

- when it has to be **right**



Leica Geosystems Leica CityMapper Calibration Certificate

Product	Leica CityMapper
Serial Number	95541
Date	11 March 2021
Inspector	Roberto Clerigo



1. System Components

Component	Type	Serial Number
Pod	CityMapper Pod	95541
GNSS/IMU	Litef LCI-100C 500 Hz	1307
LiDAR Unit	CityMapper Pod	5541
Camera Head	CH82	82603
Lens	NAT-D 2.8/80	80211
Camera Head	CH81m	81834
Lens	SAT-D 4.0/150	150242
Camera Head	CH81m	81845
Lens	SAT-D 4.0/150	150253
Camera Head	CH81m	81844
Lens	SAT-D 4.0/150	150252
Camera Head	CH81m	81843
Lens	SAT-D 4.0/150	150251

2. Estimation Process

		Passed	Date	Inspector
Image Flight	completed	ok	14.06.2019	Deniz Arslan
Image Quality Check	checked	ok	20.06.2019	Bernhard Riedl
Image Calibration	completed	ok	04.07.2019	Zoltan Poth
Image Misalignment Update	completed	ok	11.03.2021	Roberto Clerigo
LiDAR Flight	completed	ok	26.06.2019	Deniz Arslan
LiDAR Quality Check	checked	ok	27.06.2019	Rene Heierli
LiDAR Calibration and Accuracy	completed	ok	04.07.2019	Zoltan Poth
LiDAR Misalignment Update	completed	ok	10.03.2021	Roberto Clerigo

3. Inspectors

Name	Bernhard Riedl	11.03.2021	
Position	Production Manager		
Name	Zoltan Poth	11.03.2021	
Position	Support Engineer		
Name	Zoltan Poth	11.03.2021	
Position	Support Engineer		

4. Remarks

5. LiDAR Calibration Results

The calibration results for the LiDAR Unit are only valid for:

- IMU and Pod as listed in the System Components section

5.1 LiDAR Geometric Calibration Results

IMU Misalignment		Value	Unit
	ω	-0.057206	degree
	Φ	-0.007043	degree
	κ	0.140973	degree
Boresight		Value	Unit
	Θ	-0.019222	degree
	Φ	0.003641	degree
Receiver 1		Value	Unit
Range	Δ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	Δ Alpha	-0.000895	degree
Wedge Position	Δ Offset	0.307194	degree
Position Correction	X	-0.073786	degree
	Y	0.052762	degree
Mount	Roll	0.926534	degree
	Pitch	1.395511	degree
Rotation Axis	Roll	0.492475	degree
	Pitch	0.473143	degree
Wedge 1		Value	Unit
Wedge	Δ Alpha	-0.015317	degree
Wedge Position	Δ Offset	-0.065665	degree
Position Correction	X	0.024528	degree
	Y	0.018118	degree
Mount	Roll	-0.044310	degree
	Pitch	0.160365	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.026794	degree
	Pitch	-0.000151	degree

LiDAR Geometric Calibration File

HYPERION_GEOMETRY_LIDARUNIT-5541-C-855570-DATETIME-20210310-164301.XML

	Date	10.03.2021
LiDAR Misalignment Flight	Date	28.01.2021
LiDAR Misalignment Update Completed	Date	10.03.2021

5.2 LiDAR Unit Accuracy Check

Accuracy checks:

- Deviation of two perpendicular lines to GCP's
- Difference of two perpendicular lines
- Difference of forward and backward scan of one line

