIXEL: 253/2495
- PIXEL: 311/2695
- PIXEL: 490/3540
- PIXEL: 548/ 173
- PIXEL: 654/1988
- PIXEL: 755/1188
- PIXEL: 911/2592
- PIXEL: 974/3448
- PIXEL: 1039/3815
- PIXEL: 1088/3277
- PIXEL: 1131/ 548
- PIXEL: 1214/2246
- PIXEL: 1331/1346
- PIXEL: 1471/3346
- PIXEL: 1653/ 145
- PIXEL: 1723/1574
- PIXEL: 1726/3498
- PIXEL: 1998/3945
- PIXEL: 2198/3132
- PIXEL: 2215/2139
- PIXEL: 2241/3045
- PIXEL: 2434/1759
- PIXEL: 2547/3352
- PIXEL: 2635/ 671
- PIXEL: 2701/3247
- PIXEL: 2993/3699
- PIXEL: 3044/ 121
- PIXEL: 3322/1767
- PIXEL: 3642/2826
- PIXEL: 3646/2650
- PIXEL: 3862/2384
- PIXEL: 3885/1081
- PIXEL: 3961/ 51
- PIXEL: 3975/3983
- PIXEL: 4121/2613
- PIXEL: 4214/1474
- PIXEL: 4220/ 189



PIXEL: 4253/2832
PIXEL: 4315/1693
PIXEL: 4350/ 135
PIXEL: 4350/ 592
PIXEL: 4350/ 593
PIXEL: 4483/2893
PIXEL: 4589/ 453
PIXEL: 4603/2173
PIXEL: 4645/ 804
PIXEL: 4770/2629
PIXEL: 4787/1877
PIXEL: 4874/1876
PIXEL: 4951/1876
PIXEL: 4977/1684
PIXEL: 5034/2080
PIXEL: 5240/1294
PIXEL: 5293/ 208
PIXEL: 5335/ 378
PIXEL: 5417/1132
PIXEL: 5424/3539
PIXEL: 5486/3547
PIXEL: 5500/3801
PIXEL: 5543/ 576
PIXEL: 5607/2485
PIXEL: 5704/2817
PIXEL: 5738/3509
PIXEL: 5791/ 320
PIXEL: 5893/1598
PIXEL: 5896/3808
PIXEL: 6013/1994
PIXEL: 3599/3774
PIXEL: 3599/3775
PIXEL: 5210/3957
PIXEL: 5210/3958
PIXEL: 5211/3958
PIXEL: 5211/3959
PIXEL: 5212/3960

C00-01

PIXEL: 157/3868
PIXEL: 308/3081
PIXEL: 311/3352
PIXEL: 312/1983
PIXEL: 348/2634
PIXEL: 362/3164
PIXEL: 374/3947
PIXEL: 421/2235
PIXEL: 492/ 776
PIXEL: 514/1436
PIXEL: 665/1346



PIXEL: 774/3950
PIXEL: 1139/1305
PIXEL: 1439/2425
PIXEL: 1520/ 170
PIXEL: 1539/ 98
PIXEL: 1782/3839
PIXEL: 1791/2207
PIXEL: 1907/ 363
PIXEL: 2011/ 297
PIXEL: 2032/3506
PIXEL: 2131/3147
PIXEL: 2182/2709
PIXEL: 2189/3152
PIXEL: 2274/1804
PIXEL: 2298/1318
PIXEL: 2336/3025
PIXEL: 2368/ 905
PIXEL: 2633/2682
PIXEL: 2703/ 556
PIXEL: 2738/2842
PIXEL: 2774/3254
PIXEL: 2846/3484
PIXEL: 2876/3690
PIXEL: 2949/3177
PIXEL: 2991/1488
PIXEL: 3124/2391
PIXEL: 3161/3017
PIXEL: 3272/ 983
PIXEL: 3395/ 514
PIXEL: 3410/2127
PIXEL: 3476/ 790
PIXEL: 3679/3847
PIXEL: 3747/ 931
PIXEL: 3774/1097
PIXEL: 3830/1586
PIXEL: 3967/3961
PIXEL: 4080/ 470
PIXEL: 4208/3499
PIXEL: 4253/2815
PIXEL: 4332/2623
PIXEL: 4576/1045
PIXEL: 4606/3307
PIXEL: 4676/1785
PIXEL: 4749/ 245
PIXEL: 4816/ 667
PIXEL: 5005/2582
PIXEL: 5026/3346
PIXEL: 5037/3511
PIXEL: 5191/1190
PIXEL: 5251/2972
PIXEL: 5329/ 80



