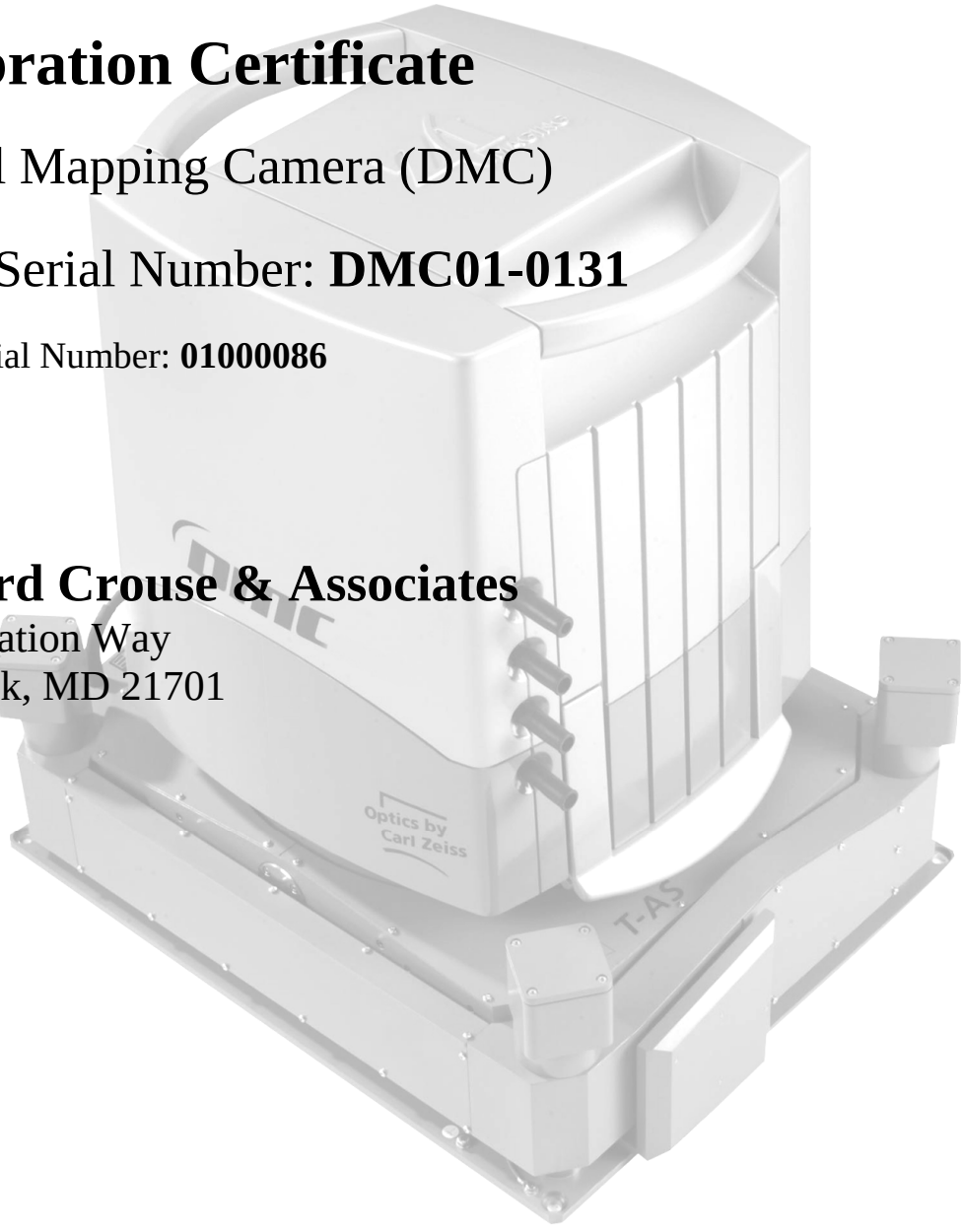
Calibration Certificate

Digital Mapping Camera (DMC)

DMC Serial Number: **DMC01-0131**

CBU Serial Number: **01000086**



For

Richard Crouse & Associates
467 Aviation Way
Frederick, MD 21701

USA

System Overview

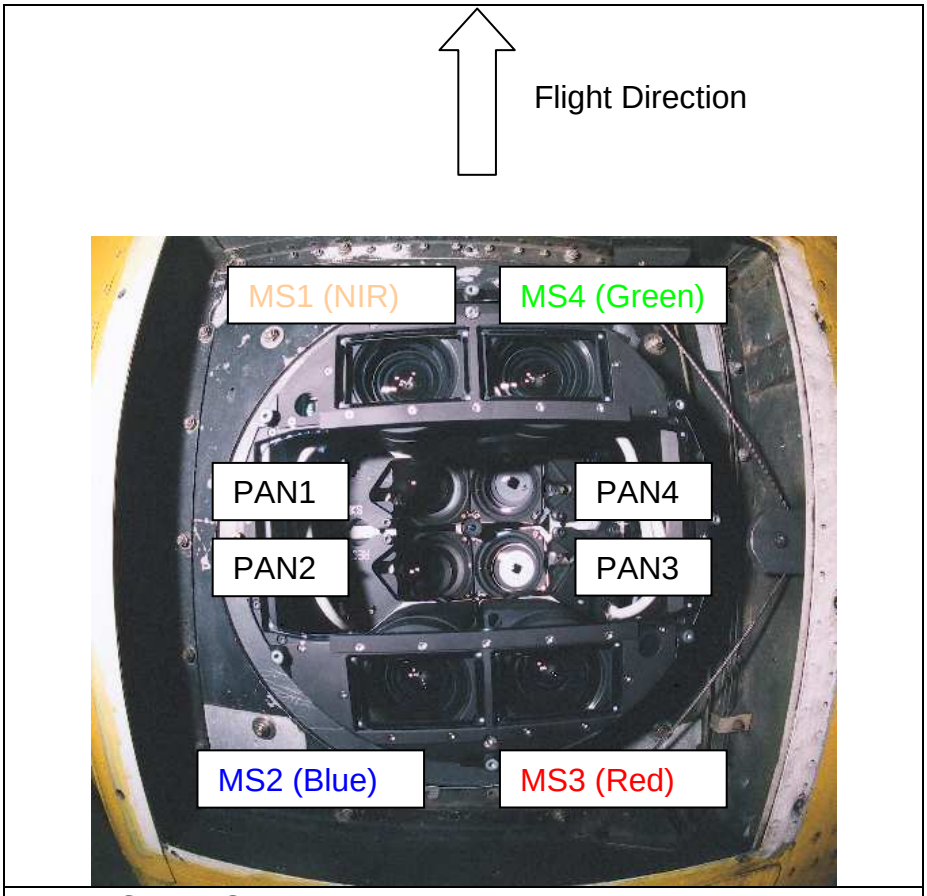


Figure: System Overview

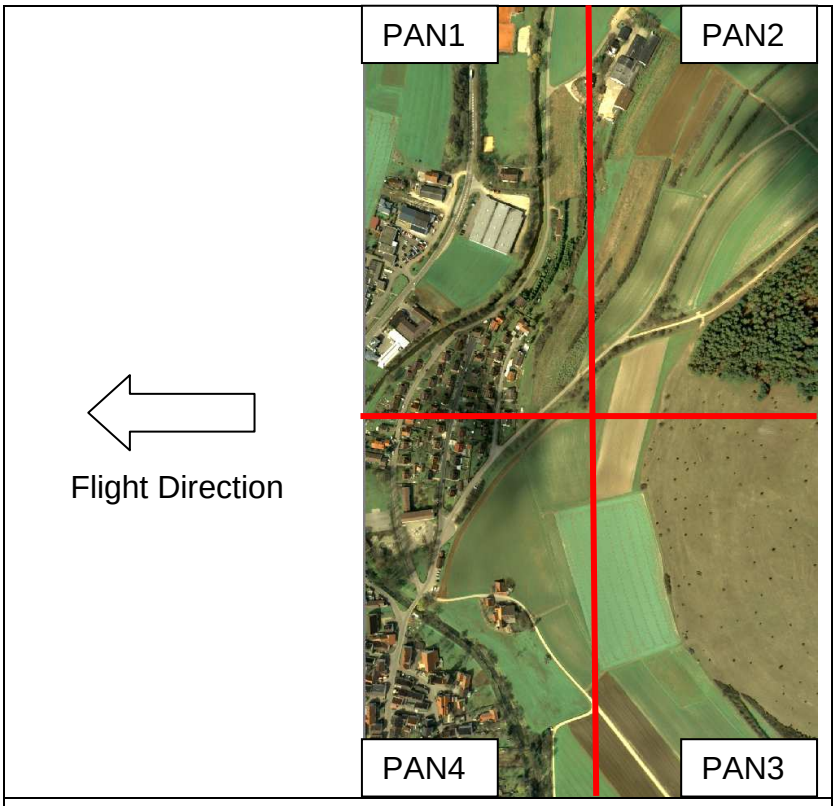


Figure Image Overview (Pan Camera)

Camera Parameter for Virtual Image (High Resolution)

Virtual Focal Length [m]	0.12
Virtual Sensor Size [Pixel]	13824 x 7680
Virtual Pixel Size [µm]	12
Virtual Principle Point [mm]	X = 0.0 Y = 0.0
Distortion Parameter	Distortion Free

Camera Parameter for Virtual Image (Color Resolution) before Version PPS 5.0.10.3

Virtual Focal Length [m]	0.12 / 4.75
Virtual Sensor Size [Pixel]	3072 x 2048
Virtual Pixel Size [µm]	12
Virtual Principle Point [mm]	X= -0.646 Y=0.646
Distortion Parameter	Distortion Free

Camera Parameter for Virtual Image (Color Resolution) after Version PPS 5.1.10.3

Virtual Focal Length [m]	0.030
Virtual Sensor Size [Pixel]	3456x1920
Virtual Pixel Size [µm]	12
Virtual Principle Point [mm]	X = 0.0 Y = 0.0
Distortion Parameter	Distortion Free

Camera Serial Number and Burn-In flights

	Burn In Flight: 09.09.2008					
Camera	Serial Number	Calib. Date				
PAN1	00117314	02.09.2008				
PAN2	00117317	28.08.2008				
PAN3	00117318	29.08.2008				
PAN4	00117319	01.09.2008				
MS1 (NIR)	00116834	29.07.2008				
MS2 (Blue)	00116832	13.08.2008				
MS3 (Red)	00116826	12.08.2008				
MS4 (Green)	00116830	08.08.2008				

Calibration Protocol
DMC01 - 0131

Camera Orientation PAN-Cameras (Burn-In Flight 09.09.2008)

Camera (Serial Number)	X [m] (Accuracy)	Y [m] (Accuracy)	Z [m] (Accuracy)	Omega [Deg] (Accuracy)	Phi [Deg] (Accuracy)	Kappa [Deg] (Accuracy)
PAN1 (00115583)	0.064 (0)	-0.079 (0)	1000 (0)	17.969 (0.001)	10.096 (0.001)	86.701 (0.001)
PAN2 (00115584)	-0.064 (0)	-0.079 (0)	1000 (0)	17.945 (0.001)	-10.193 (0.001)	93.116 (0.001)
PAN3 (00115546)	-0.064 (0)	0.079 (0)	1000 (0)	-17.973 (0.001)	-10.080 (0.001)	-92.671 (0.001)
PAN4 (00115794)	0.064 (0)	0.079 (0)	1000 (0)	-17.940 (0.001)	10.178 (0.001)	-87.035 (0.001)

The data is connected to the virtual projection center of the virtual image.
The above Platform calibration values are initial values and are be liable to slight fluctuations between project images and between different projects. The position is fix and error free. The rotation axes of the angles are (in this order)

Omega	x-Axis
Phi	y-Axis
Kappa	z-Axis

The results of the Platform calibration were generated with DMC Postprocessing SW (PPS), Version 5.4, from Intergraph Z/I Imaging photogrammetric product suite.

Platform calibration performed by

Dipl. Ing. C. Müller

08.09.2008
Date

Calibration Protocol
DMC01 - 0131

Aerotriangulation Results (Burn-In Flight 09.09.2008)

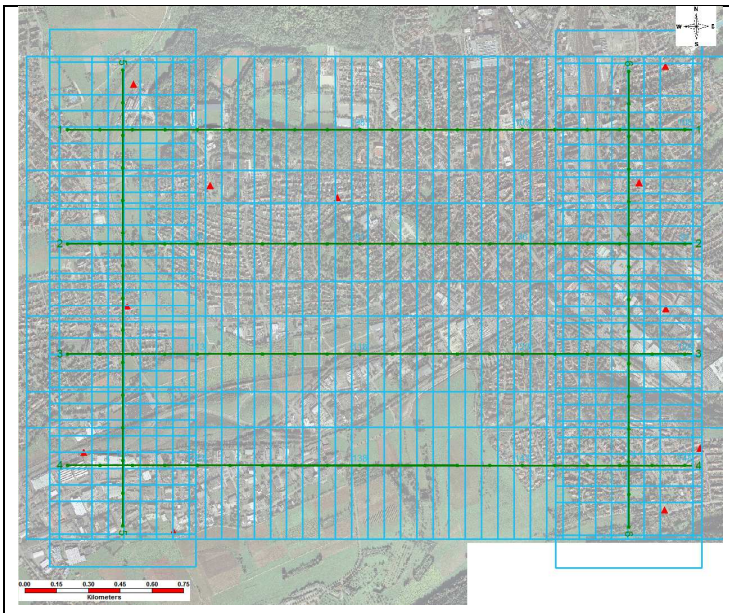


Photo Scale	1:5000
Flying Height [m]	600 AGL
Flying Altitude [m]	1060 AMSL
Run-Spacing [m]	580.6
Base-Length [m]	184.3
Number of Exposures	98
Side-lap [%]	30
End-lap [%]	60
Terrain Height [m]	460
Number of strips	6
Photos in one strip	2 x 15 N-S 4 x 17 W-E
Photos Used	98
Control Points Used	34
Check Points Used	
GSD [cm]	6

Statistic results:

Matching results: 0 Weak Areas – covered with clouds
Whole Block 98 exposures used
0 exposures not used

Whole Block Sigma relativ: 2.780 um

Whole Block Sigma absolut: 2.805 um

Whole Block

Photo-T Parameters and Results for Project Aa_6cm_131

PhotoT Triangulation Options

```
Adjustment Mode             : Absolute
Precision Computation       : Enabled
Error Detection             : Disabled
Camera Calibration          : Disabled
Self-Calibration            : Disabled
Given EO/GPS                : Disabled
Antenna Offsets             : Disabled
GPS Shift/Drift Correction  : Disabled
INS Shift/Drift Correction  : Disabled
```

Parameters

Parameter	X/Omega	Y/Phi	Z/Kappa	XY
RMS Control	0.058	0.044	0.060	0.052
RMS Check				
RMS Limits	0.060	0.060	0.100	
Max Ground Residual	0.116	0.119	0.137	
Residual Limits	0.100	0.100	0.150	
Mean Std Dev Object	0.019	0.020	0.048	
RMS Photo Position				

Calibration Protocol
DMC01 - 0131

```
          RMS Photo Attitude
 Mean Std Dev Photo Position   0.042  0.038   0.028
 Mean Std Dev Photo Attitude   0.003  0.004   0.001

Key Statistics

       Sigma:         2.8  um
       Number of iterations: 2
       Degrees of Freedom:   12049
```

The results of the Aerotriangulation were generated with ImageStation Automatic Triangulation (ISAT), Version 5.3, from Intergraph Z/I Imaging photogrammetric product suite.

Aerotriangulation performed by

Dipl. Ing. C. Müller

08.09.2008
Date

Calibration Protocol
DMC01 - 0131

Calibration Certificate N° 00117314

Object	Digital Aerial Survey Camera
Manufacturer	Z/I Imaging D-73431 Aalen
Type	DMC-Panchromatic
Serial Number	00117314

Calibration performed at:
Carl Zeiss Jena

Number of pages of the certificate 68

Date of Calibration 02.Sep.2008

CertifiedDate	Division Head	Person in Charge
18.Sep.2008	(H. Sohnle)	(S. Schröder)

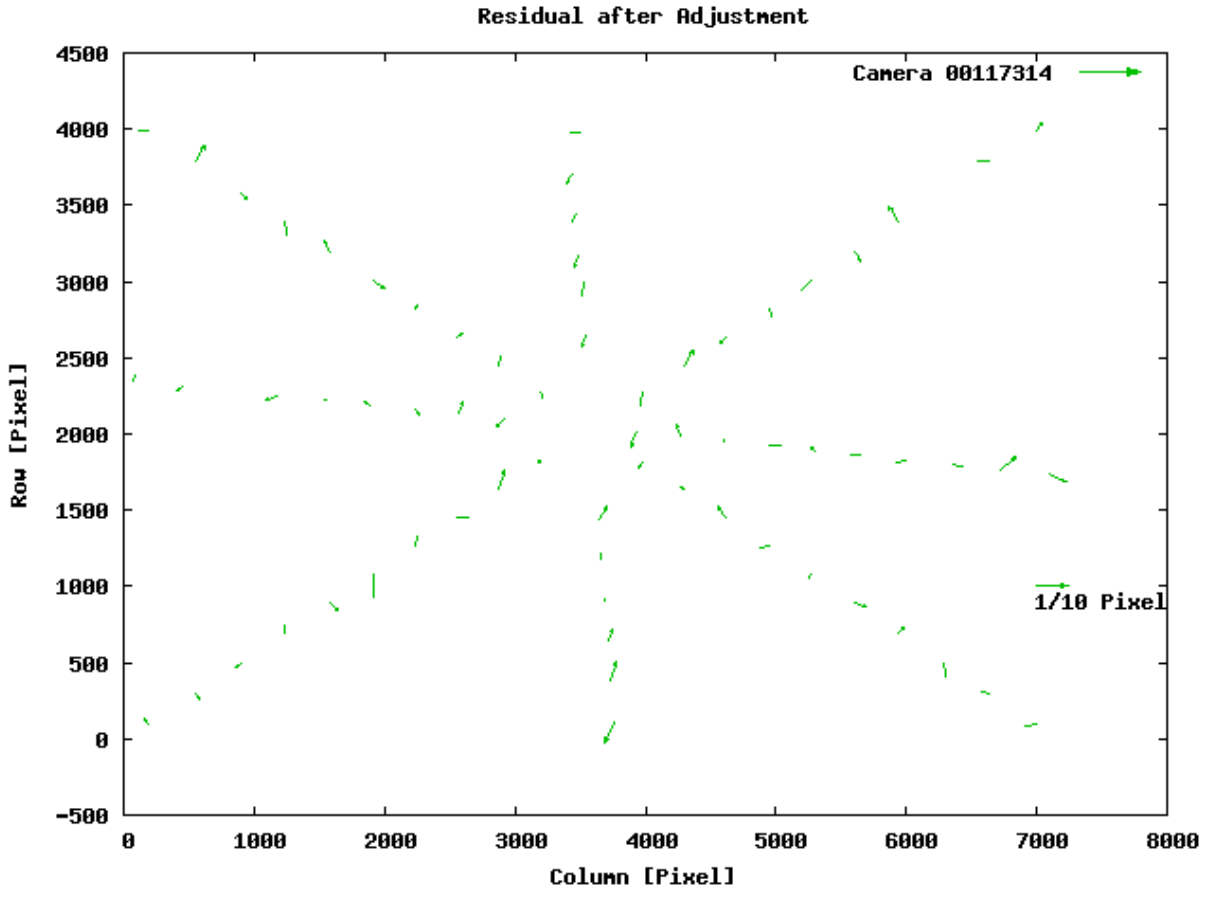
Geometric Calibration Protocol

Calibration Parameters for single camera head

Camera Type	DMC-Panchromatic
Nominal Focal Length	0.12 m
Serial Number	00117314

	Param	Adjusted	Std.dev.
Principal Point [m]	x_0	4.54E-05	5.764E-06
	y_0	5.339E-05	3.477E-06
Focal Length [m]	Δf	-0.0004738	1.006E-06
Radial Distortion	K_1	0.8374	0.02579
	K_2	-400.4	23.23
	K_3	1217	6116
Decentring distortion	P_1	-0.000471	0.0001314
	P_2	0.0003039	6.582E-05
In Plane Distortion	B_1	-2.508E-06	6.682E-06
	B_2	-1.592E-05	3.838E-06

Adjusted Focal length = 0.12+ dc =0.1195262 [m]



Residuals in Image after Adjustment

Max Residual [µm]: 0.8

Threshold [µm]: 8.5

Remarks:

The images after the post processing are distortion free. For interior orientation parameters of the DMC virtual image see section: “Calibration Parameter of the virtual images”.