5.2.1 Multi-line accuracy of two perpendicular lines to ground control points

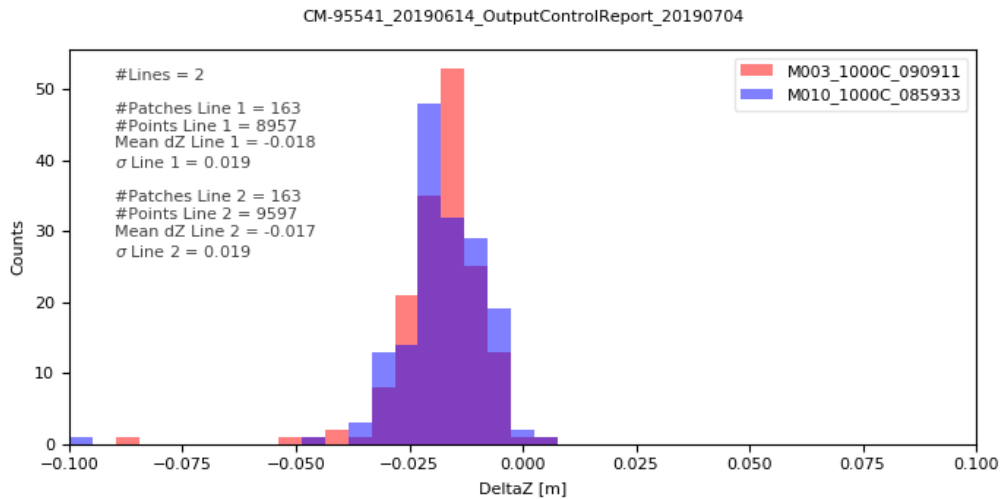


Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

M010_1000C_085933

190824 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
Dark Green	≤ 0.04	190375	99.76
Bright Green	0.04-0.07	394	0.21
Yellow	0.07-0.1	27	0.01
Red	> 0.1	28	0.01



Figure 2 Vertical difference between forward and backward scan at 1000 m AGL.

5.2.3 Multi-line accuracy between two perpendicular lines

Vertical Accuracy Flightline Comparison- 20190705_104519

M010_1000C_085933_vs_M003_1000C_090911

37932 valid patches with size of 2 m found. Only patches with standard deviation < 0.05 m and minimum of 5 points are included.

Color	Limits [m]	Number of patches	Proportion of total number of patches [%]
Dark Green	<=0.04	37904	99.93
Bright Green	0.04-0.07	11	0.03
Yellow	0.07-0.1	2	0.01
Red	>0.1	15	0.04



Figure 3 Vertical difference between two perpendicular lines at 1000 m AGL.

6. Imaging Sensors Estimation Results

The estimation results for the camera head and lens combination are only valid for:

- IMU and Pod as listed in the System Components section.
- Camera Head, lens and specified position as listed in the Estimation Results sections.

6.1 Camera Model of distortion free images

All factory calibration results contain fixed nominal focal lengths and zero principal point offsets. Leica HxMap applies the grid to create distortion-free images of nominal focal length and pixel size.

6.1.1 CH8x Model

Camera Head		Component	
Lens		CH82	
		NAT-D 2.8/80	
Camera Model			
Focal Length		Distance [mm]	
	c		83.00
Radial Symmetric Distorsion		Distance [mm]	
	k ₀		0.0000
	k ₁		0.0000
	k ₂		0.0000
Decentering Distortion		Distance [mm]	
	p ₁		0.0000
	p ₂		0.0000
Non-Orthogonality Distortion		Distance [mm]	
	b ₁		0.0000
	b ₂		0.0000
Pixel Size (Height and Width)		Distance [mm]	
	RGB		0.0052
	NIR		0.0120
Rows and Columns		Rows	Columns
	Active RGB	7752	10320
	Raw RGB	7788	10336
	Active NIR	3654	4478
	Raw NIR	3366	4500

6.1.2 CH81m Model

		Component	
Camera Head		CH81m	
Lens		SAT-D 4.0/150	
Camera Model			
Focal Length		Distance [mm]	
	c	156.00	
Radial Symmetric Distorsion		Distance [mm]	
	k ₀	0.0000	
	k ₁	0.0000	
	k ₂	0.0000	
Decentering Distortion		Distance [mm]	
	p ₁	0.0000	
	p ₂	0.0000	
Non-Orthogonality Distortion		Distance [mm]	
	b ₁	0.0000	
	b ₂	0.0000	
Pixel Size (Height and Width)		Distance [mm]	
	RGB	0.0052	
Rows and Columns		Rows	Columns
	Active RGB	7752	10320
	Raw RGB	7788	10336