PIXEL: 5662/ 963
PIXEL: 5662/2231
PIXEL: 6003/2969
PIXEL: 6023/ 984
PIXEL: 6023/ 985
PIXEL: 6023/ 986
PIXEL: 6023/ 987

C00-02

PIXEL: 78/1365
PIXEL: 126/3866
PIXEL: 213/2947
PIXEL: 272/3960
PIXEL: 302/2695
PIXEL: 334/2250
PIXEL: 340/1324
PIXEL: 347/3276
PIXEL: 347/3277
PIXEL: 455/1344
PIXEL: 500/3354
PIXEL: 591/3958
PIXEL: 680/ 670
PIXEL: 735/3641
PIXEL: 905/2207
PIXEL: 1025/2563
PIXEL: 1071/2000
PIXEL: 1088/2056
PIXEL: 1268/2101
PIXEL: 1288/ 766
PIXEL: 1427/ 584
PIXEL: 1445/2595
PIXEL: 1494/2253
PIXEL: 1582/ 254
PIXEL: 1596/1594
PIXEL: 1596/1595
PIXEL: 1639/2567
PIXEL: 1641/2068
PIXEL: 1727/1191
PIXEL: 1791/ 625
PIXEL: 1802/ 145
PIXEL: 1812/1768
PIXEL: 2001/ 188
PIXEL: 2039/1455
PIXEL: 2190/1986
PIXEL: 2196/ 165
PIXEL: 2233/3280
PIXEL: 2291/ 125
PIXEL: 2309/3567
PIXEL: 2320/2672
PIXEL: 2504/3403



PIXEL: 2570/3655
PIXEL: 2585/1333
PIXEL: 2623/3599
PIXEL: 2650/ 465
PIXEL: 2699/1911
PIXEL: 2840/ 402
PIXEL: 2878/ 978
PIXEL: 3061/ 854
PIXEL: 3122/2270
PIXEL: 3172/2017
PIXEL: 3212/ 203
PIXEL: 3222/3274
PIXEL: 3323/3460
PIXEL: 3337/3257
PIXEL: 3355/ 572
PIXEL: 3406/ 845
PIXEL: 3410/2675
PIXEL: 3419/1053
PIXEL: 3576/1272
PIXEL: 3595/2958
PIXEL: 3636/1498
PIXEL: 3636/1499
PIXEL: 3643/3592
PIXEL: 3798/3714
PIXEL: 3914/3118
PIXEL: 4022/3992
PIXEL: 4022/3993
PIXEL: 4050/3619
PIXEL: 4128/1964
PIXEL: 4150/3292
PIXEL: 4252/3490
PIXEL: 4253/3024
PIXEL: 4258/ 792
PIXEL: 4575/2338
PIXEL: 4608/3500
PIXEL: 4655/2237
PIXEL: 4683/1184
PIXEL: 4756/3428
PIXEL: 4932/ 392
PIXEL: 4960/ 41
PIXEL: 5036/2725
PIXEL: 5079/2087
PIXEL: 5109/ 933
PIXEL: 5173/3215
PIXEL: 5274/2485
PIXEL: 5385/ 694
PIXEL: 5468/2541
PIXEL: 5487/1432
PIXEL: 5511/ 628
PIXEL: 5511/ 629
PIXEL: 5589/1363



PIXEL: 5765/3663
PIXEL: 5824/2569
PIXEL: 5905/2799
PIXEL: 5913/2404
PIXEL: 5959/3123
PIXEL: 5981/3884
PIXEL: 809/2167
PIXEL: 810/2166
PIXEL: 810/2167
PIXEL: 926/ 132
PIXEL: 1854/ 258
PIXEL: 5513/ 667
PIXEL: 5785/ 329