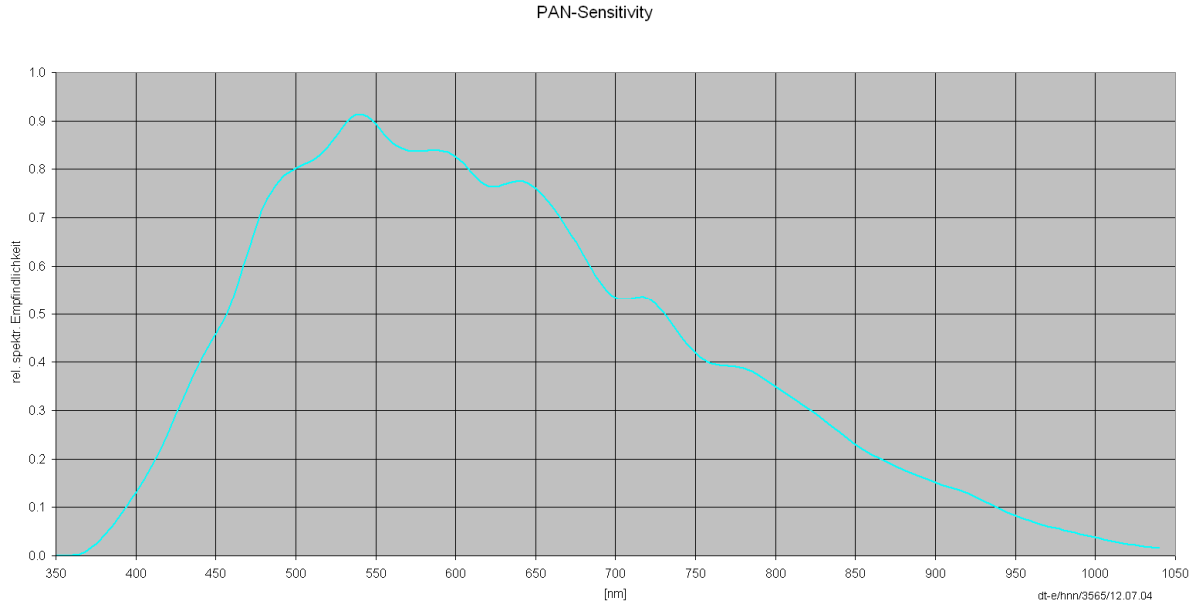
The calibration model is explained in the section “Calibration Model” at the end of this documentation.

Radiometric Calibration Protocol

In this section you’ll find the radiometric calibration results.

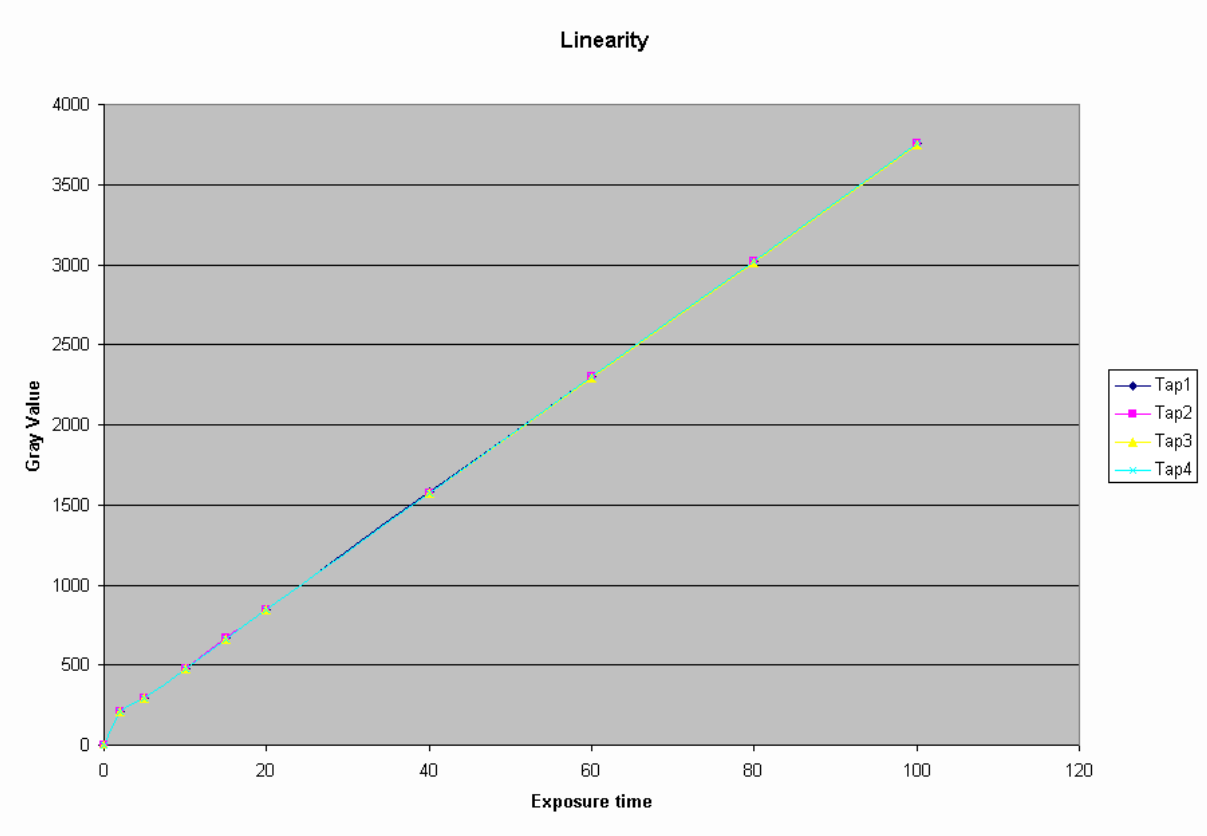
Camera ID	00117314
Sensor Revision Number	2
Lens Revision Number	1
Filter Revision Number	-
Aperture Revision Number	1

Sensitivity of camera



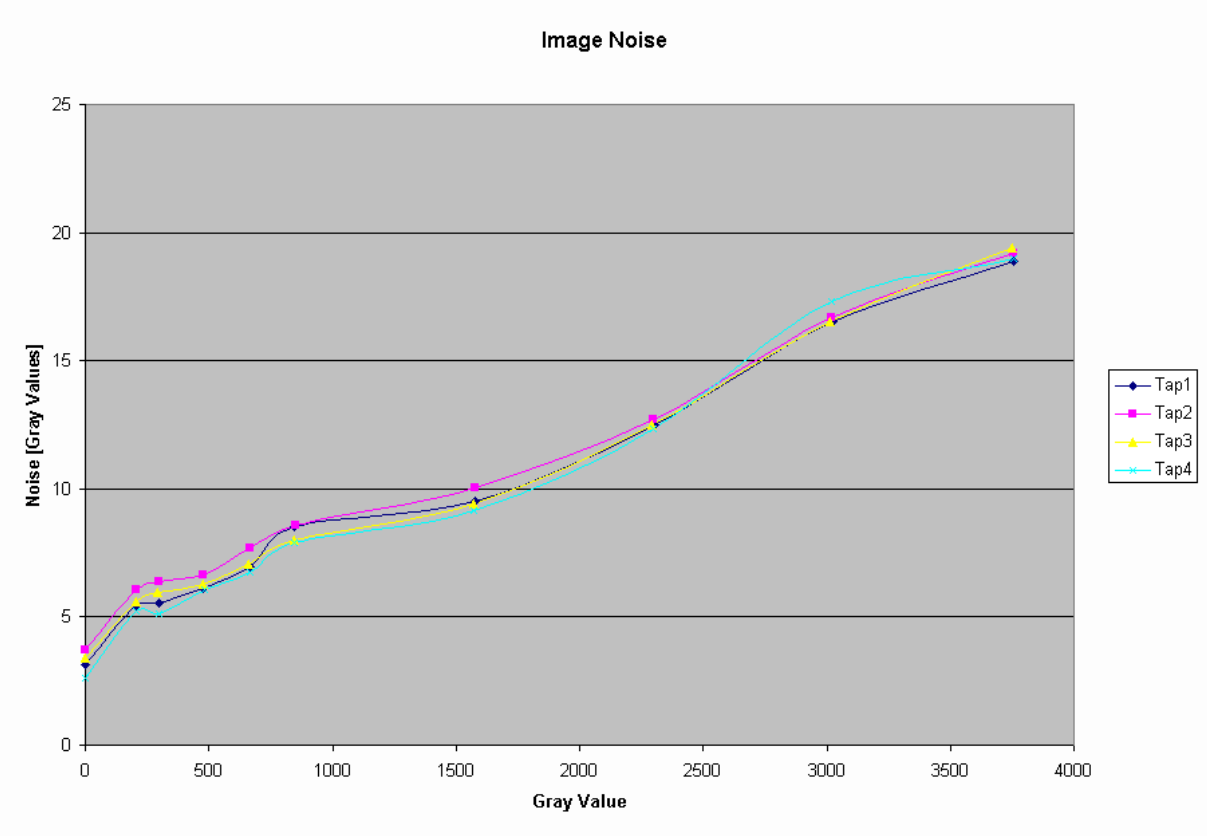
Remark:
Measurement is done without the influence of the shutter and the Analog/Digital converter. This graph is similar for the same lens and filter revision numbers. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Linearity



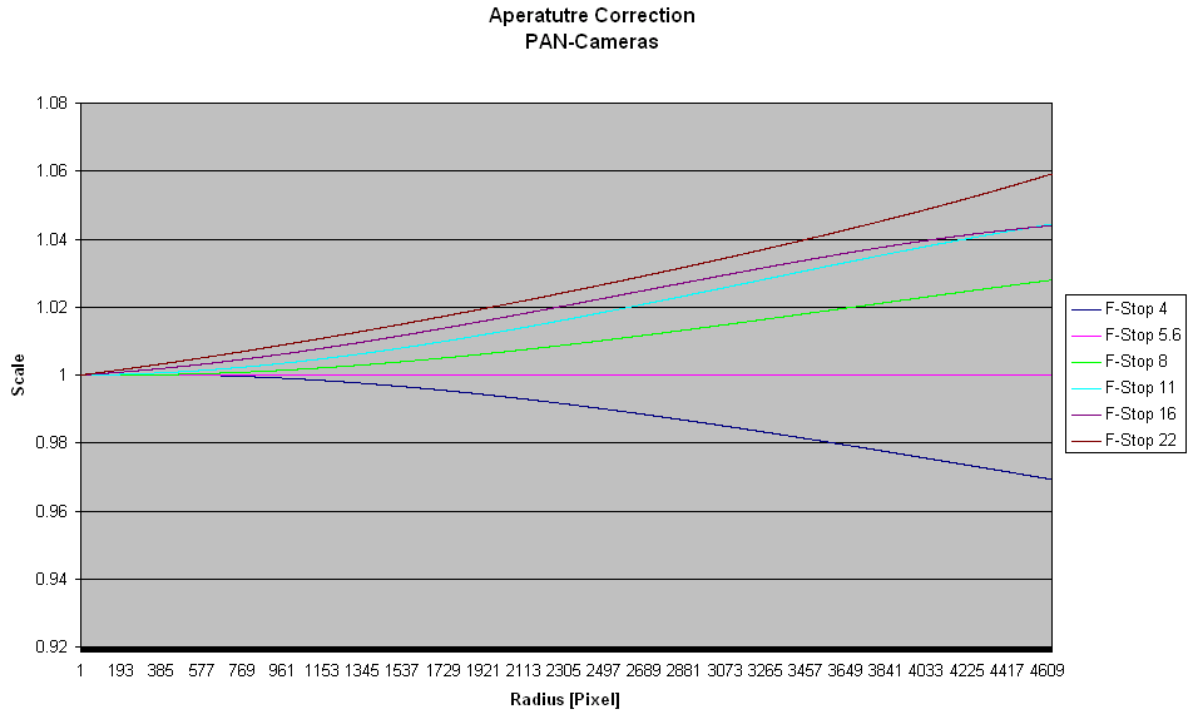
Remark:
The sensor linearity is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Noise



Remark:
The sensor noise is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Aperture Correction



Remark:
This measurement is similar for the same aperture revision number. For more details see Appendix: "Radiometric Calibration Model".

Defect Pixel List

Number of defect pixels: 7

Number of defect clusters: 0

Number of defect columns: 0

Nr	Row	Column
0	3623	1545
1	3624	1545
2	3623	1546
3	3624	1546
4	3625	1546
5	3623	1547

6 3624 1547

Defect	Column	RowStart	ColumnStart	RowEnd	ColumnEnd

Remark

See Appendix for definition of defect pixels and maximal allowed numbers.

Calibration Protocol
DMC01 - 0131

Calibration Certificate N^{O} 00117317

Object	Digital Aerial Survey Camera
Manufacturer	Z/I Imaging D-73431 Aalen
Type	DMC-Panchromatic
Serial Number	00117317

Calibration performed at:
Carl Zeiss Jena

Number of pages of the certificate 68

Date of Calibration 28.Aug.2008

CertifiedDate	Division Head	Person in Charge
18.Sep.2008	(H. Sohnle)	(S. Schröder)

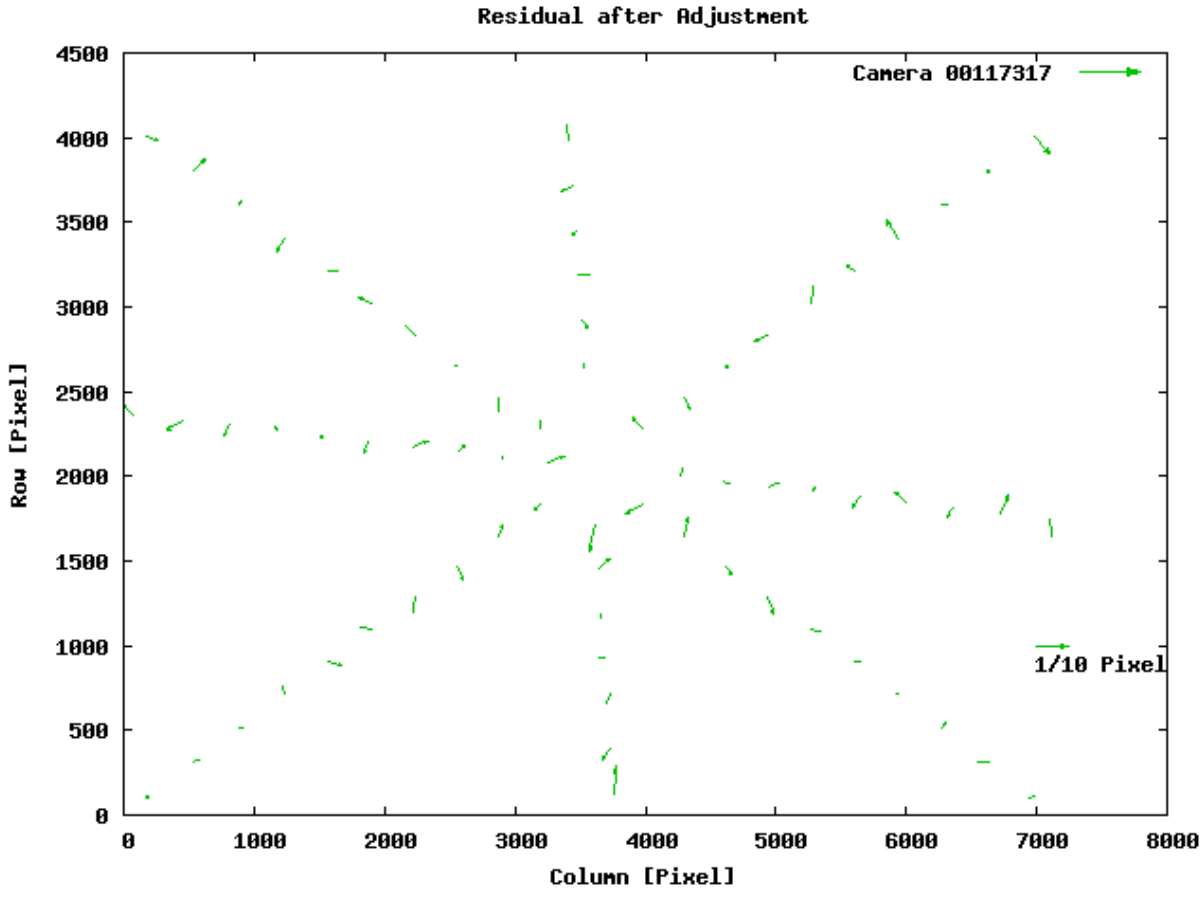
Geometric Calibration Protocol

Calibration Parameters for single camera head

Camera Type	DMC-Panchromatic
Nominal Focal Length	0.12 m
Serial Number	00117317

	Param	Adjusted	Std.dev.
Principal Point [m]	x_0	4.363E-05	6.046E-06
	y_0	-0.0001474	3.658E-06
Focal Length [m]	Δf	-0.0004241	1.055E-06
Radial Distortion	K_1	0.85	0.0271
	K_2	-420.5	24.42
	K_3	5485	6431
Decentring distortion	P_1	9.815E-06	0.0001378
	P_2	0.000297	6.939E-05
In Plane Distortion	B_1	2.424E-06	7.038E-06
	B_2	2.548E-05	4.046E-06

Adjusted Focal length = 0.12+ dc =0.1195759 [m]



Residuals in Image after Adjustment

Max Residual [µm]: 0.8

Threshold [µm]: 8.5

Remarks:

The images after the post processing are distortion free. For interior orientation parameters of the DMC virtual image see section: “Calibration Parameter of the virtual images”.