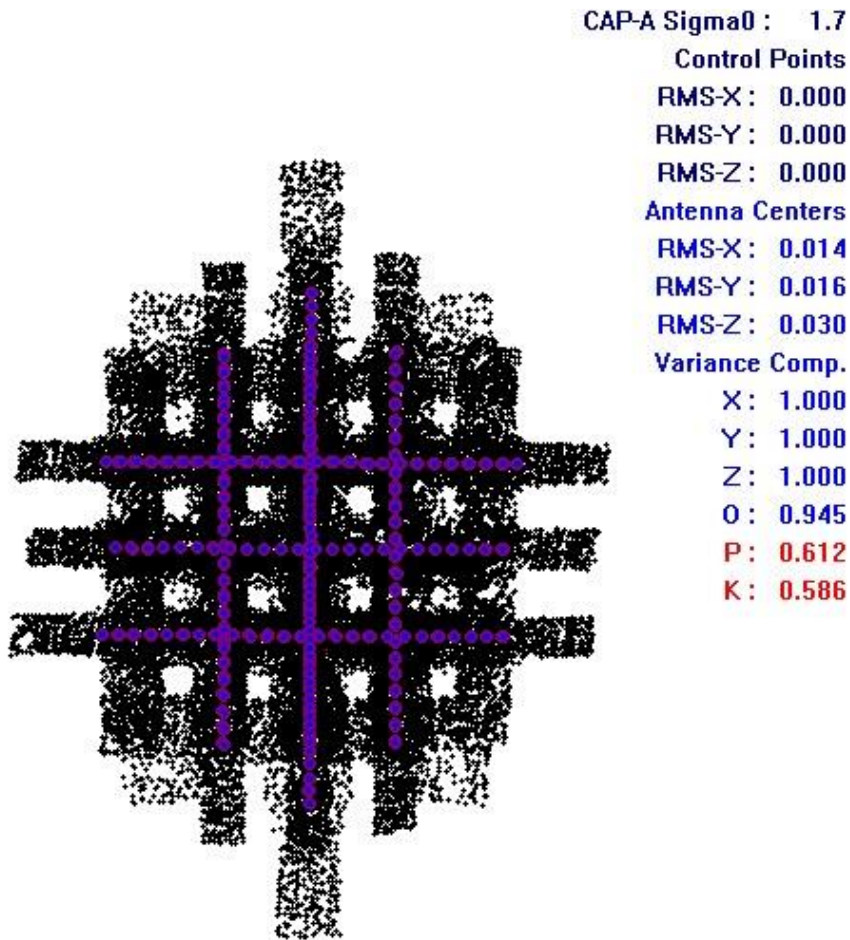
6.2 Results of Geometric Calibration

6.2.1 Calibration method for Green Reference Band

Estimation of additional parameters (focal length, principal point, radial symmetric distortion, correction grid) and IMU misalignment in simultaneous bundle adjustment

Reference band (green)	Distance [mm]
Resulting sigma naught of bundle adjustment:	0.0017

Final bundle adjustment results after elimination of tie point blunders:



6.2.2 Calibration method for Other Spectral Bands

Estimation of additional parameters (correction grid), based on the result for green in simultaneous bundle adjustment

Other Spectral Bands	Distance [mm]
Co-registration to green better than:	0.002

Leica HxMap applies the grid to create distortion-free images of nominal focal length and fixed pixel size of 0.0052 mm.