C00-03

PIXEL: 170/2505
PIXEL: 190/3345
PIXEL: 195/1245
PIXEL: 344/2450
PIXEL: 373/1238
PIXEL: 409/1338
PIXEL: 431/ 529
PIXEL: 478/1927
PIXEL: 630/3664
PIXEL: 903/1513
PIXEL: 926/2677
PIXEL: 929/ 525
PIXEL: 936/1252
PIXEL: 956/2515
PIXEL: 1056/1581
PIXEL: 1131/2659
PIXEL: 1131/3359
PIXEL: 1154/ 226
PIXEL: 1190/ 921
PIXEL: 1247/ 477
PIXEL: 1251/3031
PIXEL: 1330/3272
PIXEL: 1403/ 931
PIXEL: 1482/2549
PIXEL: 1519/2413
PIXEL: 1571/ 58
PIXEL: 1585/1057
PIXEL: 1642/2711
PIXEL: 1653/1116
PIXEL: 1720/2773
PIXEL: 1720/2774
PIXEL: 1752/2008
PIXEL: 1780/3509
PIXEL: 1807/1180
PIXEL: 1807/1967



PIXEL: 1938/3691
PIXEL: 1966/2155
PIXEL: 2011/1138
PIXEL: 2075/3633
PIXEL: 2101/2770
PIXEL: 2147/3668
PIXEL: 2249/3929
PIXEL: 2302/ 307
PIXEL: 2396/3994
PIXEL: 2436/3197
PIXEL: 2475/2796
PIXEL: 2550/ 839
PIXEL: 2685/2093
PIXEL: 2760/3929
PIXEL: 2925/ 416
PIXEL: 2949/3488
PIXEL: 3109/2754
PIXEL: 3160/3482
PIXEL: 3260/1809
PIXEL: 3279/ 427
PIXEL: 3291/2211
PIXEL: 3456/1197
PIXEL: 3478/2563
PIXEL: 3545/ 334
PIXEL: 3636/3407
PIXEL: 3712/3732
PIXEL: 3717/3863
PIXEL: 3733/3497
PIXEL: 3752/1824
PIXEL: 3947/2200
PIXEL: 3979/3738
PIXEL: 4017/2714
PIXEL: 4043/ 391
PIXEL: 4057/2405
PIXEL: 4207/3711
PIXEL: 4370/3633
PIXEL: 4407/ 395
PIXEL: 4563/ 404
PIXEL: 4664/1457
PIXEL: 4767/3417
PIXEL: 4773/3398
PIXEL: 4804/2609
PIXEL: 4824/3582
PIXEL: 4833/2075
PIXEL: 4844/3149
PIXEL: 4894/2494
PIXEL: 4896/ 947
PIXEL: 4955/3141
PIXEL: 5022/2267
PIXEL: 5022/2566
PIXEL: 5089/3834



PIXEL: 5127/ 288
PIXEL: 5147/ 612
PIXEL: 5178/3148
PIXEL: 5232/2051
PIXEL: 5455/ 152
PIXEL: 5525/ 412
PIXEL: 5782/ 377
PIXEL: 5967/1970
PIXEL: 2208/ 69
PIXEL: 2812/3545
PIXEL: 4675/2491
PIXEL: 4901/2337
PIXEL: 5281/1913

C01-00

PIXEL: 32/1740
PIXEL: 102/ 437
PIXEL: 107/3293
PIXEL: 154/1393
PIXEL: 515/ 444
PIXEL: 521/2401
PIXEL: 533/2896
PIXEL: 556/2231
PIXEL: 780/1003
PIXEL: 846/ 502
PIXEL: 928/3192
PIXEL: 1009/1767
PIXEL: 1120/ 587
PIXEL: 1128/1418
PIXEL: 1258/1192
PIXEL: 1529/3036
PIXEL: 1612/2410
PIXEL: 1618/2680
PIXEL: 1620/3001
PIXEL: 1654/ 457
PIXEL: 1953/2749
PIXEL: 1955/3201
PIXEL: 1970/2668
PIXEL: 2070/ 922
PIXEL: 2098/1218
PIXEL: 2151/2395
PIXEL: 2191/2236
PIXEL: 2472/1858
PIXEL: 2650/3610
PIXEL: 2709/2599
PIXEL: 2764/3030
PIXEL: 2774/ 147
PIXEL: 2919/1660
PIXEL: 2963/2326
PIXEL: 2978/3530