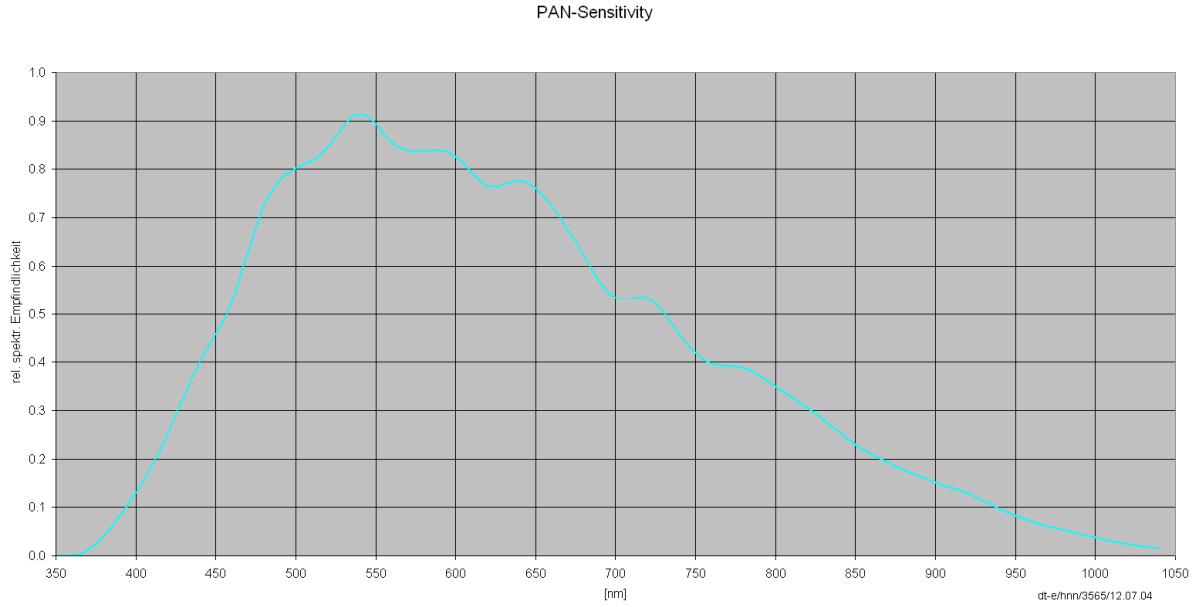
The calibration model is explained in the section “Calibration Model” at the end of this documentation.

Radiometric Calibration Protocol

In this section you’ll find the radiometric calibration results.

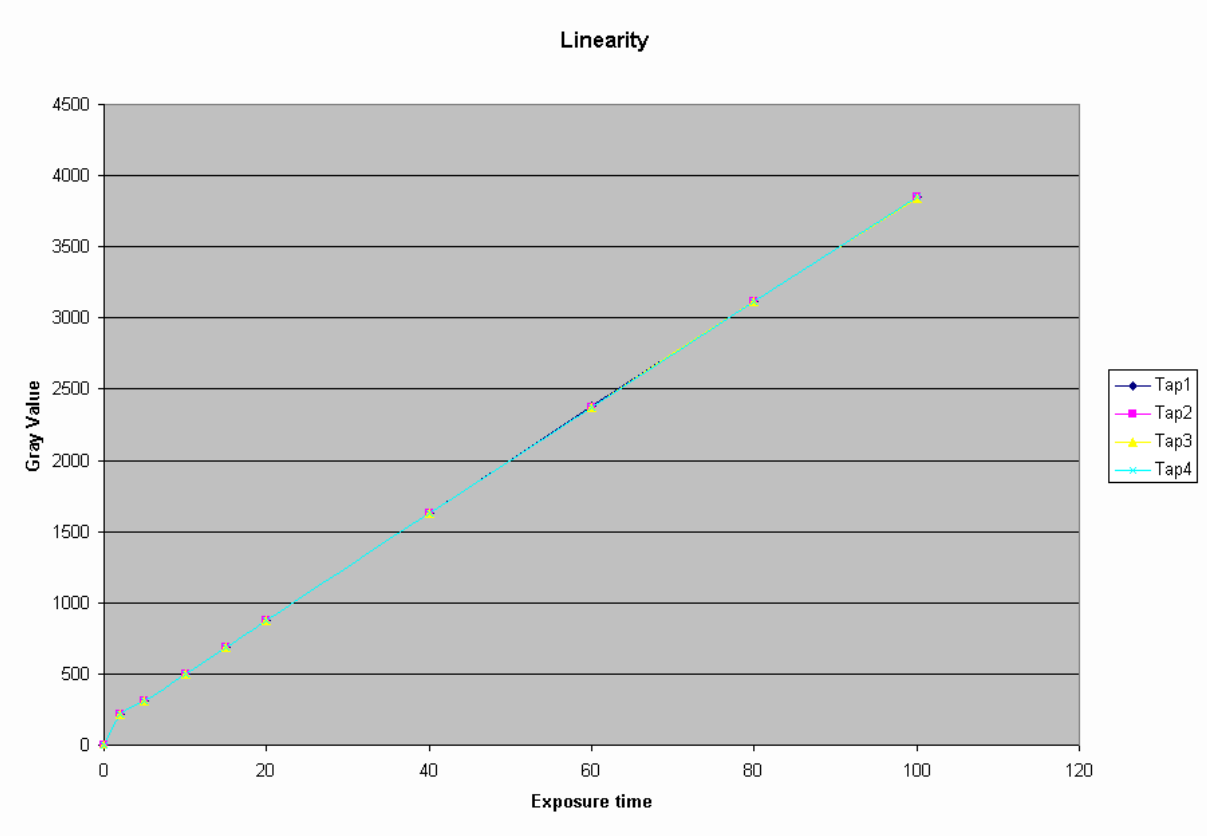
Camera ID	00117317
Sensor Revision Number	2
Lens Revision Number	1
Filter Revision Number	-
Aperture Revision Number	1

Sensitivity of camera



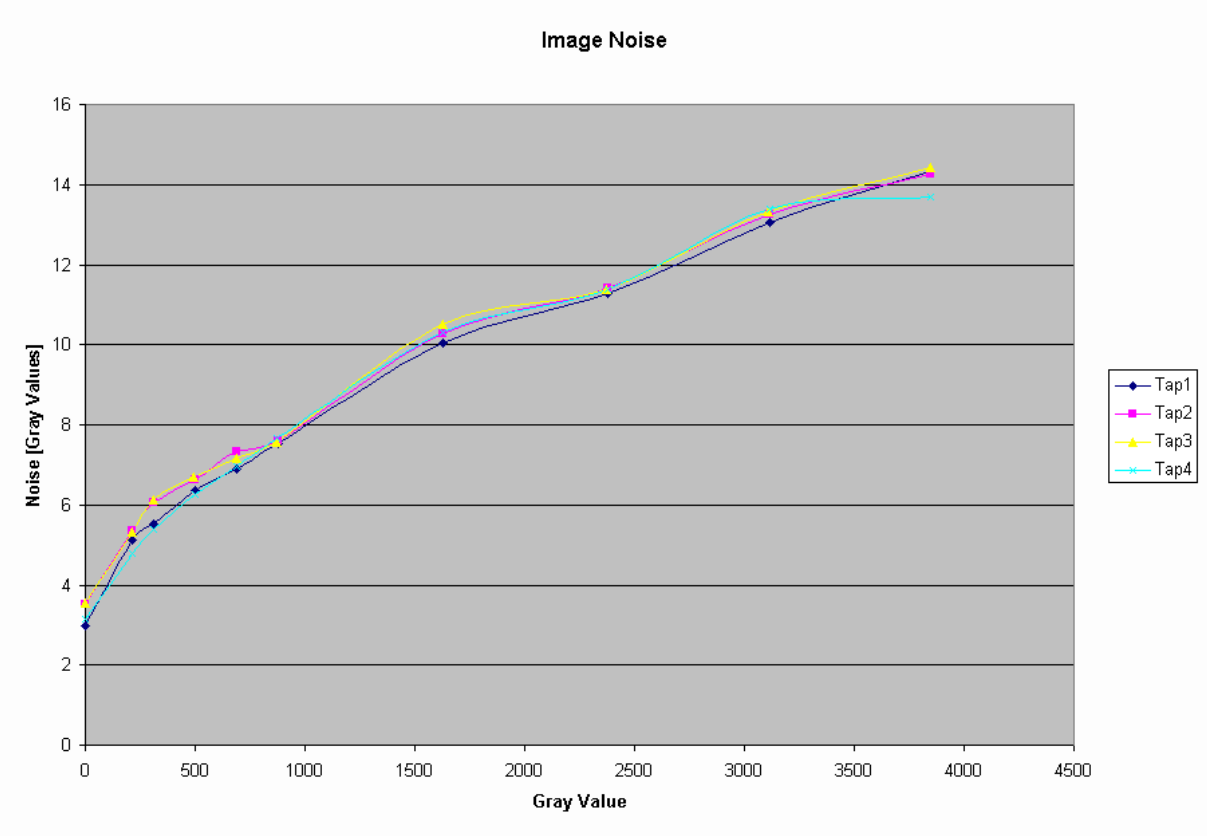
Remark:
Measurement is done without the influence of the shutter and the Analog/Digital converter. This graph is similar for the same lens and filter revision numbers. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Linearity



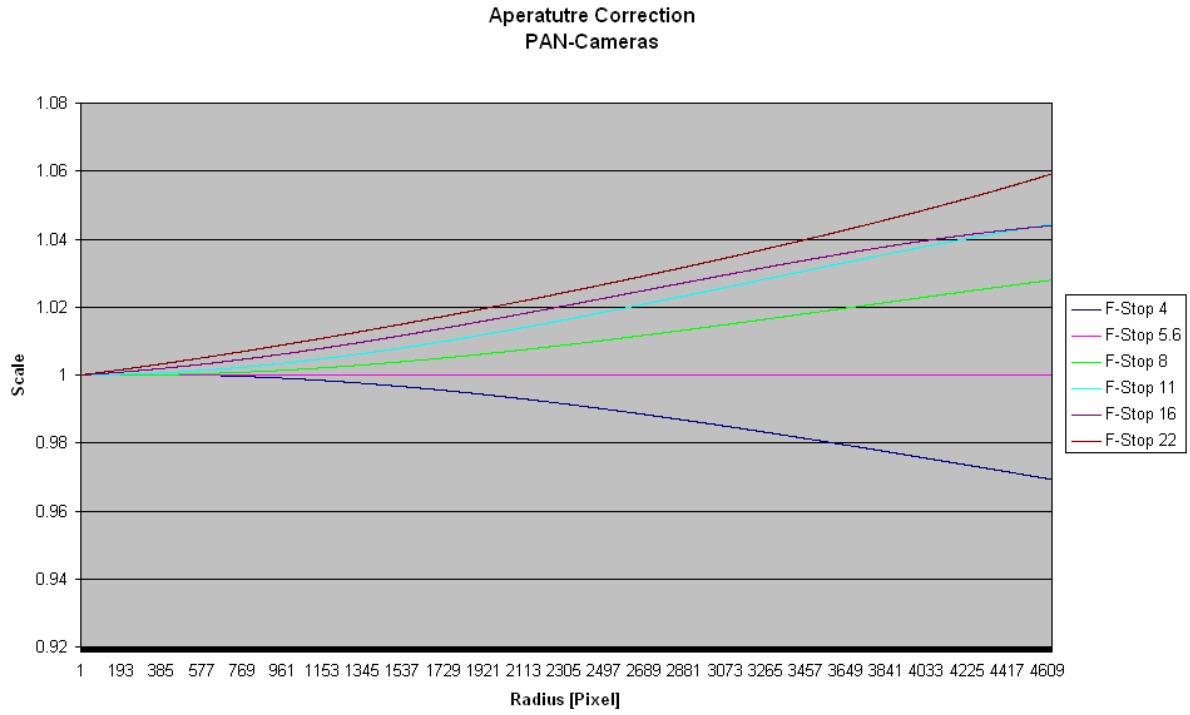
Remark:
The sensor linearity is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Noise



Remark:
The sensor noise is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Aperture Correction



Remark:
This measurement is similar for the same aperture revision number. For more details see Appendix: "Radiometric Calibration Model".

Defect Pixel List

Number of defect pixels: 0

Number of defect clusters: 0

Number of defect columns: 2

Nr Row Column

Defect Column	RowStart	ColumnStart	RowEnd	ColumnEnd
0	519	3704	2047	3704
1	2048	6553	2815	6553

Remark

See Appendix for definition of defect pixels and maximal allowed numbers.

Calibration Protocol
DMC01 - 0131

Calibration Certificate N^{O} 00117318

Object	Digital Aerial Survey Camera
Manufacturer	Z/I Imaging D-73431 Aalen
Type	DMC-Panchromatic
Serial Number	00117318

Calibration performed at:
Carl Zeiss Jena

Number of pages of the certificate 68

Date of Calibration 29.Aug.2008

CertifiedDate	Division Head	Person in Charge
18.Sep.2008	(H. Sohnle)	(S. Schröder)

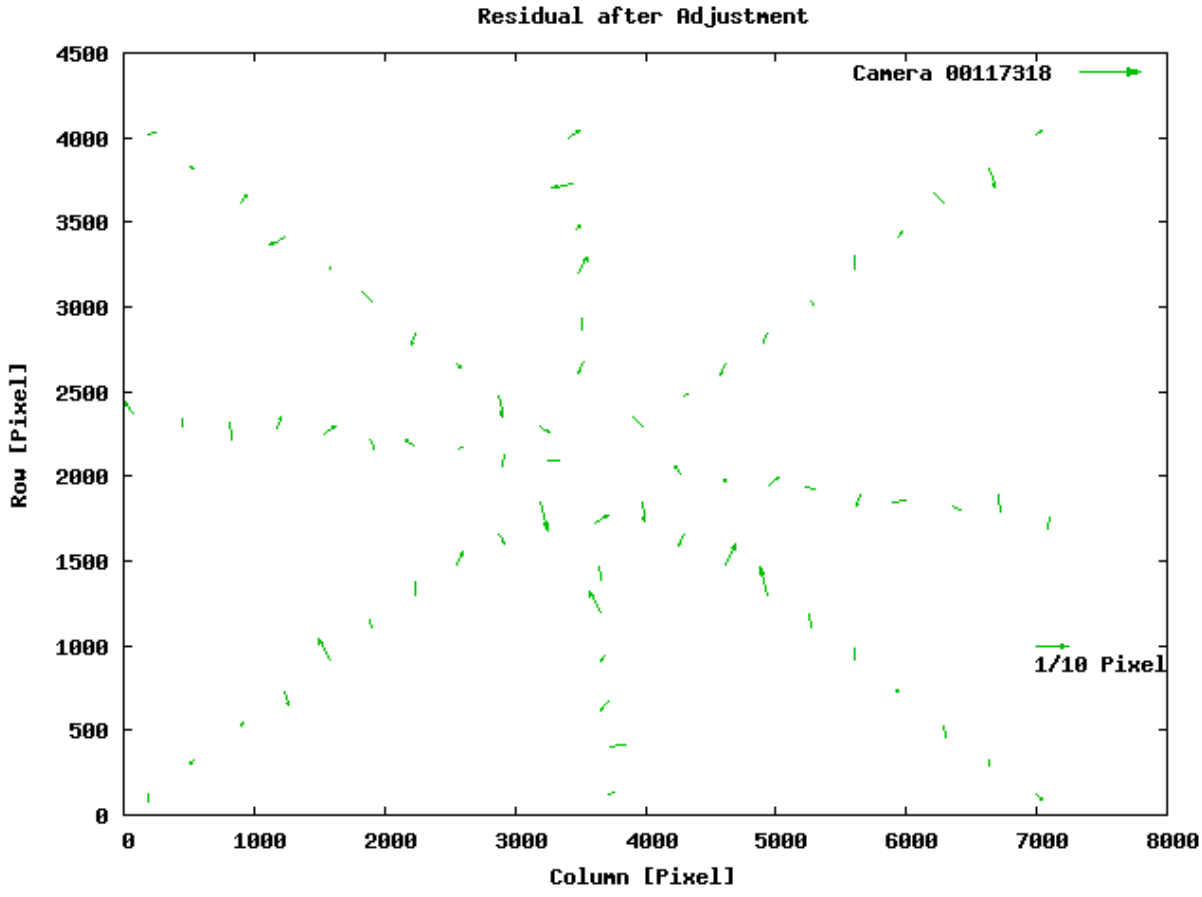
Geometric Calibration Protocol

Calibration Parameters for single camera head

Camera Type	DMC-Panchromatic
Nominal Focal Length	0.12 m
Serial Number	00117318

	Param	Adjusted	Std.dev.
Principal Point [m]	x_0	3.799E-05	6.169E-06
	y_0	-0.0003121	3.732E-06
Focal Length [m]	Δf	-0.0004621	1.076E-06
Radial Distortion	K_1	0.7207	0.02765
	K_2	-307.1	24.91
	K_3	-20990	6561
Decentring distortion	P_1	-0.0001896	0.0001406
	P_2	-0.0004378	7.079E-05
In Plane Distortion	B_1	-3.007E-05	7.181E-06
	B_2	1.073E-05	4.128E-06

Adjusted Focal length = 0.12+ dc =0.1195379 [m]



Residuals in Image after Adjustment

Max Residual [µm]: 0.9

Threshold [µm]: 8.5

Remarks:

The images after the post processing are distortion free. For interior orientation parameters of the DMC virtual image see section: “Calibration Parameter of the virtual images”.

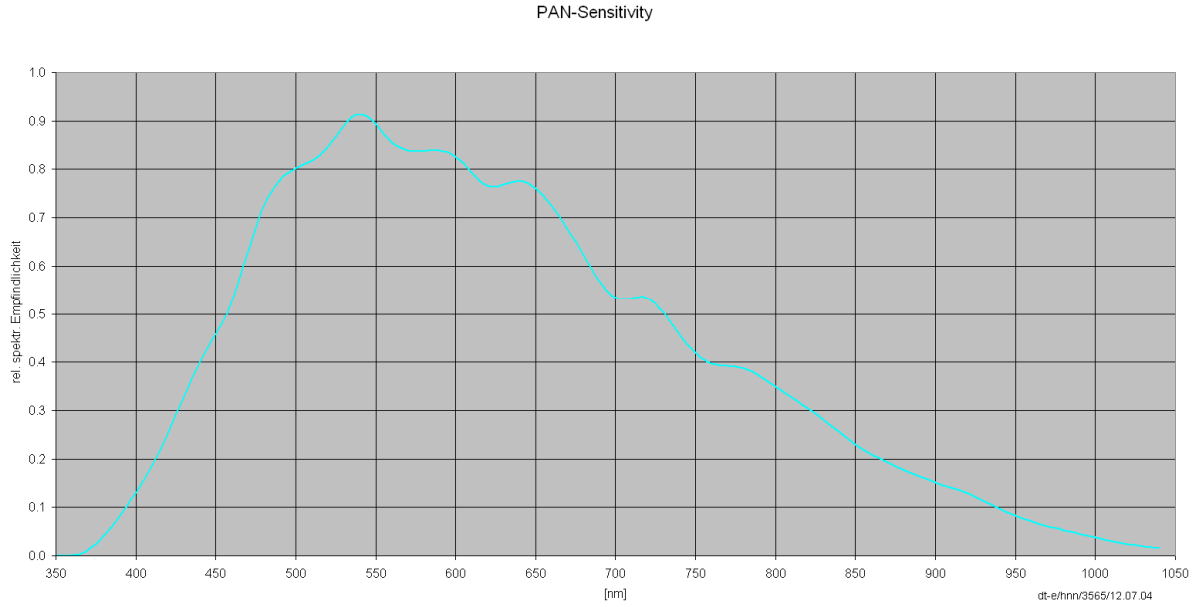
The calibration model is explained in the section “Calibration Model” at the end of this documentation.

Radiometric Calibration Protocol

In this section you’ll find the radiometric calibration results.