6.3 Estimation Results for Nadir Camera Head and Lens

	Component	Serial Number
Camera Head	CH82	82603
Lens	NAT-D 2.8/80	80211
View Direction in Pod Position	Nadir	
IMU Misalignment	Angle [degree]	
	ω	0.053109
	ϕ	0.023869
	κ	0.323889
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
	c	83.00

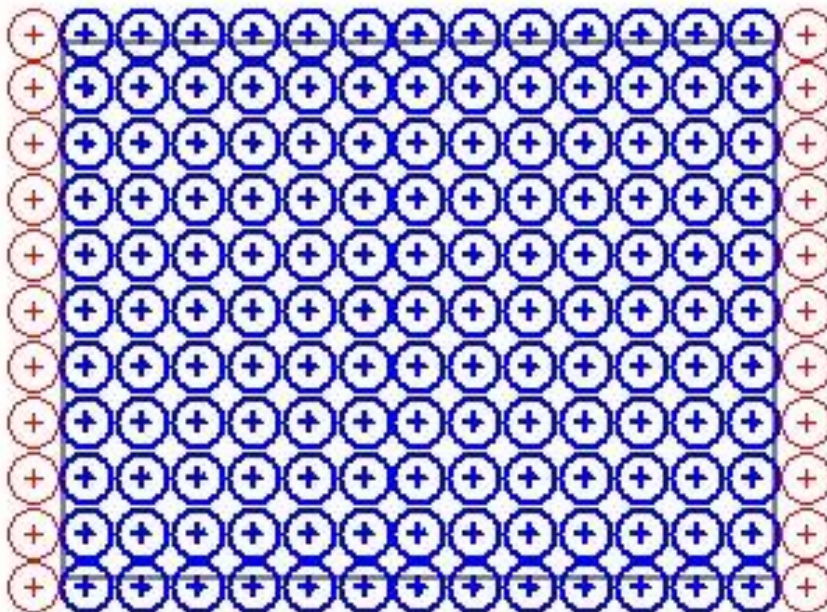
Geometric Calibration File

RCD30_Geometry_CameraHead-82603-E-798528_LensSystem-80211-B-785423_DateTime-20210107-210952.xml

Geometric Calibration	Date	03.07.2019
Radiometric Calibration	Date	04.06.2019
Misalignment Flight	Date	28.01.2021
Misalignment Update Completed	Date	11.03.2021

Remaining image space residuals after applying the calibration results

RMS-X: 0.10
RMS-Y: 0.12



Radius of circles is 0.0010 mm

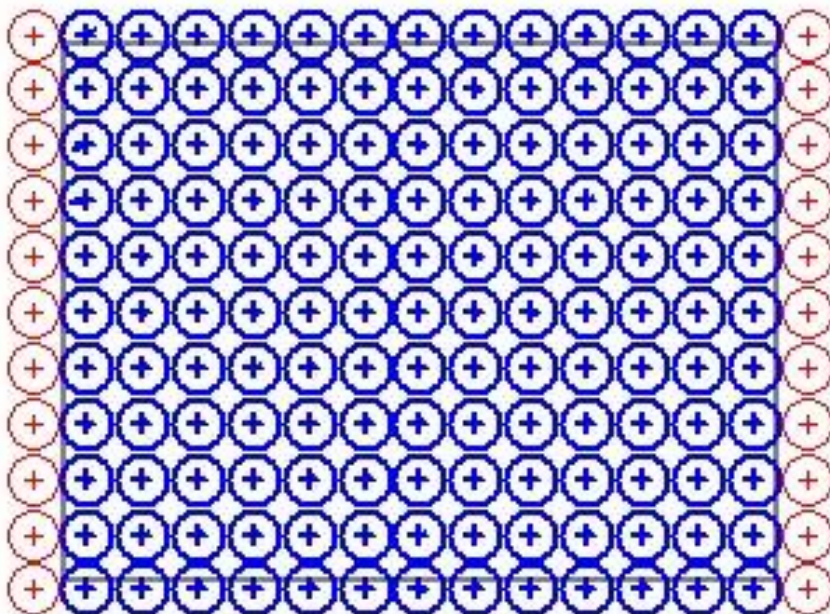
6.4 Estimation Results for Forward Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81834
Lens	SAT-D 4.0/150	150242
View Direction in Pod Position	Forward	
IMU Misalignment	Angle [degree]	
	ω	0.467890
	Φ	-0.065220
	κ	0.155620
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81834-D-842157_LensSystem-150242-B-819435_DateTime-20210107-210952.xml		
Geometric Calibration	Date	03.07.2019
Radiometric Calibration	Date	08.04.2019
Misalignment Flight	Date	28.01.2021
Misalignment Update Completed	Date	11.03.2021