PIXEL: 2981/3287
PIXEL: 3069/1447
PIXEL: 3348/ 867
PIXEL: 3572/1168
PIXEL: 3661/1718
PIXEL: 3753/1205
PIXEL: 3762/1996
PIXEL: 3770/3474
PIXEL: 3829/1519
PIXEL: 3852/2644
PIXEL: 4054/1398
PIXEL: 4242/2291
PIXEL: 4295/2353
PIXEL: 4335/1350
PIXEL: 4351/ 390
PIXEL: 4406/1463
PIXEL: 4564/3328
PIXEL: 4734/1265
PIXEL: 4752/1314
PIXEL: 4781/ 895
PIXEL: 4795/3856
PIXEL: 4852/3492
PIXEL: 4884/ 420
PIXEL: 4886/2387
PIXEL: 5133/1788
PIXEL: 5167/ 880
PIXEL: 5400/1314
PIXEL: 5407/2276
PIXEL: 5418/ 455
PIXEL: 5470/ 526
PIXEL: 5533/1026
PIXEL: 5597/1566
PIXEL: 5671/1273
PIXEL: 5696/2537
PIXEL: 5858/ 154
PIXEL: 5866/2831
PIXEL: 5876/ 119
PIXEL: 5900/2290
PIXEL: 5963/3113
PIXEL: 3627/1141

C01-01

PIXEL: 54/3932
PIXEL: 403/1952
PIXEL: 449/ 874
PIXEL: 521/3392
PIXEL: 579/1828
PIXEL: 618/3871
PIXEL: 999/3642
PIXEL: 1062/1909



PIXEL: 1127/2607
PIXEL: 1134/2184
PIXEL: 1206/3960
PIXEL: 1297/ 501
PIXEL: 1358/3122
PIXEL: 1388/ 831
PIXEL: 1395/3736
PIXEL: 1427/3434
PIXEL: 1484/ 567
PIXEL: 1520/ 599
PIXEL: 1619/2967
PIXEL: 1621/1849
PIXEL: 1697/ 812
PIXEL: 1976/2347
PIXEL: 2066/2449
PIXEL: 2073/2969
PIXEL: 2142/1653
PIXEL: 2173/1999
PIXEL: 2274/3780
PIXEL: 2374/ 783
PIXEL: 2390/2954
PIXEL: 2390/2955
PIXEL: 2431/1931
PIXEL: 2634/ 404
PIXEL: 2890/1707
PIXEL: 2929/2483
PIXEL: 3102/1478
PIXEL: 3109/ 410
PIXEL: 3167/1300
PIXEL: 3202/ 980
PIXEL: 3205/2337
PIXEL: 3235/ 956
PIXEL: 3246/1687
PIXEL: 3283/ 14
PIXEL: 3334/3439
PIXEL: 3380/ 170
PIXEL: 3400/ 219
PIXEL: 3410/3872
PIXEL: 3459/2117
PIXEL: 3509/3038
PIXEL: 3584/3409
PIXEL: 3666/ 32
PIXEL: 3693/3124
PIXEL: 3830/3913
PIXEL: 3950/2653
PIXEL: 4135/3781
PIXEL: 4232/ 836
PIXEL: 4278/ 288
PIXEL: 4378/ 786
PIXEL: 4429/ 761
PIXEL: 4433/2876



PIXEL: 4550/2481
PIXEL: 4552/1301
PIXEL: 4609/3683
PIXEL: 4784/ 689
PIXEL: 4786/3287
PIXEL: 4839/ 794
PIXEL: 4930/ 167
PIXEL: 5137/3475
PIXEL: 5167/2593
PIXEL: 5654/ 43
PIXEL: 5671/3049
PIXEL: 5783/3159
PIXEL: 5945/1759
PIXEL: 677/2196
PIXEL: 973/2000

C02-00

PIXEL: 65/3442
PIXEL: 99/1667
PIXEL: 187/3868
PIXEL: 243/2184
PIXEL: 295/ 991
PIXEL: 385/ 979
PIXEL: 455/2562
PIXEL: 575/1101
PIXEL: 637/2722
PIXEL: 663/1113
PIXEL: 791/1366
PIXEL: 795/ 110
PIXEL: 915/1357
PIXEL: 1163/ 668
PIXEL: 1190/2240
PIXEL: 1493/3991
PIXEL: 1511/2461
PIXEL: 1782/3950
PIXEL: 1791/ 462
PIXEL: 1917/ 17
PIXEL: 1918/1241
PIXEL: 2064/ 801
PIXEL: 2086/1902
PIXEL: 2123/ 46
PIXEL: 2232/1346
PIXEL: 2301/3474
PIXEL: 2315/2631
PIXEL: 2358/1822
PIXEL: 2373/ 908
PIXEL: 2471/ 269
PIXEL: 2530/3494
PIXEL: 2567/1769
PIXEL: 2572/2988