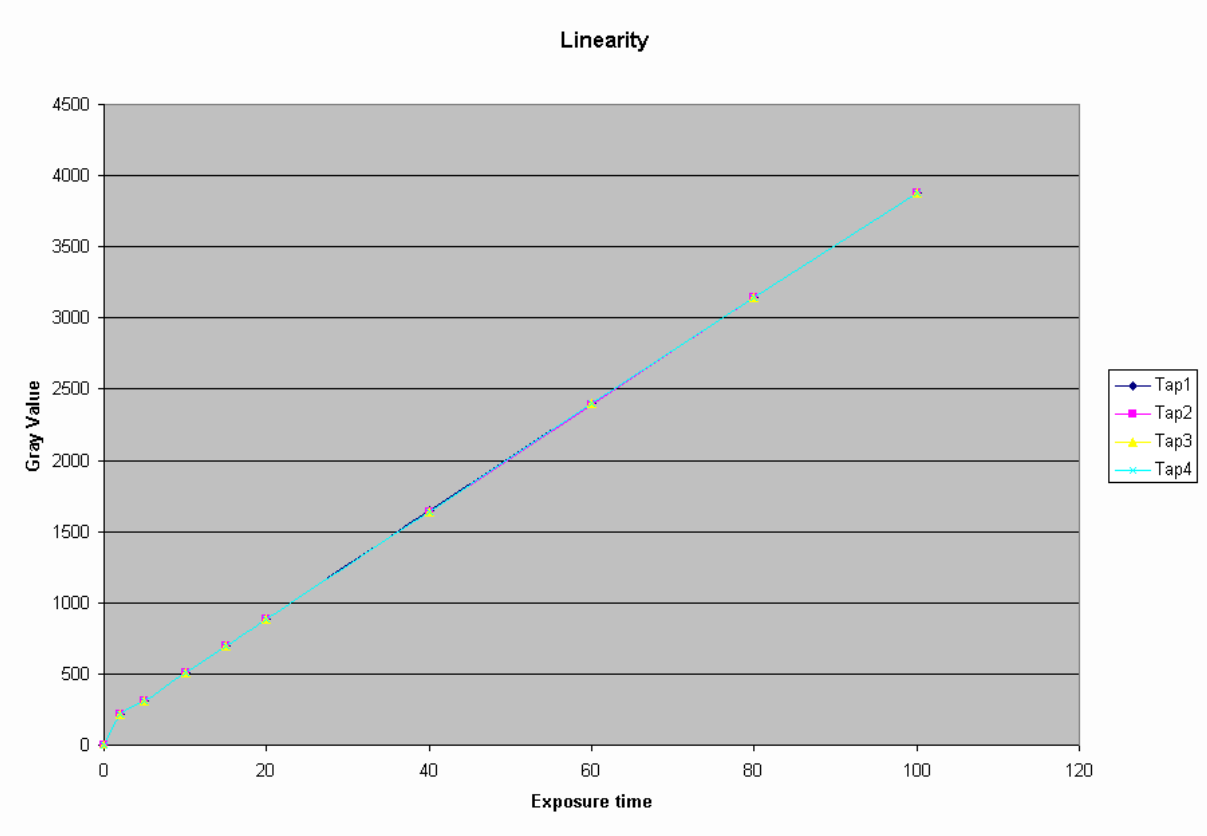
Camera ID	00117318
Sensor Revision Number	2
Lens Revision Number	1
Filter Revision Number	-
Aperture Revision Number	1

Sensitivity of camera



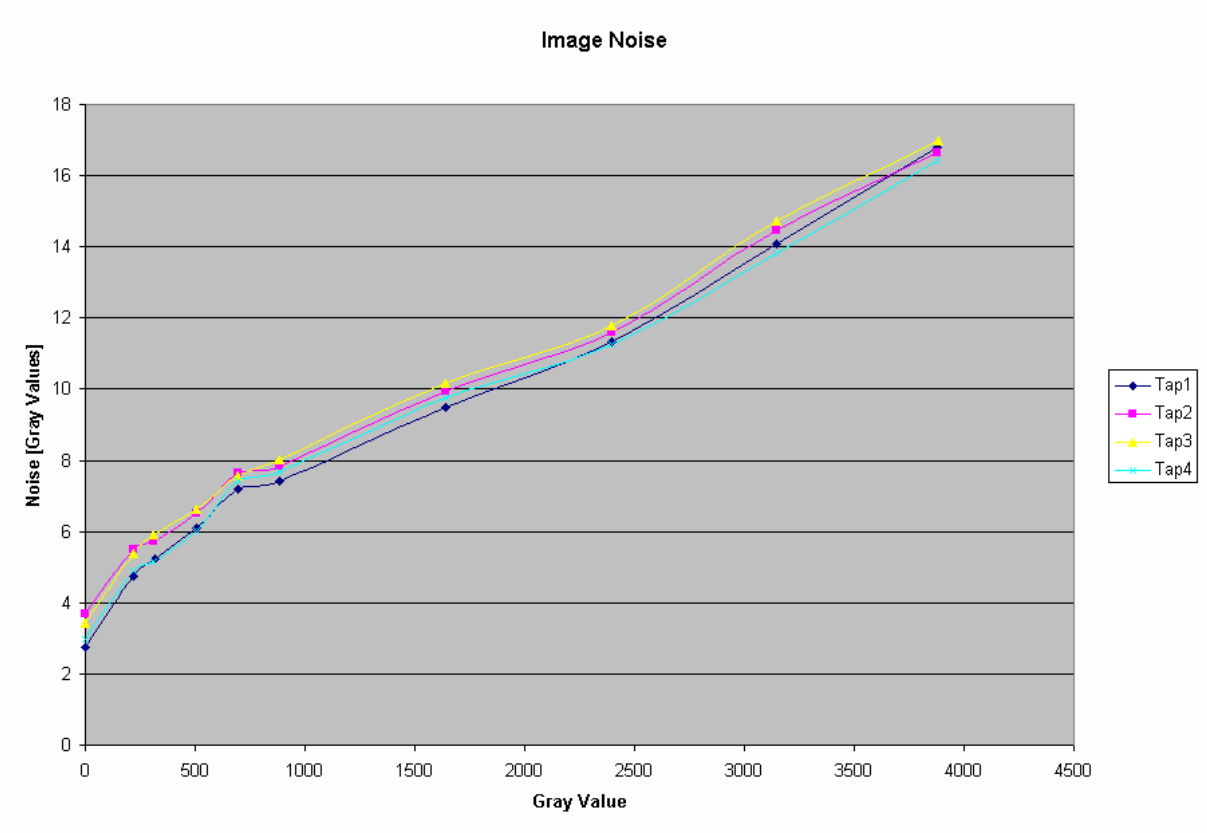
Remark:
Measurement is done without the influence of the shutter and the Analog/Digital converter. This graph is similar for the same lens and filter revision numbers. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Linearity



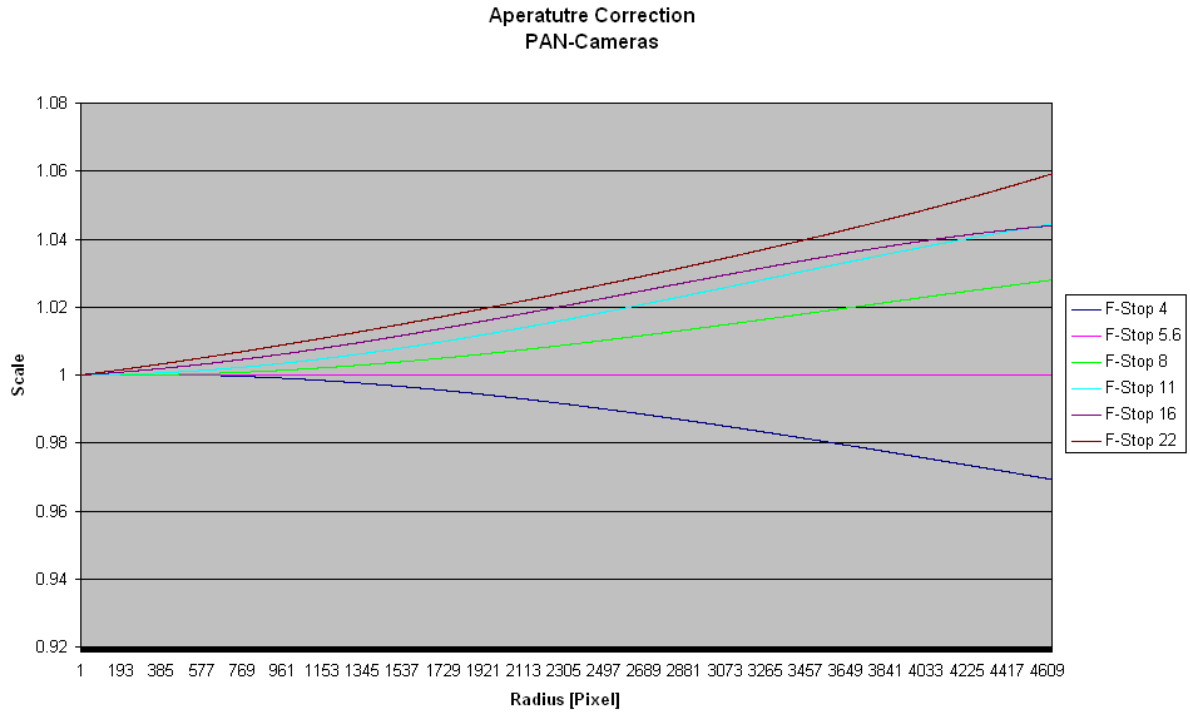
Remark:
The sensor linearity is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Noise



Remark:
The sensor noise is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Aperture Correction



Remark:
This measurement is similar for the same aperture revision number. For more details see Appendix: "Radiometric Calibration Model".

Defect Pixel List

Number of defect pixels: 0

Number of defect clusters: 0

Number of defect columns: 0

Nr Row Column

Defect Column RowStart ColumnStart RowEnd ColumnEnd

Remark

See Appendix for definition of defect pixels and maximal allowed numbers.

Calibration Protocol
DMC01 - 0131

Calibration Certificate N° 00117319

Object	Digital Aerial Survey Camera
Manufacturer	Z/I Imaging D-73431 Aalen
Type	DMC-Panchromatic
Serial Number	00117319

Calibration performed at:
Carl Zeiss Jena

Number of pages of the certificate 68

Date of Calibration 01.Sep.2008

CertifiedDate	Division Head	Person in Charge
18.Sep.2008	(H. Sohnle)	(S. Schröder)

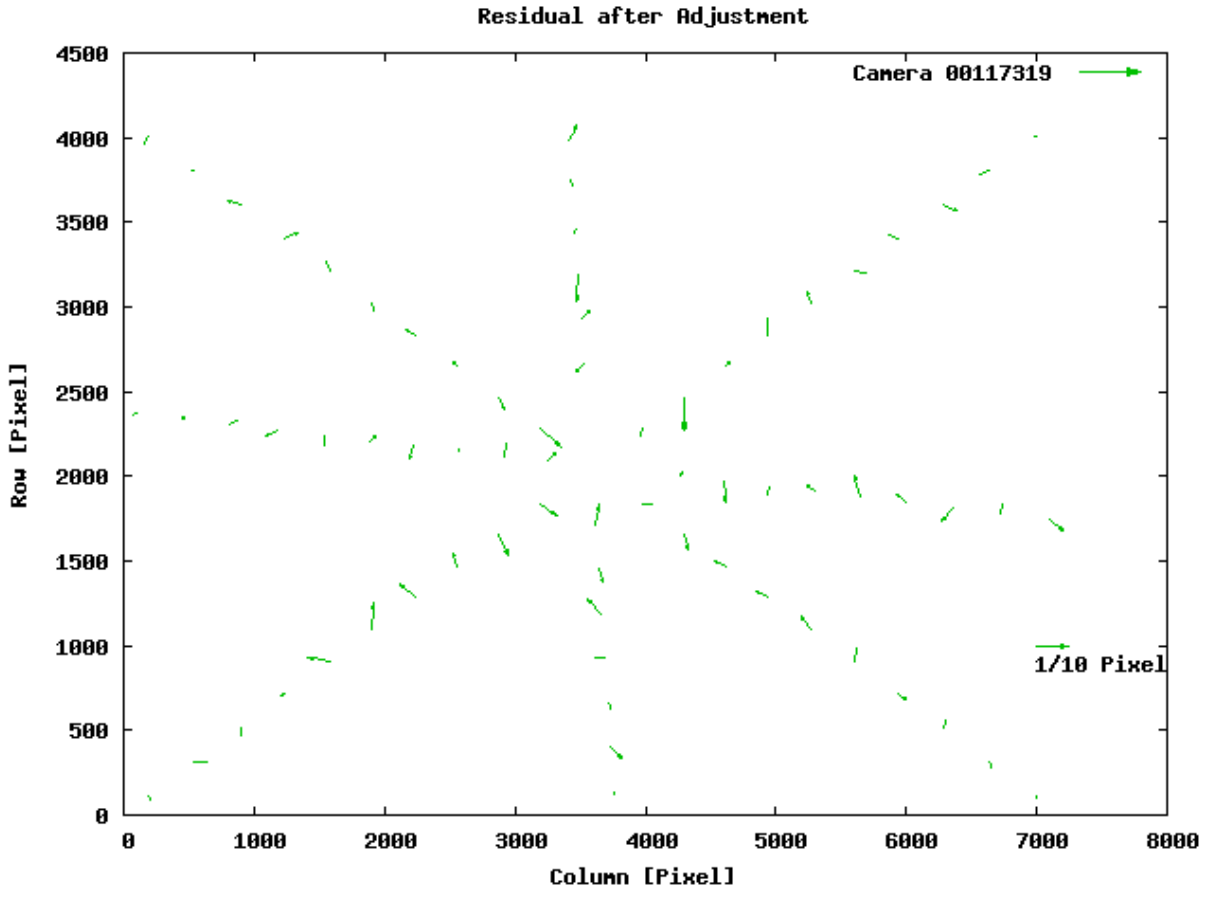
Geometric Calibration Protocol

Calibration Parameters for single camera head

Camera Type	DMC-Panchromatic
Nominal Focal Length	0.12 m
Serial Number	00117319

	Param	Adjusted	Std.dev.
Principal Point [m]	x_0	5.905E-05	6.437E-06
	y_0	-0.000135	3.895E-06
Focal Length [m]	Δf	-0.0004428	1.123E-06
Radial Distortion	K_1	0.5804	0.02885
	K_2	-231.9	26
	K_3	-37740	6847
Decentring distortion	P_1	-2.713E-05	0.0001467
	P_2	0.0001345	7.387E-05
In Plane Distortion	B_1	-4.842E-05	7.493E-06
	B_2	-1.508E-05	4.307E-06

Adjusted Focal length = 0.12+ dc =0.1195572 [m]



Residuals in Image after Adjustment

Max Residual [µm]: 1.0

Threshold [µm]: 8.5

Remarks:

The images after the post processing are distortion free. For interior orientation parameters of the DMC virtual image see section: “Calibration Parameter of the virtual images”.

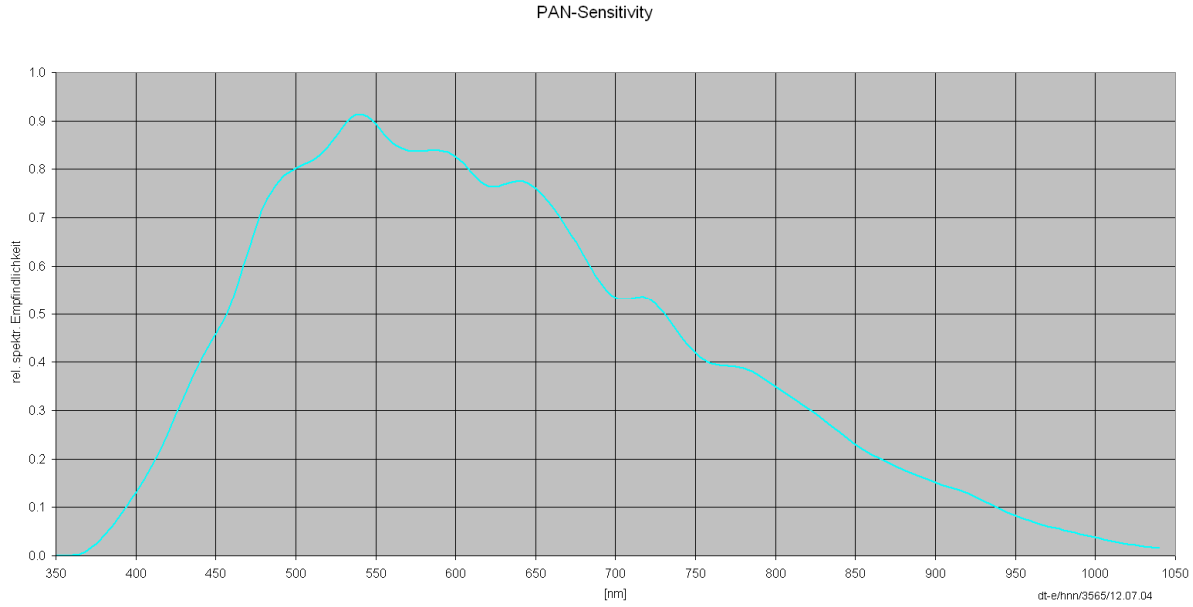
The calibration model is explained in the section “Calibration Model” at the end of this documentation.

Radiometric Calibration Protocol

In this section you’ll find the radiometric calibration results.

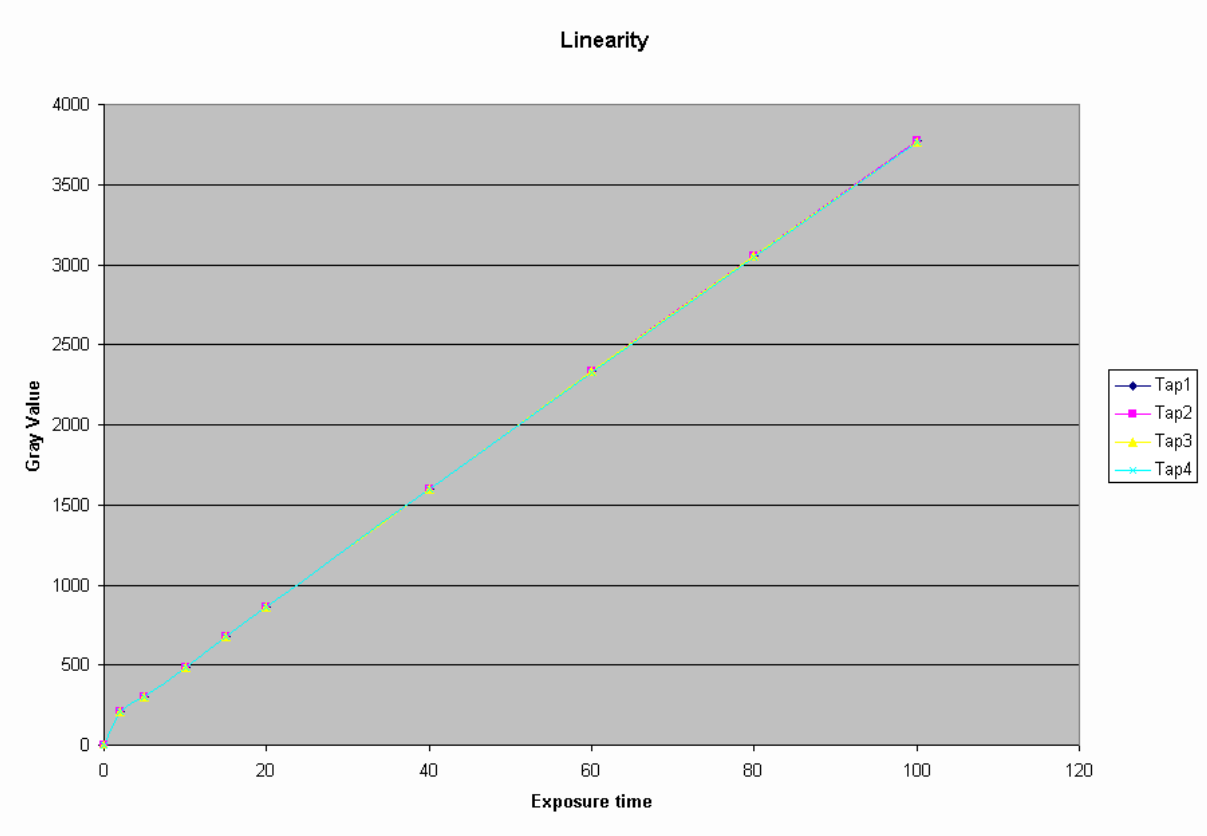
Camera ID	00117319
Sensor Revision Number	2
Lens Revision Number	1
Filter Revision Number	-
Aperture Revision Number	1

