

- when it has to be **right**



Leica Geosystems Leica CityMapper Calibration Certificate

Product	Leica CityMapper
Serial Number	95530
Date	25 March 2019
Inspector	Zoltan Poth



1. System Components

Component	Type	Serial Number
Pod	CityMapper Pod	95530
GNSS/IMU	Litef LCI-100C 500 Hz	1258
LiDAR Unit	Hyperion II	5529
Camera Head	CH82	82645
Lens	NAT-D 2.8/80	80246
Camera Head	CH81m	81808
Lens	SAT-D 4.0/150	150216
Camera Head	CH81m	81809
Lens	SAT-D 4.0/150	150217
Camera Head	CH81m	81810
Lens	SAT-D 4.0/150	150218
Camera Head	CH81m	81820
Lens	SAT-D 4.0/150	150228

2. Estimation Process

		Passed	Date	Inspector
Image Flight	completed	ok	03.12.2019	Deniz Arslan
Image Quality Check	checked	ok	03.15.2019	Bernhard Riedl
Image Calibration	completed	ok	03.24.2019	Xu Wang
Image Misalignment Update	completed			
LiDAR Flight	completed	ok	02.17.2019	Deniz Arslan
LiDAR Quality Check	checked	ok	02.26.2019	Rene Heierli
LiDAR Calibration and Accuracy	completed	ok	03.24.2019	Xu Wang
LiDAR Misalignment Update	completed			

3. Inspectors

Name	Bernhard Riedl	25.03.2019	
Position	Production Manager		
Name	Xu Wang	25.03.2019	
Position	Support Engineer		
Name	Xu Wang	25.03.2019	
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	-0.095282	degree
	Φ	0.009757	degree
	κ	-0.050741	degree
Boresight		Value	Unit
	Θ	0.008303	degree
	Φ	0.005041	degree
Receiver 1		Value	Unit
Range	Δ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	Δ Alpha	0.029061	degree
Wedge Position	Δ Offset	0.029258	degree
Position Correction	X	-0.027588	degree
	Y	-0.041467	degree
Mount	Roll	0.278001	degree
	Pitch	0.740613	degree
Rotation Axis	Roll	-0.063632	degree
	Pitch	0.134369	degree
Wedge 1		Value	Unit
Wedge	Δ Alpha	-0.009401	degree
Wedge Position	Δ Offset	0.238539	degree
Position Correction	X	0.035975	degree
	Y	-0.010397	degree
Mount	Roll	0.140716	degree
	Pitch	0.007278	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.082373	degree
	Pitch	-0.033513	degree

LiDAR Geometric Calibration File

HYPERION_GEOMETRY_LIDARUNIT-5529-C-855570-DATETIME-20190227-235025.XML

	Date	27.02.2019
LiDAR Misalignment Flight	Date	-
LiDAR Misalignment Update Completed	Date	-

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

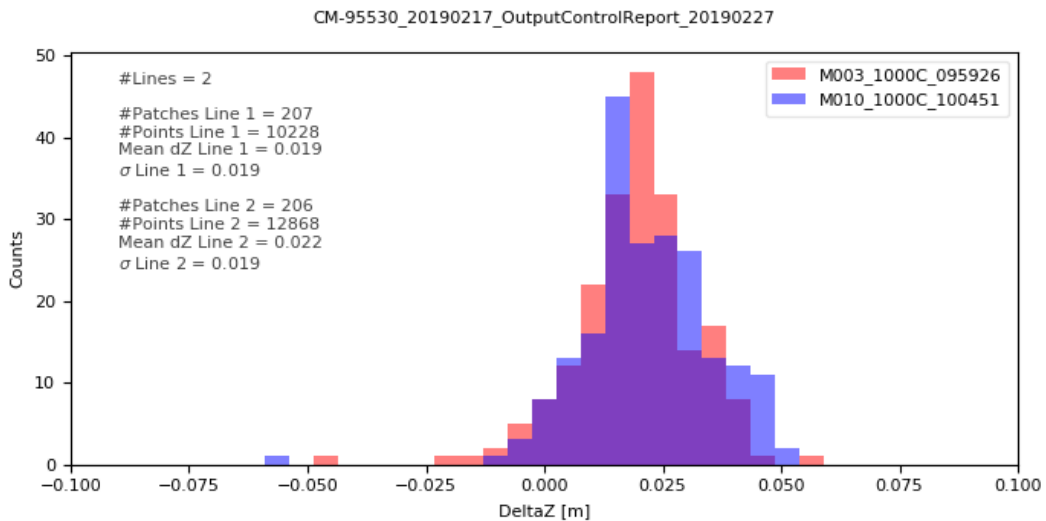


Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

M010_1000C_100451

413021 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 [%]
Green	≤ 0.04	412667	99.91
Yellow	0.04-0.07	309	0.07
Orange	0.07-0.1	34	0.01
Red	> 0.1	11	0.00



Vertical difference

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

Multi-line accuracy between two perpendicular lines

M003_1000C_095926_vs_M010_1000C_100451

47206 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	47149	99.88
Bright Green	0.04-0.07	37	0.08
Yellow	0.07-0.1	5	0.01
Red	>0.1	15	0.03



Vertical difference

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

Camera Head		Component	
Lens		CH81m	
		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