PIXEL: 2690/ 328
PIXEL: 2731/1450
PIXEL: 2804/ 322
PIXEL: 2840/ 377
PIXEL: 2872/3174
PIXEL: 2938/1130
PIXEL: 2944/3032
PIXEL: 3056/2850
PIXEL: 3128/1288
PIXEL: 3243/3584
PIXEL: 3251/1329
PIXEL: 3411/ 956
PIXEL: 3542/1869
PIXEL: 3885/2810
PIXEL: 3976/ 471
PIXEL: 4009/2554
PIXEL: 4051/3347
PIXEL: 4083/2672
PIXEL: 4185/1763
PIXEL: 4208/1118
PIXEL: 4505/1565
PIXEL: 4566/ 55
PIXEL: 4677/1200
PIXEL: 4696/1108
PIXEL: 4736/3702
PIXEL: 4783/1308
PIXEL: 4794/1304
PIXEL: 4808/1262
PIXEL: 4832/ 722
PIXEL: 4977/3736
PIXEL: 4984/ 215
PIXEL: 5155/1945
PIXEL: 5200/1458
PIXEL: 5210/ 705
PIXEL: 5250/1345
PIXEL: 5288/ 311
PIXEL: 5295/ 699
PIXEL: 5375/ 572
PIXEL: 5467/1420
PIXEL: 5492/2151
PIXEL: 5494/ 901
PIXEL: 5517/2249
PIXEL: 5546/1577
PIXEL: 5621/ 849
PIXEL: 5651/2903
PIXEL: 5707/2226
PIXEL: 5801/2106
PIXEL: 5813/2830
PIXEL: 3787/1192
PIXEL: 3787/1193
PIXEL: 3788/1192



PIXEL: 3788/1193
PIXEL: 4154/ 453

C02-01

PIXEL: 70/2881
PIXEL: 123/3815
PIXEL: 126/ 561
PIXEL: 169/2314
PIXEL: 190/1098
PIXEL: 209/ 228
PIXEL: 222/2779
PIXEL: 352/ 656
PIXEL: 417/ 685
PIXEL: 430/ 230
PIXEL: 434/1815
PIXEL: 546/ 375
PIXEL: 546/2300
PIXEL: 678/1157
PIXEL: 779/2627
PIXEL: 847/1933
PIXEL: 937/3397
PIXEL: 1058/1127
PIXEL: 1062/2191
PIXEL: 1114/1669
PIXEL: 1114/1670
PIXEL: 1200/ 85
PIXEL: 1264/1263
PIXEL: 1469/ 585
PIXEL: 1498/2565
PIXEL: 1499/1166
PIXEL: 1599/1462
PIXEL: 1645/ 158
PIXEL: 1648/2769
PIXEL: 1665/2730
PIXEL: 1785/1213
PIXEL: 1786/1003
PIXEL: 1827/1756
PIXEL: 1887/3329
PIXEL: 2019/1370
PIXEL: 2031/3656
PIXEL: 2057/3628
PIXEL: 2072/1071
PIXEL: 2131/2601
PIXEL: 2189/3388
PIXEL: 2239/1019
PIXEL: 2373/3511
PIXEL: 2395/2669
PIXEL: 2536/3317
PIXEL: 2657/ 248
PIXEL: 2695/ 439