Sensitivity of camera



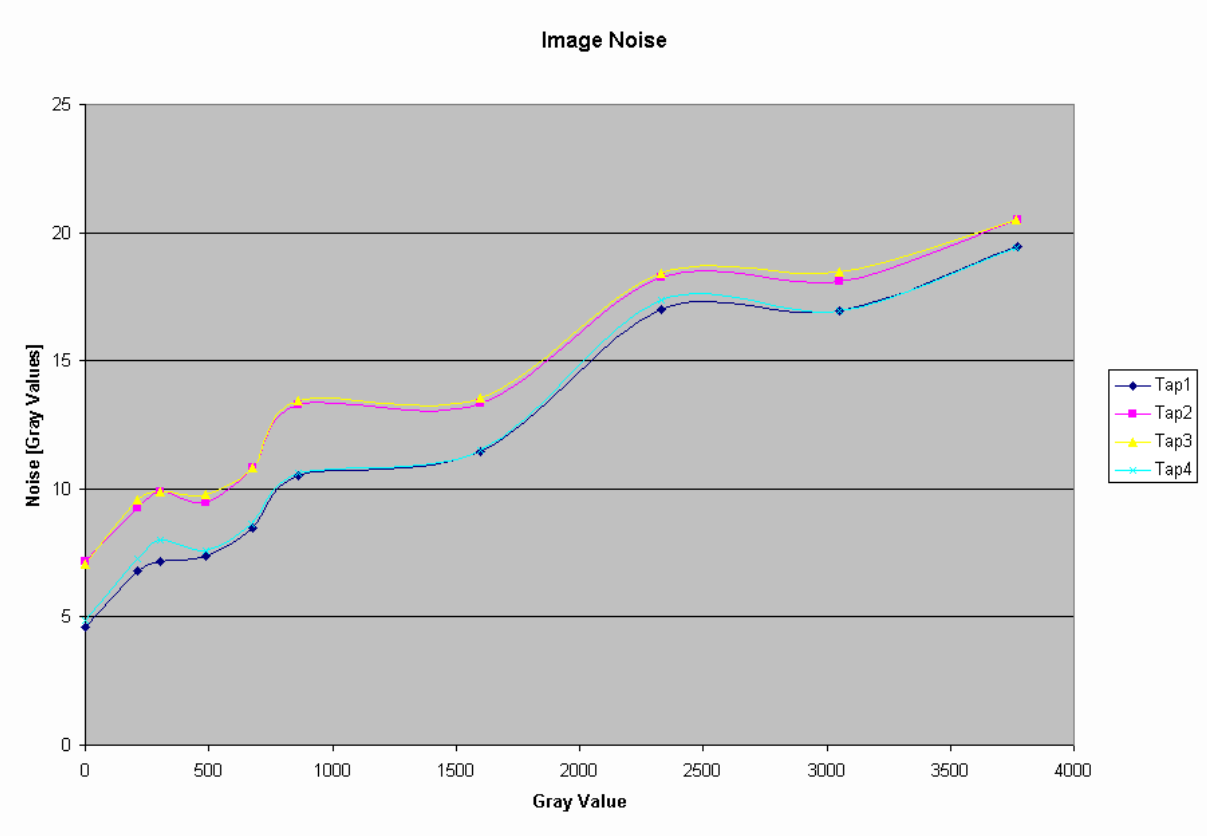
Remark:
Measurement is done without the influence of the shutter and the Analog/Digital converter. This graph is similar for the same lens and filter revision numbers. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Linearity



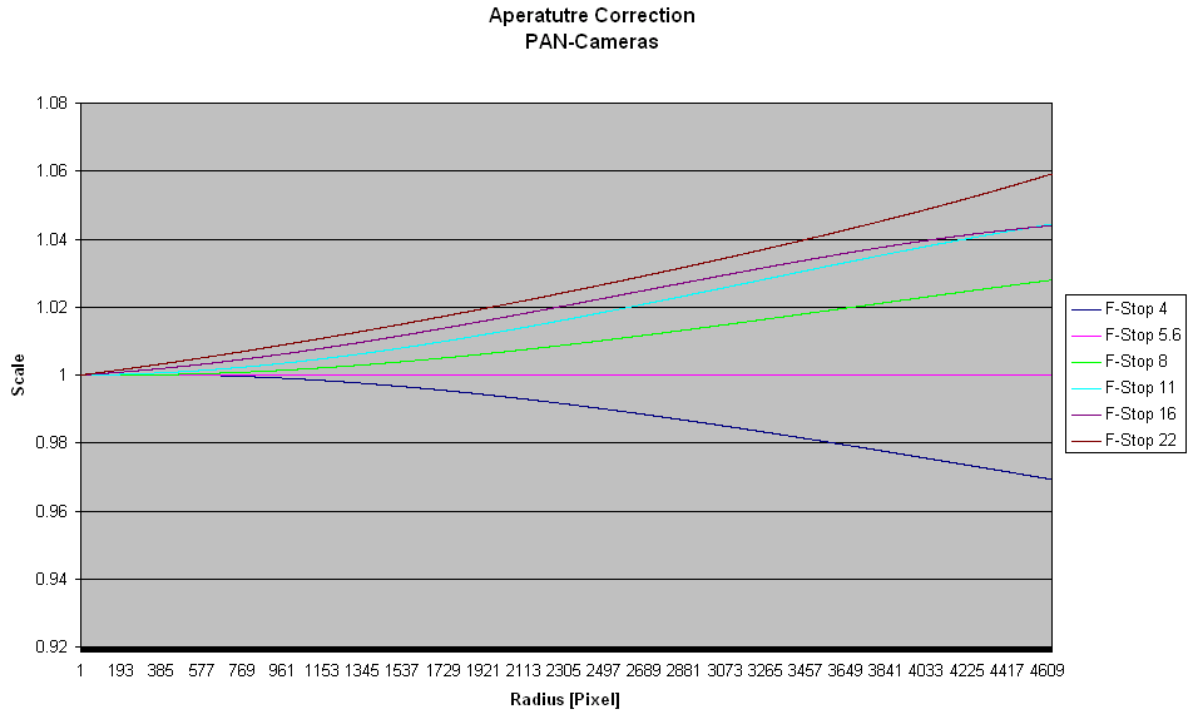
Remark:
The sensor linearity is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Noise



Remark:
The sensor noise is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Aperture Correction



Remark:
This measurement is similar for the same aperture revision number. For more details see Appendix: "Radiometric Calibration Model".

Defect Pixel List

Number of defect pixels: 2
Number of defect clusters: 0
Number of defect columns: 0

Nr	Row	Column
0	848	4811
1	848	4812

Defect	Column	RowStart	ColumnStart	RowEnd	ColumnEnd

Remark

See Appendix for definition of defect pixels and maximal allowed numbers.

Calibration Protocol
DMC01 - 0131

Calibration Certificate N^{O} 00116834

Object	Digital Aerial Survey Camera
Manufacturer	Z/I Imaging D-73431 Aalen
Type	DMC-MS-NIR
Serial Number	00116834

Calibration performed at:
Carl Zeiss Jena

Number of pages of the certificate 68

Date of Calibration 29.Jul.2008

CertifiedDate	Division Head	Person in Charge
18.Sep.2008	(H. Sohnle)	(S. Schröder)

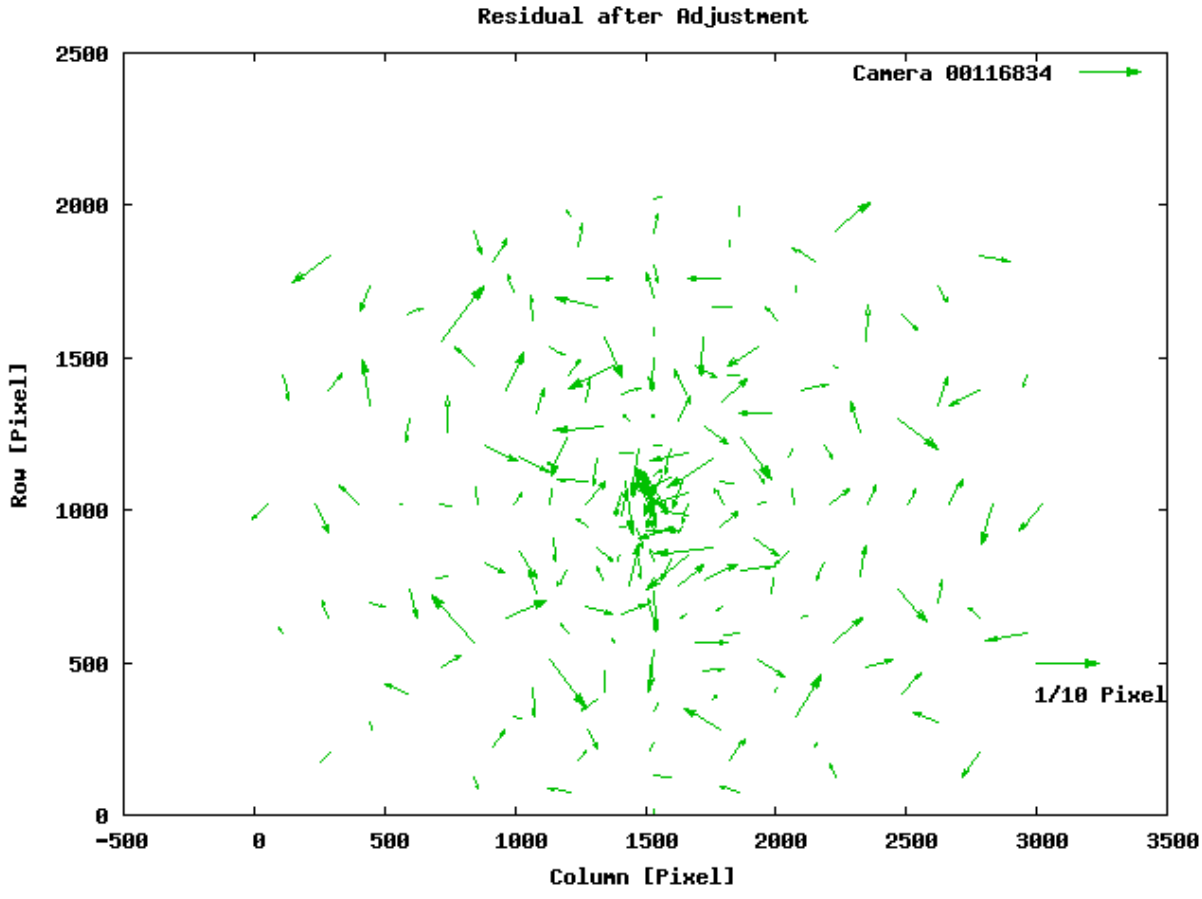
Geometric Calibration Protocol

Calibration Parameters for single camera head

Camera Type	DMC-MS-NIR
Nominal Focal Length	0.025 m
Serial Number	00116834

	Param	Adjusted	Std.dev.
Principal Point [m]	x_0	-2.163E-05	1.049E-06
	y_0	3.499E-05	7.406E-07
Focal Length [m]	Δf	3.474E-05	3.882E-07
Radial Distortion	K_1	-143	0.3263
	K_2	217900	2081
	K_3	-138000000	3746000
Decentring distortion	P_1	-0.0008762	0.0005452
	P_2	0.0004097	0.0003384
In Plane Distortion	B_1	5.478E-05	9.602E-06
	B_2	-2.441E-05	7.762E-06

Adjusted Focal length = 0.025+ dc =0.02503474 [m]



Residuals in Image after Adjustment

Max Residual [µm]: 1.2

Threshold [µm]: 8.5

Remarks:

The images after the post processing are distortion free. For interior orientation parameters of the DMC virtual image see section: “Calibration Parameter of the virtual images”.

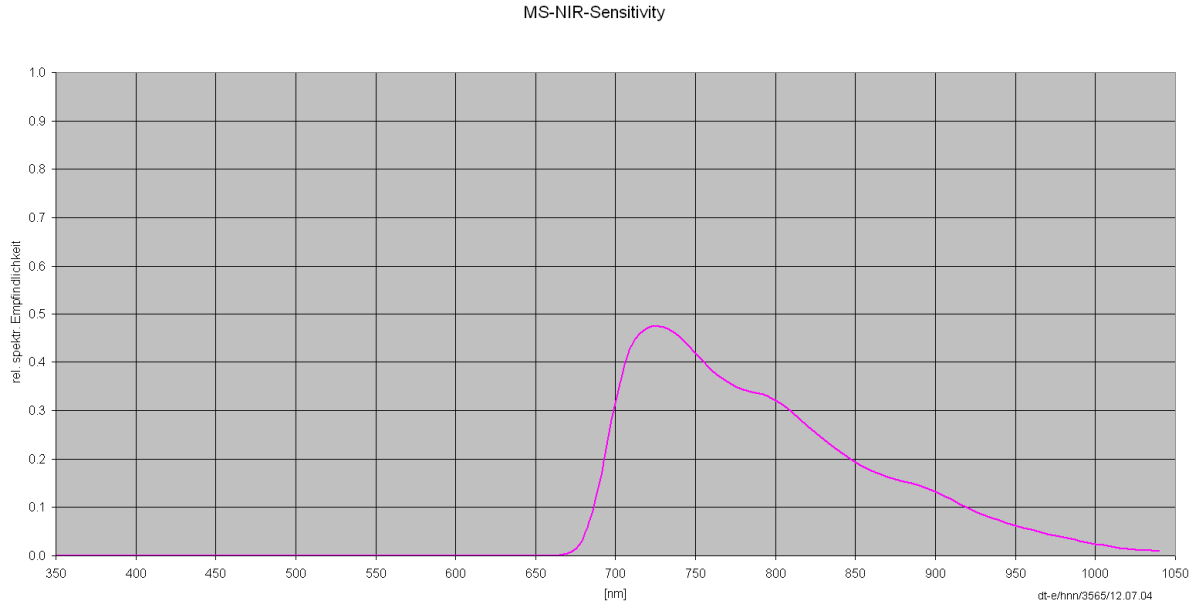
The calibration model is explained in the section “Calibration Model” at the end of this documentation.

Radiometric Calibration Protocol

In this section you’ll find the radiometric calibration results.

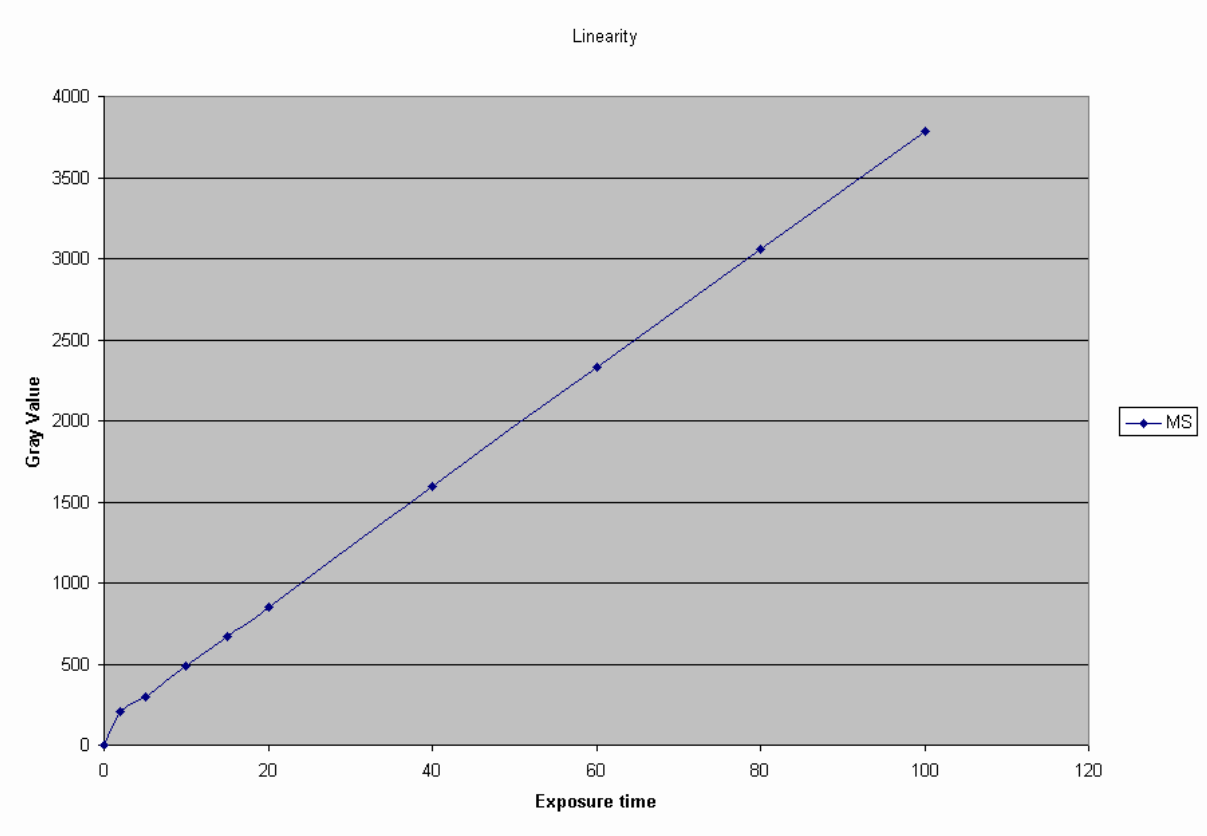
Camera ID	00116834
Sensor Revision Number	0
Lens Revision Number	1
Filter Revision Number	1
Aperture Revision Number	1

Sensitivity of camera



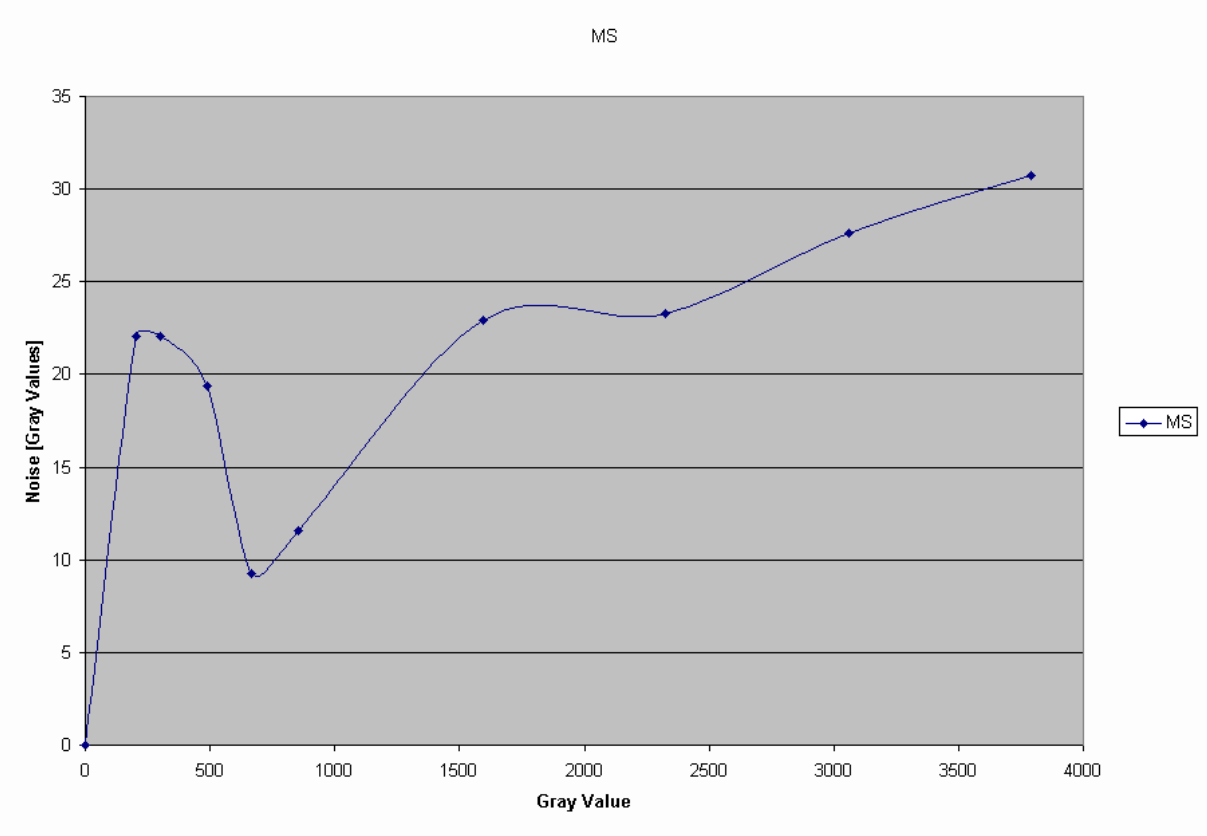
Remark:
Measurement is done without the influence of the shutter and the Analog/Digital converter. This graph is similar for the same lens and filter revision numbers. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Linearity