Remaining image space residuals after applying the calibration results

RMS-X: 0.20

RMS-Y: 0.13



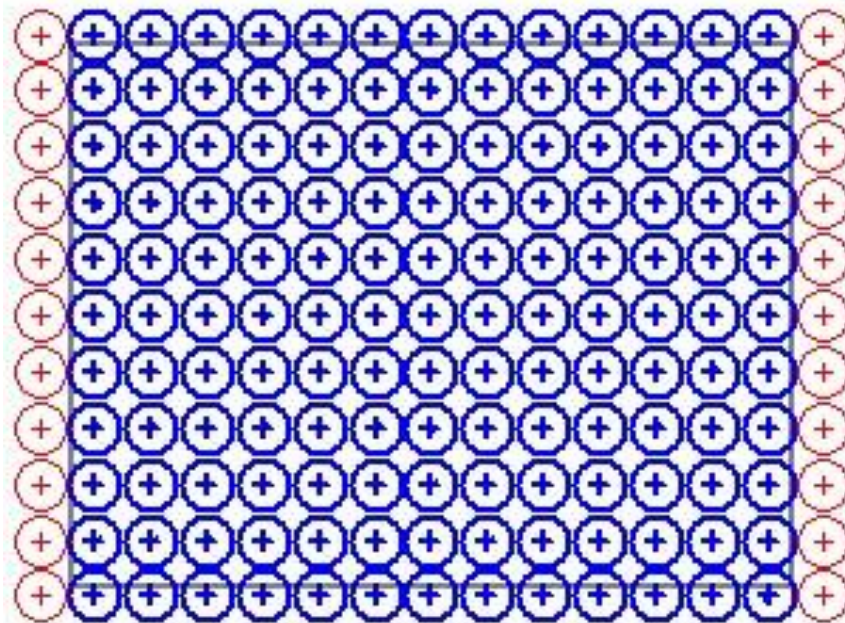
Radius of circles is 0.0010 mm

6.5 Estimation Results for Backward Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81845
Lens	SAT-D 4.0/150	150253
View Direction in Pod Position	Backward	
IMU Misalignment	Angle [degree]	
	ω	-0.081570
	ϕ	-0.082760
	κ	0.138040
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81845-D-842157_LensSystem-150253-B-819435_DateTime-20210107-210952.xml		
Geometric Calibration	Date	03.07.2019
Radiometric Calibration	Date	05.06.2019
Misalignment Flight	Date	28.01.2021
Misalignment Update Completed	Date	11.03.2021