PIXEL: 2696/3243
PIXEL: 2752/ 255
PIXEL: 2772/2828
PIXEL: 2791/ 28
PIXEL: 2906/2972
PIXEL: 2915/2069
PIXEL: 2965/3210
PIXEL: 3353/ 115
PIXEL: 3466/ 63
PIXEL: 3609/1316
PIXEL: 3760/2434
PIXEL: 3760/2435
PIXEL: 3794/2034
PIXEL: 3908/2725
PIXEL: 3962/3006
PIXEL: 4021/1874
PIXEL: 4025/3511
PIXEL: 4029/ 829
PIXEL: 4107/2239
PIXEL: 4165/ 123
PIXEL: 4216/ 685
PIXEL: 4240/ 274
PIXEL: 4251/1725
PIXEL: 4408/3206
PIXEL: 4514/1647
PIXEL: 4690/2668
PIXEL: 4701/ 678
PIXEL: 4910/ 410
PIXEL: 5113/ 165
PIXEL: 5139/ 928
PIXEL: 5347/ 303
PIXEL: 5430/ 133
PIXEL: 5583/2972
PIXEL: 5606/ 177
PIXEL: 5610/ 872
PIXEL: 5647/1103
PIXEL: 5680/2192
PIXEL: 5681/3653
PIXEL: 5682/3919
PIXEL: 5700/ 274
PIXEL: 5709/3203
PIXEL: 5909/3326
PIXEL: 5910/2936
PIXEL: 6022/ 27
PIXEL: 1451/ 607
PIXEL: 1451/ 608
PIXEL: 3997/2490

C03-00

PIXEL: 490/1796



PIXEL: 647/2448
PIXEL: 790/1198
PIXEL: 805/3910
PIXEL: 915/1220
PIXEL: 989/3525
PIXEL: 1021/2904
PIXEL: 1220/ 920
PIXEL: 1240/1158
PIXEL: 1260/3916
PIXEL: 1337/1188
PIXEL: 1405/3083
PIXEL: 1536/ 610
PIXEL: 1640/1193
PIXEL: 1737/3534
PIXEL: 1827/2684
PIXEL: 1861/3280
PIXEL: 1969/1747
PIXEL: 2048/2885
PIXEL: 2163/1466
PIXEL: 2189/2694
PIXEL: 2194/1883
PIXEL: 2318/3845
PIXEL: 2338/1849
PIXEL: 2451/1655
PIXEL: 2551/1530
PIXEL: 2584/ 399
PIXEL: 2836/ 271
PIXEL: 2856/2255
PIXEL: 2900/ 427
PIXEL: 3127/2504
PIXEL: 3132/3895
PIXEL: 3155/2886
PIXEL: 3270/1786
PIXEL: 3420/3265
PIXEL: 3432/ 845
PIXEL: 3563/3546
PIXEL: 3565/1087
PIXEL: 3637/ 126
PIXEL: 3824/ 201
PIXEL: 3871/ 330
PIXEL: 4096/2048
PIXEL: 4117/1251
PIXEL: 4560/2180
PIXEL: 4658/1952
PIXEL: 4821/2235
PIXEL: 4845/1775
PIXEL: 4864/2794
PIXEL: 4970/2369
PIXEL: 5133/3102
PIXEL: 5238/3920
PIXEL: 5269/2798



PIXEL: 5291/2635
PIXEL: 5307/3509
PIXEL: 5337/ 668
PIXEL: 5468/3378
PIXEL: 5649/ 736
PIXEL: 5681/ 792
PIXEL: 5750/3922
PIXEL: 5773/3892
PIXEL: 5808/2993
PIXEL: 5905/1254
PIXEL: 429/3821
PIXEL: 429/3822
PIXEL: 484/3841
PIXEL: 764/3843
PIXEL: 5751/3490

C04-00

PIXEL: 256/ 592
PIXEL: 278/1956
PIXEL: 412/3141
PIXEL: 671/2291
PIXEL: 763/ 479
PIXEL: 830/ 199
PIXEL: 1081/ 742
PIXEL: 1303/2596
PIXEL: 1623/3180
PIXEL: 2058/3362
PIXEL: 2194/ 378
PIXEL: 2270/2415
PIXEL: 2311/3318
PIXEL: 2453/1677
PIXEL: 2453/3968
PIXEL: 2618/1671
PIXEL: 2676/3201
PIXEL: 2924/3981
PIXEL: 3080/1971
PIXEL: 3095/1919
PIXEL: 3215/3701
PIXEL: 3307/2291
PIXEL: 3384/1138
PIXEL: 3398/3759
PIXEL: 3401/1879
PIXEL: 3457/3475
PIXEL: 3513/3121
PIXEL: 3590/2779
PIXEL: 3596/1715
PIXEL: 3616/ 103
PIXEL: 4161/ 626
PIXEL: 4253/3873
PIXEL: 4281/3560