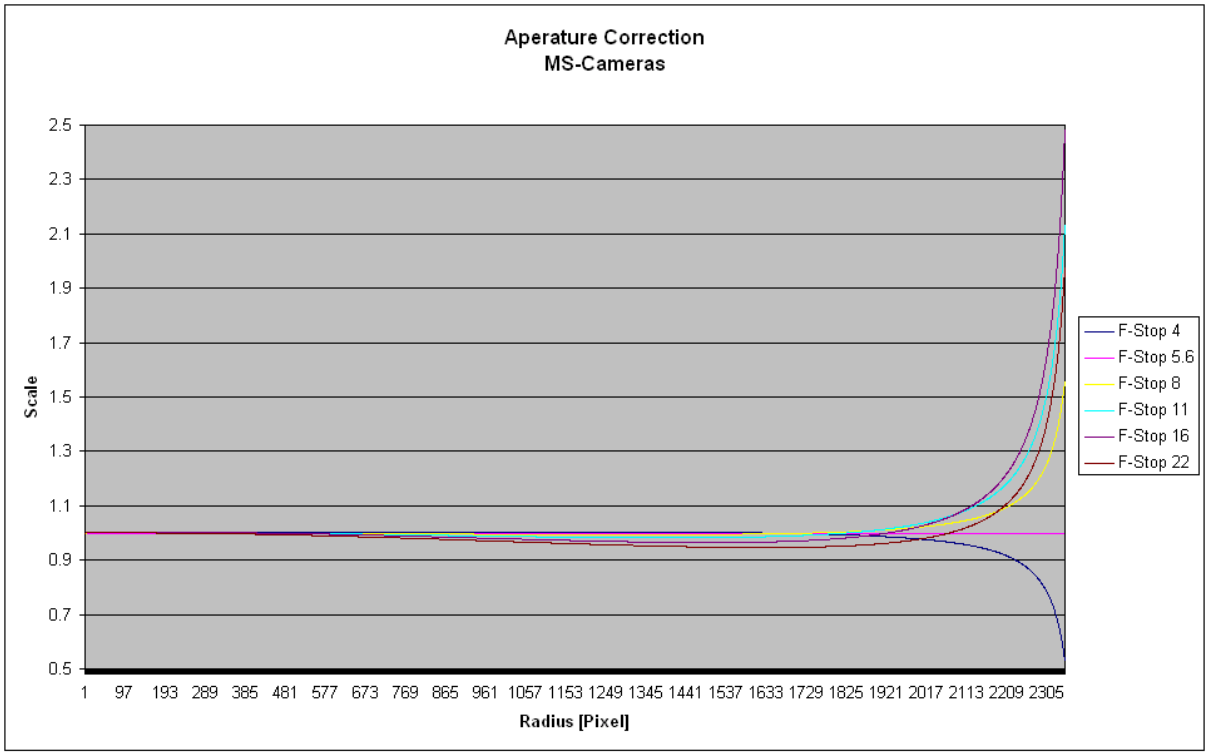
Remark:
The sensor linearity is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Noise



Remark:
The sensor noise is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Aperture Correction



Remark:
This measurement is similar for the same aperture revision number. For more details see Appendix: "Radiometric Calibration Model".

Defect Pixel List

Number of defect pixels: 0

Number of defect clusters: 0

Number of defect columns: 0

Nr Row Column

Defect Column RowStart ColumnStart RowEnd ColumnEnd

Remark

See Appendix for definition of defect pixels and maximal allowed numbers.

Calibration Protocol
DMC01 - 0131

Calibration Certificate N^{O} 00116832

Object	Digital Aerial Survey Camera
Manufacturer	Z/I Imaging D-73431 Aalen
Type	DMC-MS-Blue
Serial Number	00116832

Calibration performed at:
Carl Zeiss Jena

Number of pages of the certificate 68

Date of Calibration 13.Aug.2008

CertifiedDate	Division Head	Person in Charge
18.Sep.2008	(H. Sohnle)	(S. Schröder)

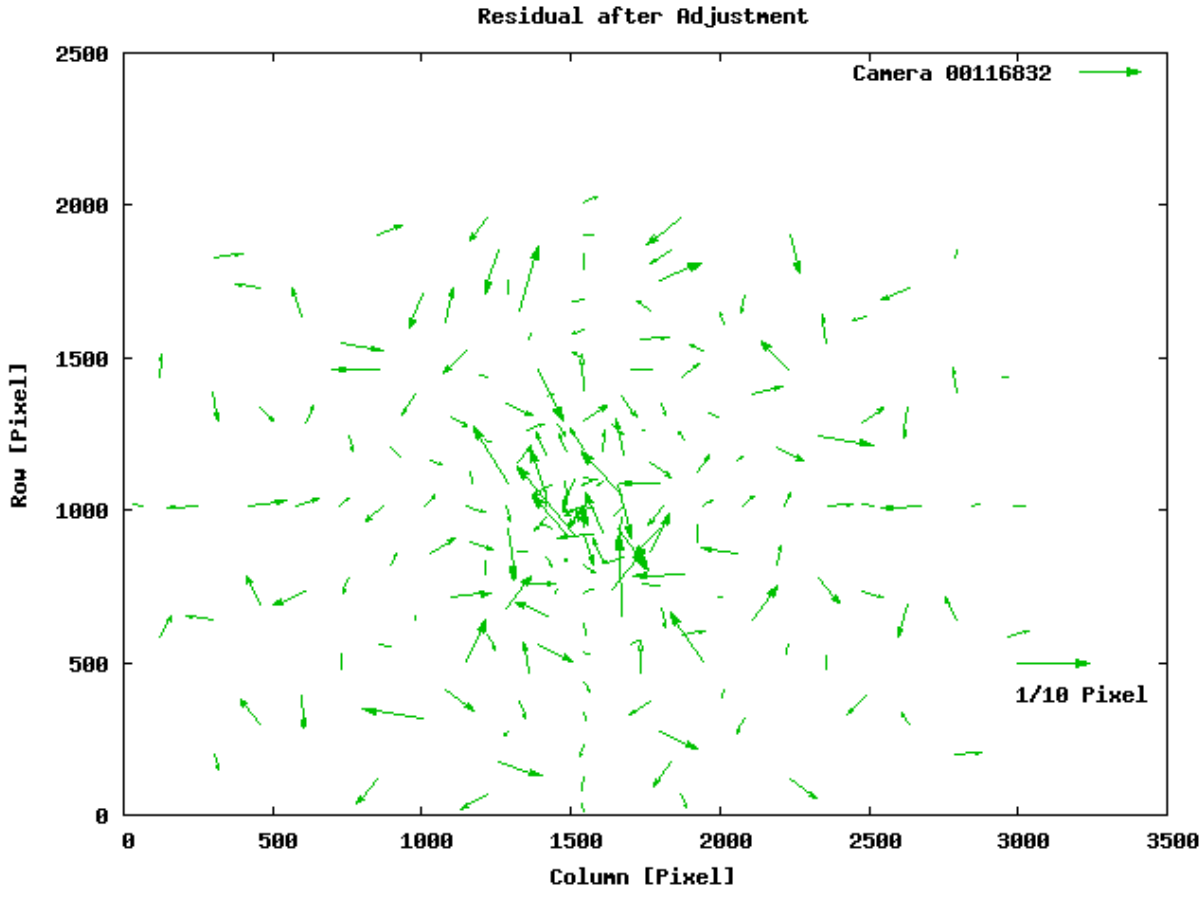
Geometric Calibration Protocol

Calibration Parameters for single camera head

Camera Type	DMC-MS-Blue
Nominal Focal Length	0.025 m
Serial Number	00116832

	Param	Adjusted	Std.dev.
Principal Point [m]	x_0	0.0001182	1.029E-06
	y_0	0.0001232	7.17E-07
Focal Length [m]	Δf	-2.999E-05	3.729E-07
Radial Distortion	K_1	-139.7	0.3156
	K_2	223900	2006
	K_3	-156200000	3603000
Decentring distortion	P_1	-0.002173	0.0005353
	P_2	-0.002434	0.0003262
In Plane Distortion	B_1	-5.667E-06	9.266E-06
	B_2	-5.403E-06	7.692E-06

Adjusted Focal length = 0.025+ dc =0.02497001 [m]



Residuals in Image after Adjustment

Max Residual [µm]: 1.5

Threshold [µm]: 8.5

Remarks:

The images after the post processing are distortion free. For interior orientation parameters of the DMC virtual image see section: “Calibration Parameter of the virtual images”.

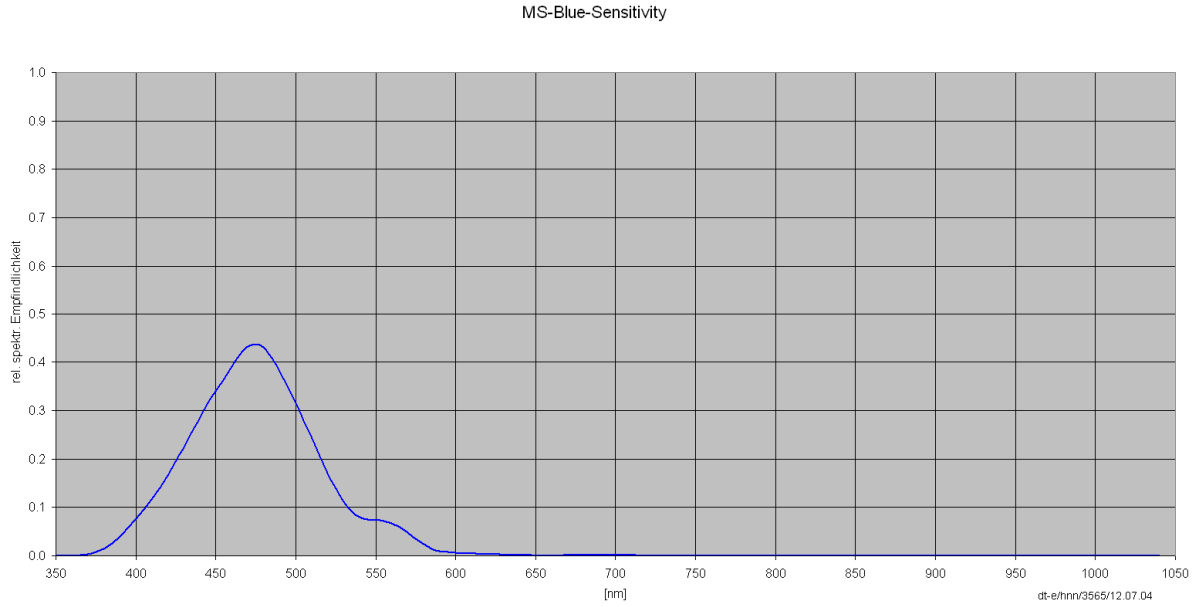
The calibration model is explained in the section “Calibration Model” at the end of this documentation.

Radiometric Calibration Protocol

In this section you’ll find the radiometric calibration results.

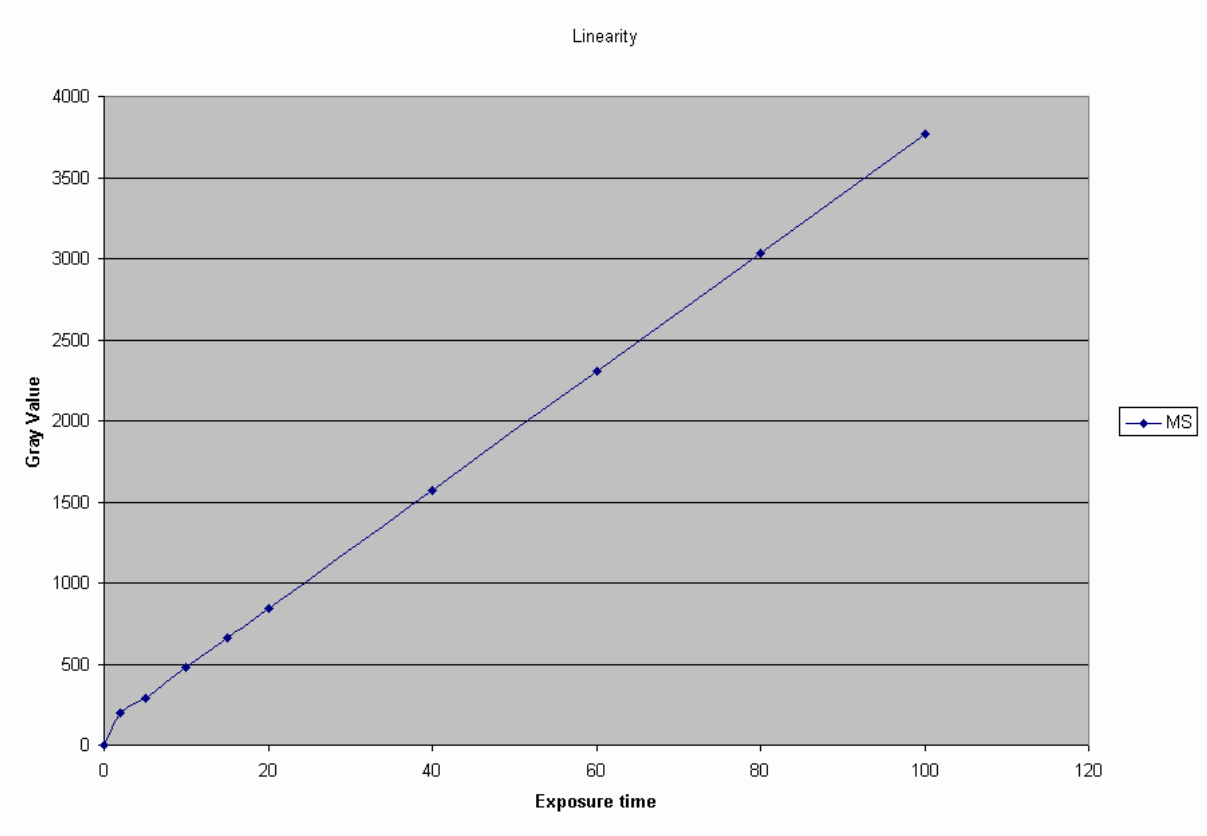
Camera ID	00116832
Sensor Revision Number	0
Lens Revision Number	1
Filter Revision Number	1
Aperture Revision Number	1

Sensitivity of camera



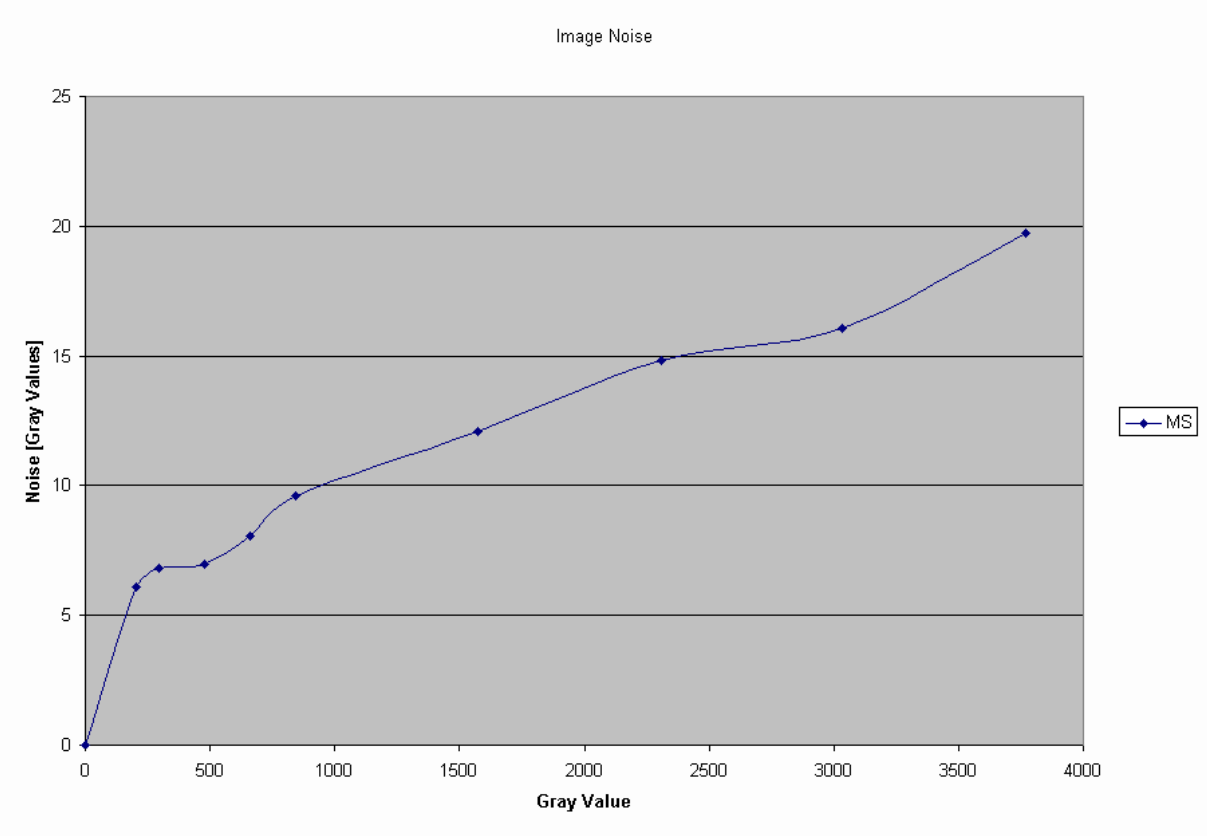
Remark:
Measurement is done without the influence of the shutter and the Analog/Digital converter. This graph is similar for the same lens and filter revision numbers. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Linearity



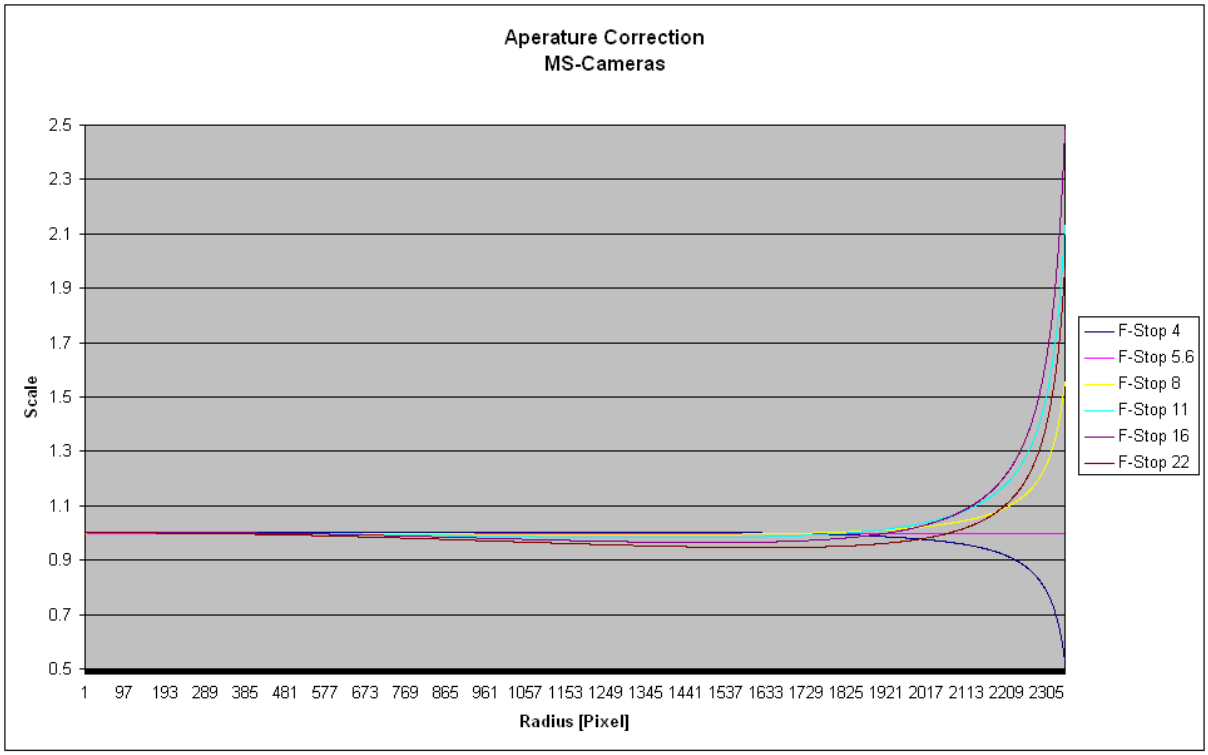
Remark:
The sensor linearity is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Noise



Remark:
The sensor noise is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Aperture Correction



Remark:
This measurement is similar for the same aperture revision number. For more details see Appendix: "Radiometric Calibration Model".