Remaining image space residuals after applying the calibration results

RMS-X: 0.13
RMS-Y: 0.09



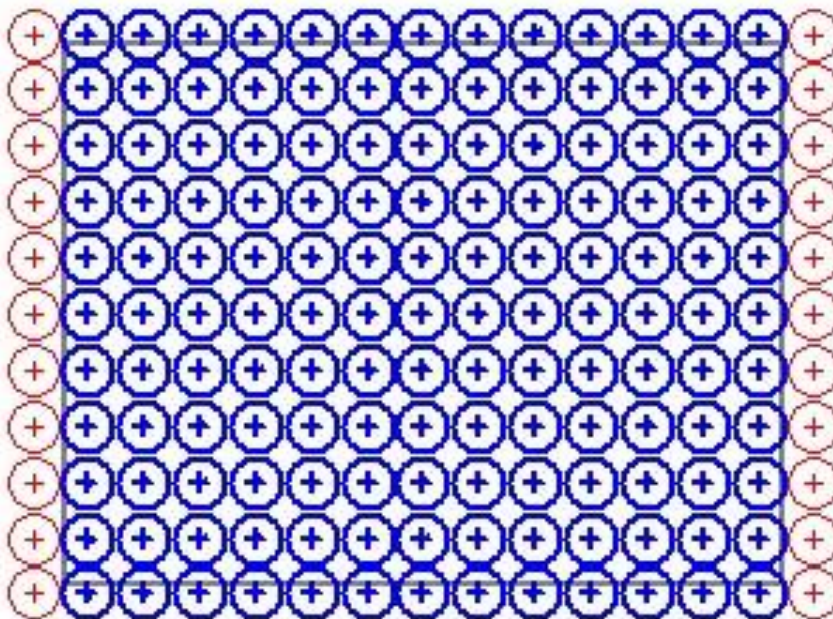
Radius of circles is 0.0010 mm

6.6 Estimation Results for Left Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81844
Lens	SAT-D 4.0/150	150252
View Direction in Pod Position	Left	
IMU Misalignment	Angle [degree]	
	ω	0.226480
	ϕ	-0.012340
	κ	0.200490
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81844-D-842157_LensSystem-150252-B-819435_DateTime-20190703-062818.xml		
Geometric Calibration	Date	03.07.2019
Radiometric Calibration	Date	11.06.2019
Misalignment Flight	Date	28.01.2021
Misalignment Update Completed	Date	11.03.2021

Remaining image space residuals after applying the calibration results

RMS-X: 0.13
RMS-Y: 0.12



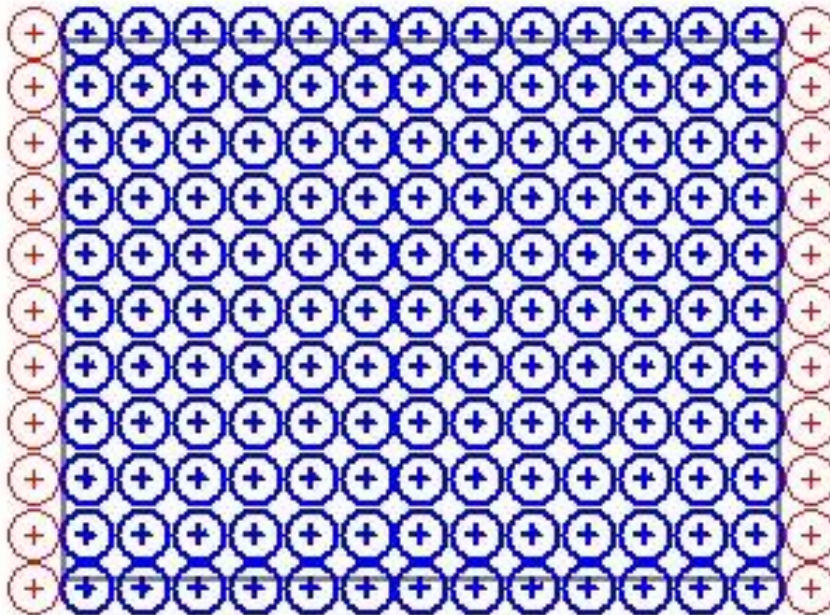
Radius of circles is 0.0010 mm

6.7 Estimation Results for Right Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81843
Lens	SAT-D 4.0/150	150251
View Direction in Pod Position	Right	
IMU Misalignment	Angle [degree]	
	ω	-0.167620
	ϕ	0.012640
	κ	0.049380
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81843-D-842157_LensSystem-150251-B-819435_DateTime-20210107-210952.xml		
Geometric Calibration Date	Date	03.07.2019
Radiometric Calibration Date	Date	23.05.2019
Misalignment Flight	Date	28.01.2021
Misalignment Update Completed	Date	11.03.2021

Remaining image space residuals after applying the calibration results

RMS-X: 0.11
RMS-Y: 0.10



Radius of circles is 0.0010 mm