PIXEL: 4304/2712
PIXEL: 4528/ 932
PIXEL: 4541/1741
PIXEL: 4807/ 716
PIXEL: 5108/ 172
PIXEL: 5108/ 173
PIXEL: 5132/ 374
PIXEL: 5150/ 320
PIXEL: 5219/2004
PIXEL: 5298/ 773
PIXEL: 5501/2359
PIXEL: 5568/2660
PIXEL: 5798/ 507
PIXEL: 5897/ 583

C05-00

PIXEL: 269/2998
PIXEL: 511/ 891
PIXEL: 582/3844
PIXEL: 584/1490
PIXEL: 649/2602
PIXEL: 994/3591
PIXEL: 1158/ 166
PIXEL: 1198/2954
PIXEL: 1384/ 616
PIXEL: 1435/1620
PIXEL: 1523/2802
PIXEL: 1591/1436
PIXEL: 1703/1756
PIXEL: 1708/ 35
PIXEL: 1979/1245
PIXEL: 2010/1885
PIXEL: 2069/ 837
PIXEL: 2082/2338
PIXEL: 2086/2559
PIXEL: 2126/1497
PIXEL: 2131/3391
PIXEL: 2547/3475
PIXEL: 2614/1663
PIXEL: 2627/1983
PIXEL: 2854/1773
PIXEL: 2865/3023
PIXEL: 2942/1585
PIXEL: 3041/3789
PIXEL: 3137/ 204
PIXEL: 3257/2265
PIXEL: 3595/1271
PIXEL: 3617/2968
PIXEL: 3787/2319
PIXEL: 3847/ 798



PIXEL: 3875/3202
PIXEL: 4179/1639
PIXEL: 4196/1668
PIXEL: 4444/1502
PIXEL: 4549/3014
PIXEL: 4589/ 807
PIXEL: 5011/1427
PIXEL: 5211/1574
PIXEL: 5252/1118
PIXEL: 5470/1418
PIXEL: 5734/2917
PIXEL: 534/ 413
PIXEL: 1496/ 143
PIXEL: 4813/1937

C06-00

PIXEL: 42/ 206
PIXEL: 207/2644
PIXEL: 237/1117
PIXEL: 397/2219
PIXEL: 421/2030
PIXEL: 479/3602
PIXEL: 648/1546
PIXEL: 692/2415
PIXEL: 723/2684
PIXEL: 754/ 210
PIXEL: 1133/2104
PIXEL: 1295/ 891
PIXEL: 1479/1434
PIXEL: 1541/3015
PIXEL: 1940/ 471
PIXEL: 2115/2301
PIXEL: 2413/2916
PIXEL: 2497/ 704
PIXEL: 2536/3344
PIXEL: 2692/3387
PIXEL: 2789/3041
PIXEL: 2942/2913
PIXEL: 2978/1834
PIXEL: 3011/3709
PIXEL: 3030/3623
PIXEL: 3391/ 888
PIXEL: 3418/3045
PIXEL: 3713/3449
PIXEL: 3802/3597
PIXEL: 3846/2563
PIXEL: 4173/3237
PIXEL: 4202/1697
PIXEL: 4354/1151
PIXEL: 4509/ 522



PIXEL: 4540/1534
PIXEL: 4722/ 164
PIXEL: 4765/2613
PIXEL: 4942/1898
PIXEL: 5087/3623
PIXEL: 5112/2806
PIXEL: 5465/1836
PIXEL: 5626/3631
PIXEL: 5672/ 518
PIXEL: 5693/1248
PIXEL: 5768/ 399
PIXEL: 5945/1204
PIXEL: 5995/2808
PIXEL: 85/ 17
PIXEL: 285/ 186