Defect Pixel List

Number of defect pixels: 0

Number of defect clusters: 0

Number of defect columns: 0

Nr Row Column

Defect Column RowStart ColumnStart RowEnd ColumnEnd

Remark

See Appendix for definition of defect pixels and maximal allowed numbers.

Calibration Protocol
DMC01 - 0131

Calibration Certificate N° 00116826

Object	Digital Aerial Survey Camera
Manufacturer	Z/I Imaging D-73431 Aalen
Type	DMC-MS-Red
Serial Number	00116826

Calibration performed at:
Carl Zeiss Jena

Number of pages of the certificate 68

Date of Calibration 12.Aug.2008

CertifiedDate	Division Head	Person in Charge
18.Sep.2008	(H. Sohnle)	(S. Schröder)

Calibration Protocol
DMC01 - 0131

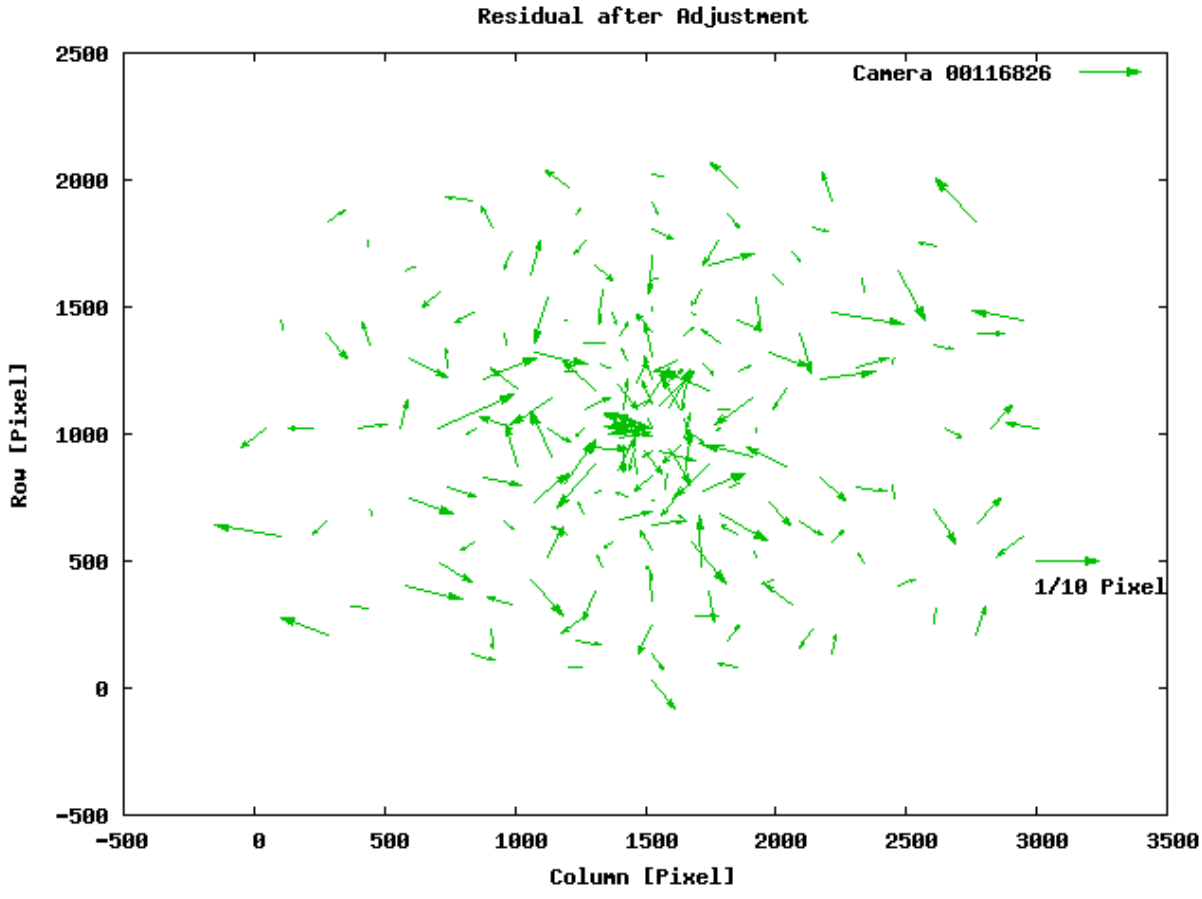
Geometric Calibration Protocol

Calibration Parameters for single camera head

Camera Type	DMC-MS-Red
Nominal Focal Length	0.025 m
Serial Number	00116826

	Param	Adjusted	Std.dev.
Principal Point [m]	x_0	-0.0001163	1.317E-06
	y_0	-2.218E-05	9.316E-07
Focal Length [m]	Δf	-5.09E-05	4.932E-07
Radial Distortion	K_1	-141.2	0.4151
	K_2	223900	2656
	K_3	-147700000	4777000
Decentring distortion	P_1	0.0005419	0.0006845
	P_2	-0.002525	0.0004262
In Plane Distortion	B_1	4.006E-05	1.261E-05
	B_2	-7.31E-06	9.743E-06

Adjusted Focal length = 0.025+ dc =0.0249491 [m]



Residuals in Image after Adjustment

Max Residual [µm]: 1.6

Threshold [µm]: 8.5

Remarks:

The images after the post processing are distortion free. For interior orientation parameters of the DMC virtual image see section: “Calibration Parameter of the virtual images”.

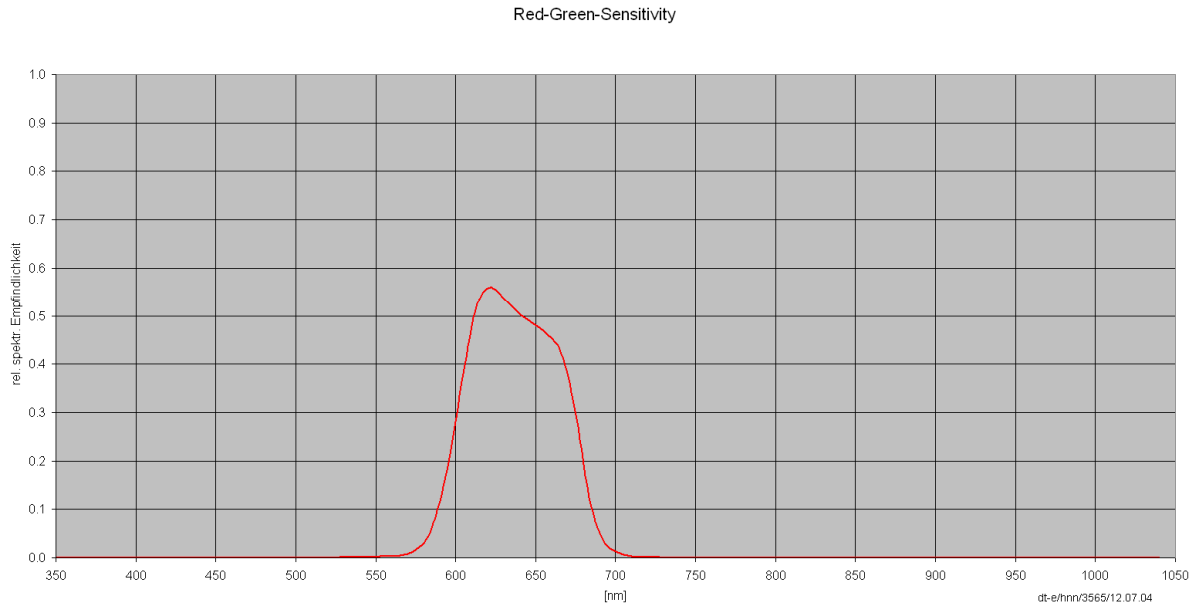
The calibration model is explained in the section “Calibration Model” at the end of this documentation.

Radiometric Calibration Protocol

In this section you’ll find the radiometric calibration results.

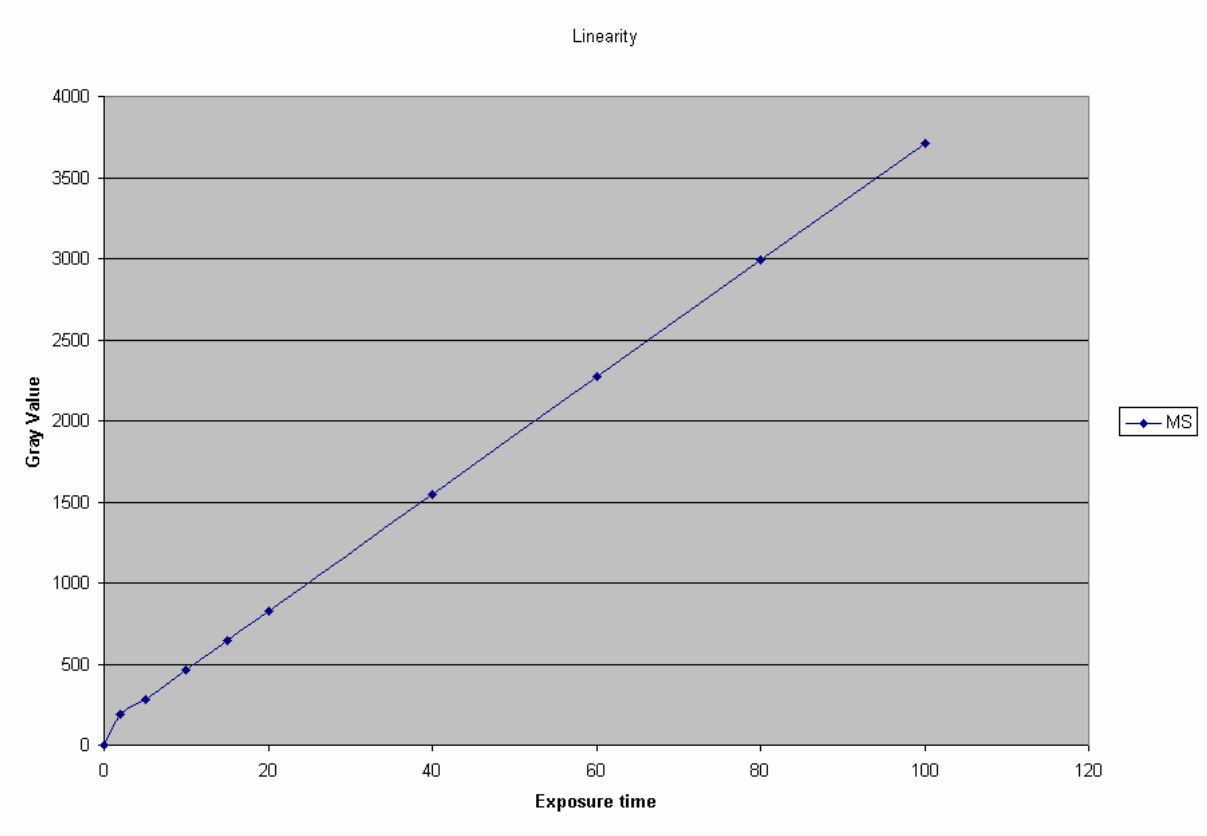
Camera ID	00116826
Sensor Revision Number	0
Lens Revision Number	1
Filter Revision Number	1
Aperture Revision Number	1

Sensitivity of camera



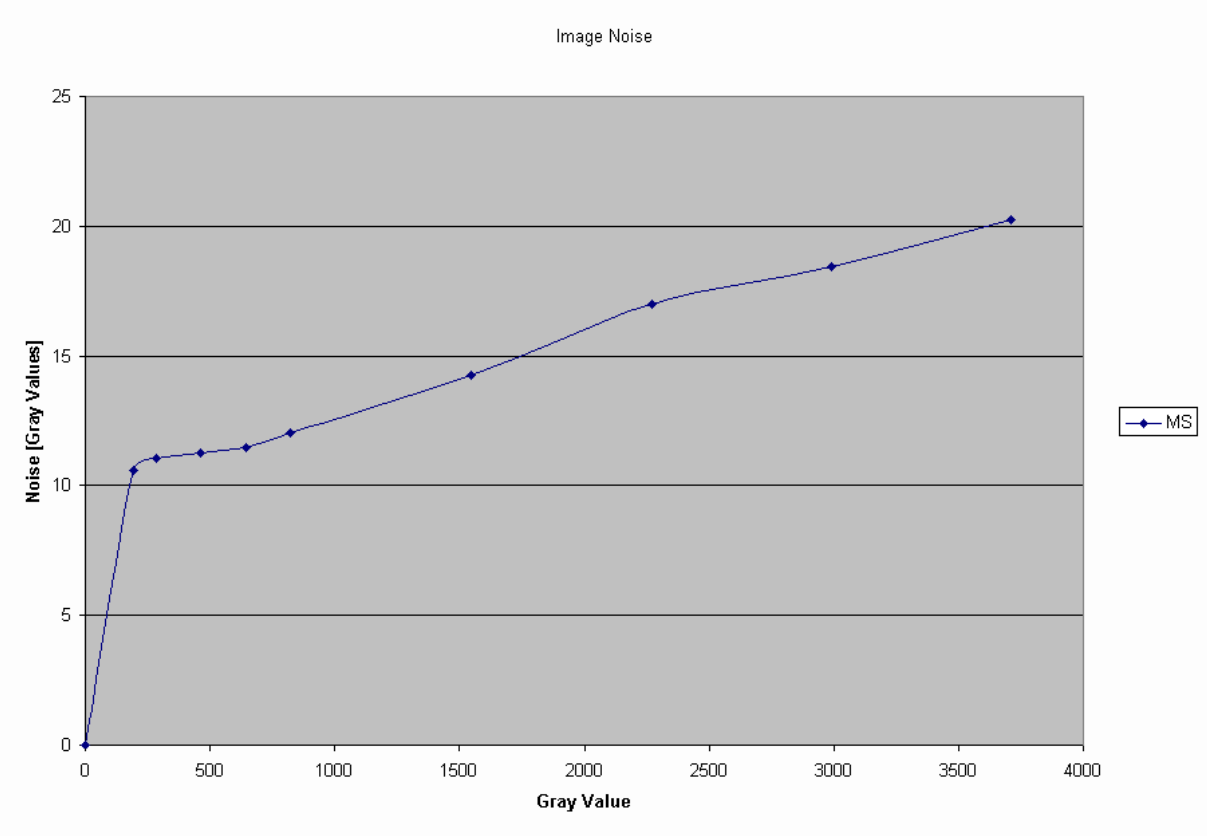
Remark:
Measurement is done without the influence of the shutter and the Analog/Digital converter. This graph is similar for the same lens and filter revision numbers. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Linearity



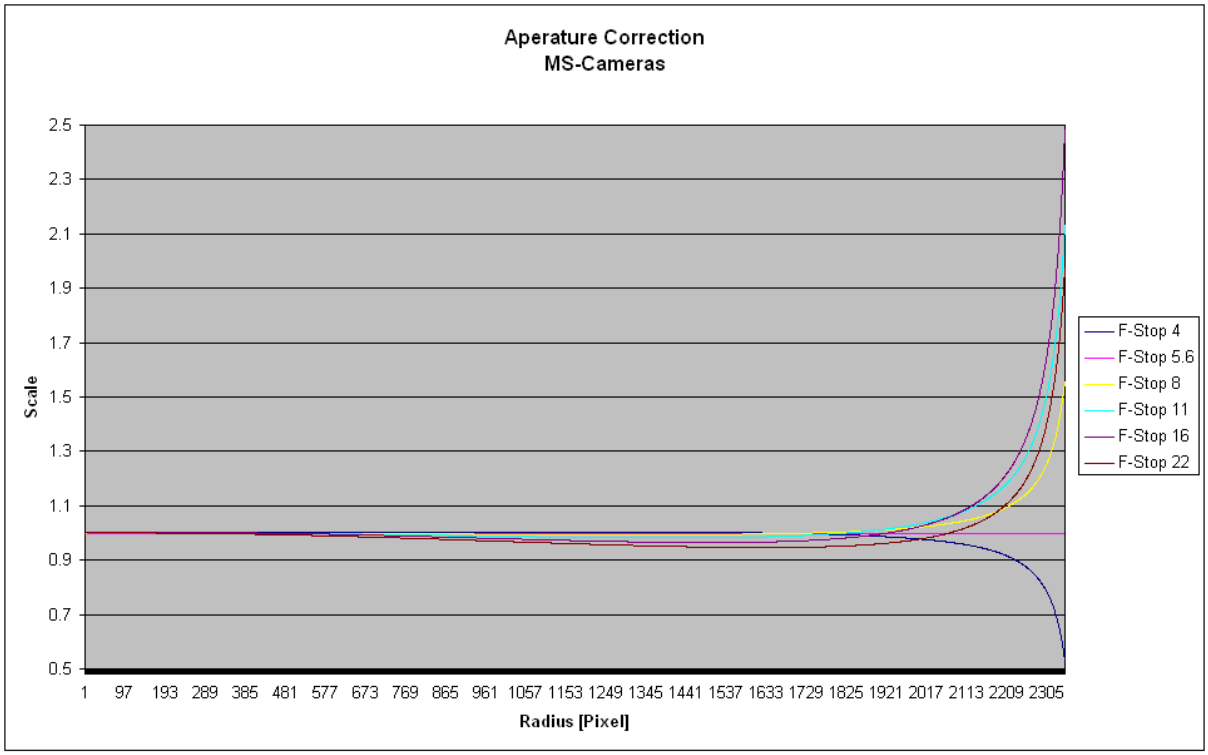
Remark:
The sensor linearity is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Noise



Remark:
The sensor noise is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Aperture Correction



Remark:
This measurement is similar for the same aperture revision number. For more details see Appendix: "Radiometric Calibration Model".