C07-00

PIXEL: 121/1992
PIXEL: 187/ 76
PIXEL: 200/ 496
PIXEL: 291/3482
PIXEL: 890/2268
PIXEL: 1138/2435
PIXEL: 1259/2309
PIXEL: 1289/ 524
PIXEL: 1363/ 877
PIXEL: 1465/2890
PIXEL: 2027/2295
PIXEL: 2156/1282
PIXEL: 2278/1035
PIXEL: 2640/ 536
PIXEL: 2654/1164
PIXEL: 2783/1404
PIXEL: 2923/3612
PIXEL: 3433/ 127
PIXEL: 3455/2763
PIXEL: 3497/1470
PIXEL: 3549/ 983
PIXEL: 3770/3042
PIXEL: 3818/ 147
PIXEL: 3995/3215
PIXEL: 4052/1899
PIXEL: 4273/3437
PIXEL: 4343/1400
PIXEL: 4442/2576
PIXEL: 4477/ 977
PIXEL: 4628/2467
PIXEL: 4675/ 423
PIXEL: 4781/1258
PIXEL: 4889/2609



PIXEL: 5189/ 318
PIXEL: 5277/1470
PIXEL: 5277/1471
PIXEL: 5424/1642
PIXEL: 5586/1036
PIXEL: 5642/1613
PIXEL: 5864/2901
PIXEL: 5883/ 229
PIXEL: 5893/1105
PIXEL: 5984/1135
PIXEL: 2710/ 565

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 Xp
Serial: UC-SXp-CI-90517044

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

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

Calibration Date: Dec-21-2018
Date of Report: Dec-28-2018
Camera Revision: Rev08.00
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 F8 [ms]	SRT F11 [ms]	SRT F16 [ms]	SRT F22 [ms]	Measurement Tolerance [ms]
C0 (Pan)	11 82 14 89	10.52	11.78	12.58	13.07	13.26	+/- 0.2
C1 (Pan)	11 86 19 59	10.01	11.28	12.04	12.65	12.98	+/- 0.2
C2 (Pan)	11 86 19 76	10.5	11.64	12.55	13.02	13.41	+/- 0.2
C3 (Pan)	11 86 19 24	9.98	11.04	11.74	12.17	12.34	+/- 0.2
C4 (Red)	11 86 49 79	11.65	12.02	12.8	13.24	13.42	+/- 0.2
C5 (Green)	11 86 49 77	11.66	12.19	12.82	13.08	13.28	+/- 0.2
C6 (Blue)	11 86 49 86	11.12	11.34	12.02	12.4	12.79	+/- 0.2
C7 (NIR)	11 86 49 97	12.17	12.76	13.34	13.73	13.73	+/- 0.2



ULTRACAM

Electronics and Sensor Calibration

Camera: UltraCam Xp
Serial: UC-SXp-CI-90517044

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

Calibration Date: Dec-21-2018
Date of Report: Dec-28-2018
Camera Revision: Rev08.00
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	14 3293/103	23.80
00_01	FTF6040-M	14 3859/114	22.80
00_02	FTF6040-M	14 3293/067	23.10
00_03	FTF6040-M	14 3293/095	23.00
01_00	FTF6040-M	14 3293/116	22.80
01_01	FTF6040-M	14 3293/041	23.00
02_00	FTF6040-M	14 3293/110	22.80
02_01	FTF6040-M	14 3293/094	23.00
03_00	FTF6040-M	14 3293/074	21.80
04_00 (red)	FTF6040-M	14 3293/026	23.00
05_00 (green)	FTF6040-M	14 3293/099	23.00
06_00 (blue)	FTF6040-M	14 3293/062	23.10
07_00 (NIR)	FTF6040-M	14 3293/072	22.00



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	14 3293/103	5640
00_01	FTF6040-M	14 3859/114	7280
00_02	FTF6040-M	14 3293/067	6450
00_03	FTF6040-M	14 3293/095	7900
01_00	FTF6040-M	14 3293/116	6220
01_01	FTF6040-M	14 3293/041	6720
02_00	FTF6040-M	14 3293/110	7910
02_01	FTF6040-M	14 3293/094	6470
03_00	FTF6040-M	14 3293/074	6430
04_00 (red)	FTF6040-M	14 3293/026	5950
05_00 (green)	FTF6040-M	14 3293/099	6280
06_00 (blue)	FTF6040-M	14 3293/062	6670
07_00 (NIR)	FTF6040-M	14 3293/072	6560



ULTRACAM

Summary

Camera:	UltraCam Xp
Serial:	UC-SXp-CI-90517044
Calibration Date:	Dec-21-2018
Date of Report:	Dec-28-2018
Camera Revision:	Rev08.00
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