Defect Pixel List

Number of defect pixels: 0

Number of defect clusters: 0

Number of defect columns: 0

Nr Row Column

Defect Column RowStart ColumnStart RowEnd ColumnEnd

Remark

See Appendix for definition of defect pixels and maximal allowed numbers.

Calibration Protocol
DMC01 - 0131

Calibration Certificate N^{O} 00116830

Object	Digital Aerial Survey Camera
Manufacturer	Z/I Imaging D-73431 Aalen
Type	DMC-MS-Green
Serial Number	00116830

Calibration performed at:
Carl Zeiss Jena

Number of pages of the certificate 68

Date of Calibration 08.Aug.2008

CertifiedDate	Division Head	Person in Charge
18.Sep.2008	(H. Sohnle)	(S. Schröder)

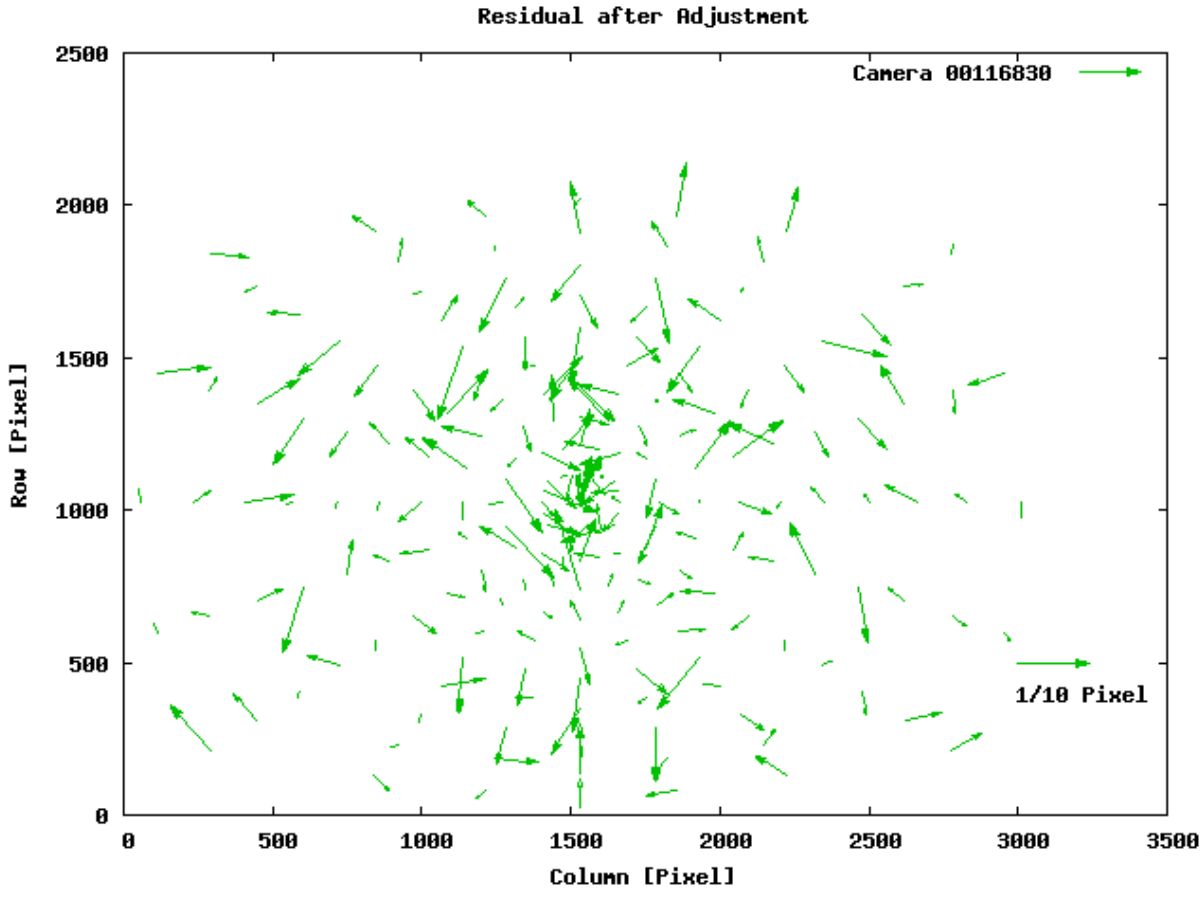
Geometric Calibration Protocol

Calibration Parameters for single camera head

Camera Type	DMC-MS-Green
Nominal Focal Length	0.025 m
Serial Number	00116830

	Param	Adjusted	Std.dev.
Principal Point [m]	x_0	-1.365E-05	1.23E-06
	y_0	-1.413E-05	8.686E-07
Focal Length [m]	Δf	-6.375E-05	4.554E-07
Radial Distortion	K_1	-140.8	0.3829
	K_2	227100	2443
	K_3	-154900000	4399000
Decentring distortion	P_1	0.002765	0.0006397
	P_2	-0.0005779	0.0003971
In Plane Distortion	B_1	-1.491E-06	1.126E-05
	B_2	2.562E-06	9.106E-06

Adjusted Focal length = 0.025+ dc =0.02493625 [m]



Residuals in Image after Adjustment

Max Residual [µm]: 1.4

Threshold [µm]: 8.5

Remarks:

The images after the post processing are distortion free. For interior orientation parameters of the DMC virtual image see section: “Calibration Parameter of the virtual images”.

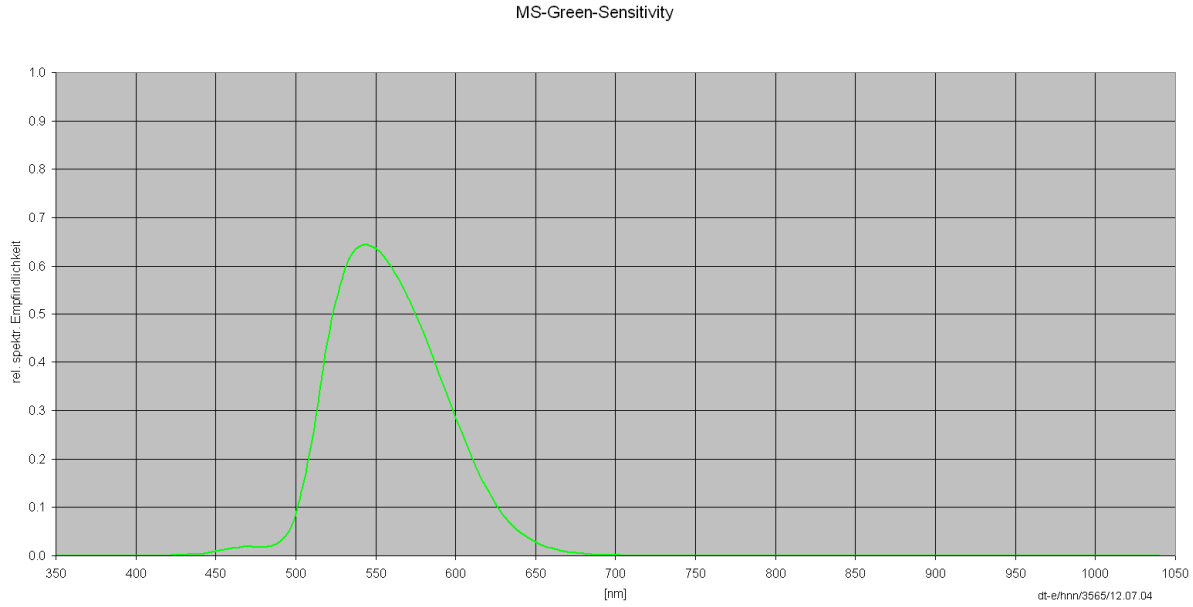
The calibration model is explained in the section “Calibration Model” at the end of this documentation.

Radiometric Calibration Protocol

In this section you’ll find the radiometric calibration results.

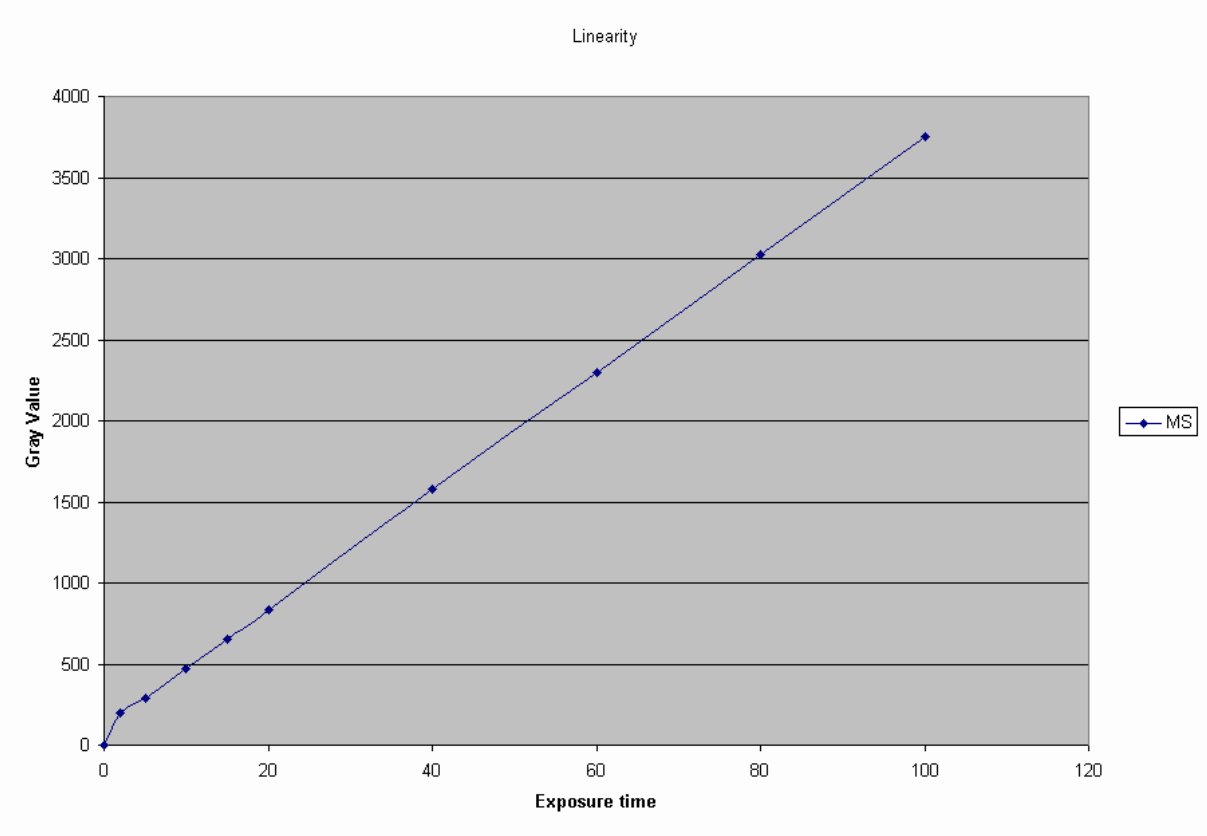
Camera ID	00116830
Sensor Revision Number	0
Lens Revision Number	1
Filter Revision Number	1
Aperture Revision Number	1

Sensitivity of camera



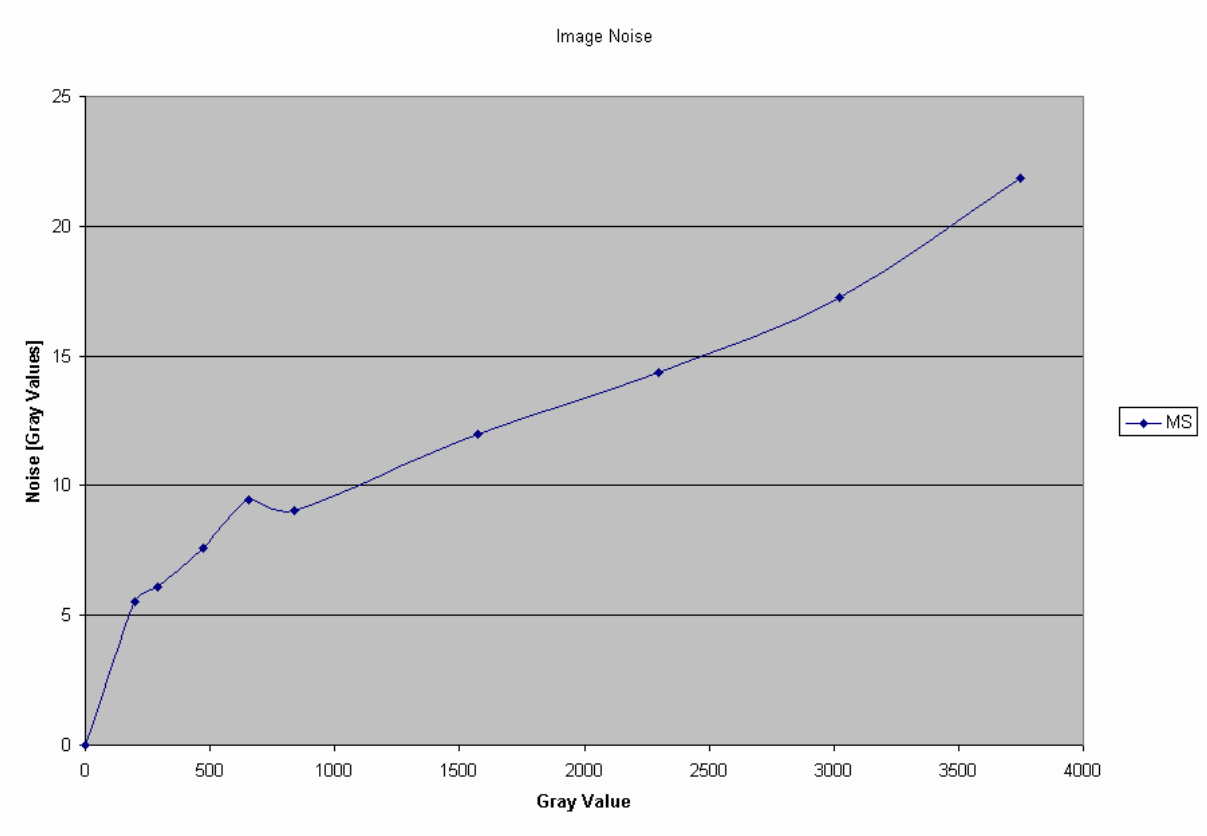
Remark:
Measurement is done without the influence of the shutter and the Analog/Digital converter. This graph is similar for the same lens and filter revision numbers. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Linearity



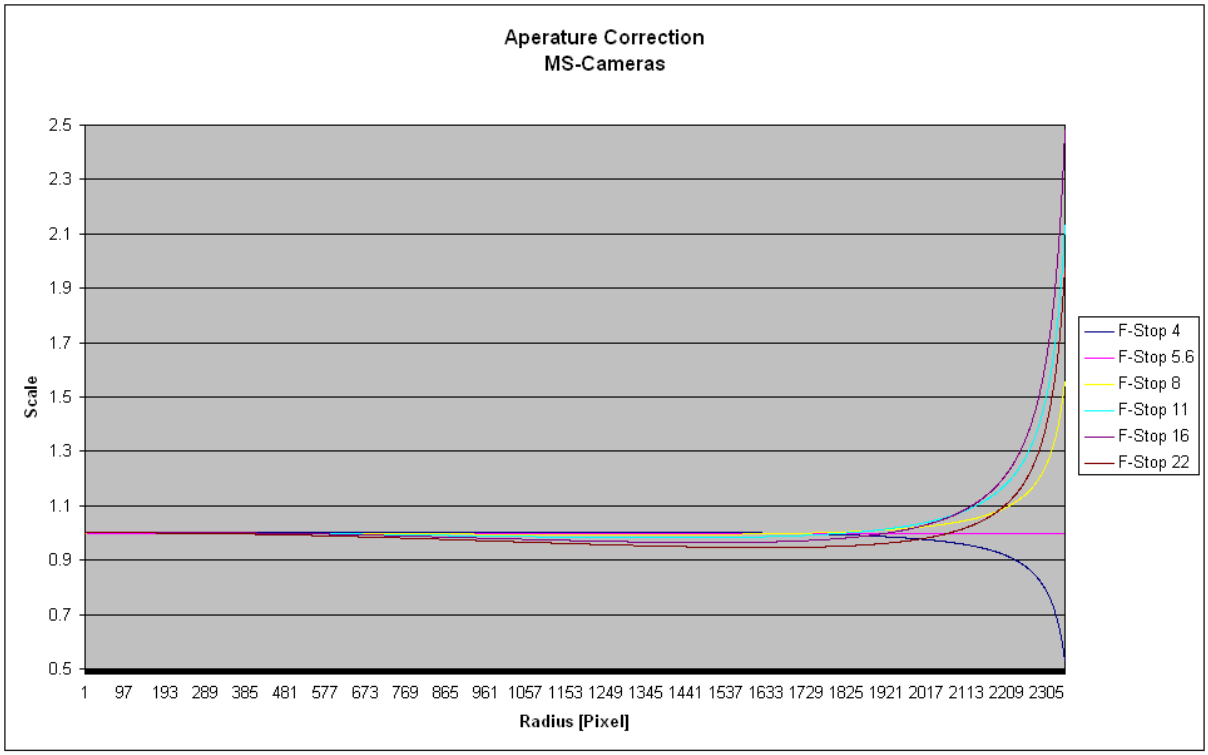
Remark:
The sensor linearity is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Sensor Noise



Remark:
The sensor noise is measured for each camera. For more details see Appendix: “Radiometric Calibration Model”.

Aperture Correction



Remark:
This measurement is similar for the same aperture revision number. For more details see Appendix: "Radiometric Calibration Model".

Defect Pixel List

Number of defect pixels: 0

Number of defect clusters: 0

Number of defect columns: 0

Nr Row Column

Defect Column RowStart ColumnStart RowEnd ColumnEnd

Remark

See Appendix for definition of defect pixels and maximal allowed numbers.

Defect Pixel Recognition

	Description	CCD Spec	Radiometric Calibration
Pixel	Bright image	Pixel whose signal, at nominal light (illumination at 50% of the linear range), deviates more than ±30% from its neighboring pixels.	Using a lower threshold for image quality
	Dark image	Pixel whose signal, in dark, deviates more than 6mV from its neighboring pixels (about 1% of nominal light).	
	Max Count	PAN < 1000 MS < 36	

	Description	CCD Spec	Radiometric Calibration
Column	Definition	A column which has more than 12 pixel defects. Column defects must be horizontally separated by 3 columns.	Using a lower threshold for image quality
	Recognition (bright and dark)	Same as defect pixel recognition	
	Max Single column	PAN ≤ 50 MS ≤ 1	
	Max double Column	PAN ≤ 4 MS ≤ 0	

Bibliography

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Dörstel C., Jacobsen K., Stallmann D. (2003): DMC – Photogrammetric accuracy – Calibration aspects and Generation of synthetic DMC images, Eds. M. Baltsavias / A.Grün, Optical 3D Sensor Workshop, Zürich

Fraser C., Digital Camera sel-f calibration. ISPRS Journal of Photogrammetry and Remote Sensing, (997, 5284): 149-159

Zeitler W., Dörstel C., Jacobsen K. (2002): Geometric calibration of the DMC: Method and Results, Proceedings ASPRS, Denver, USA.