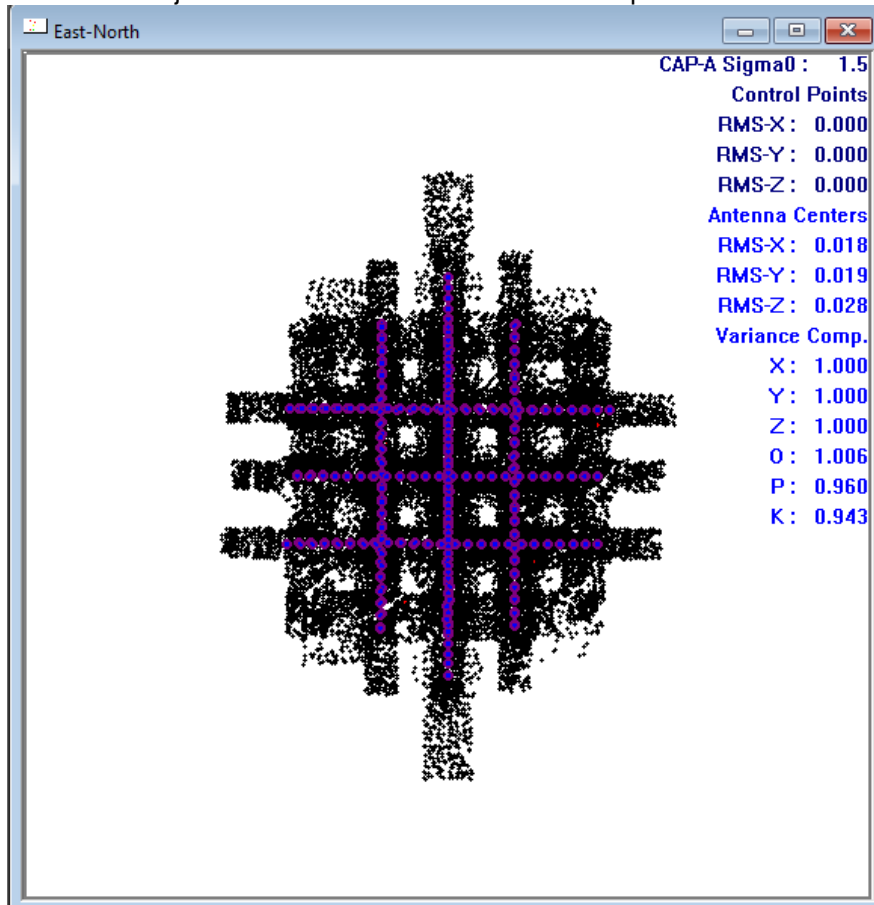
Reference band (green)

Distance [mm]

Resulting sigma naught of bundle adjustment:

0.0015

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

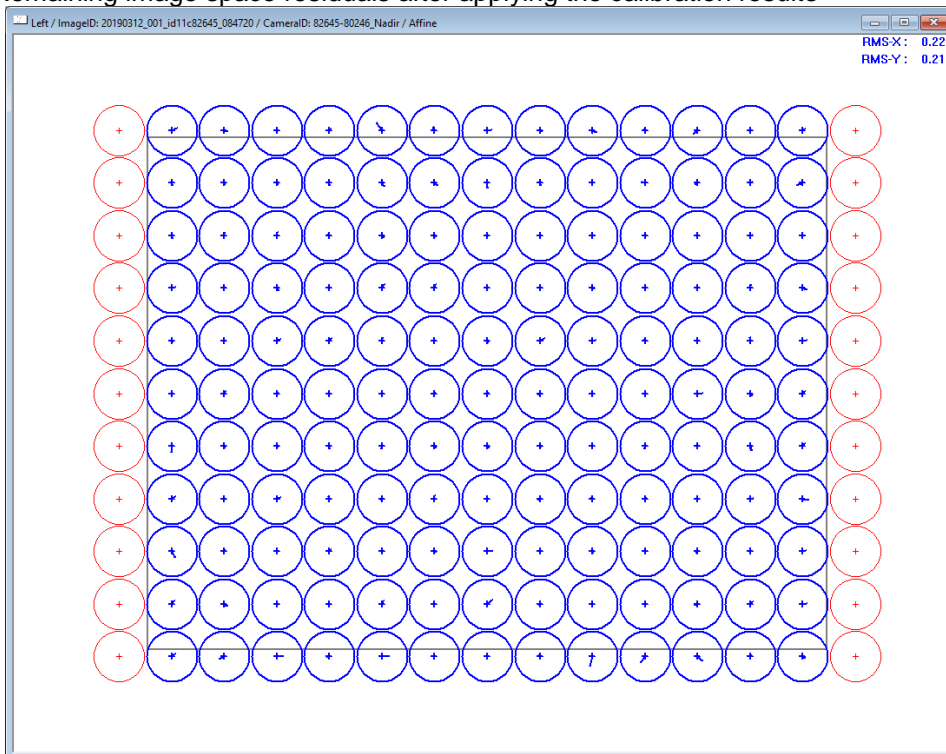
	Component	Serial Number
Camera Head	CH82	82645
Lens	NAT-D 2.8/80	80246
View Direction in Pod Position	Nadir	
IMU Misalignment	Angle [degree]	
	ω	0.03886
	Φ	-0.08746
	κ	-0.19016
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
	c	83.00

Geometric Calibration File

RCD30_Geometry_CameraHead-82645-E-798528_LensSystem-80246-B-785423_DateTime-20190324-090839.xml

Geometric Calibration	Date	24.03.2019
Radiometric Calibration	Date	11.01.2019
Misalignment Flight	Date	-
Misalignment Update Completed	Date	-

Remaining image space residuals after applying the calibration results

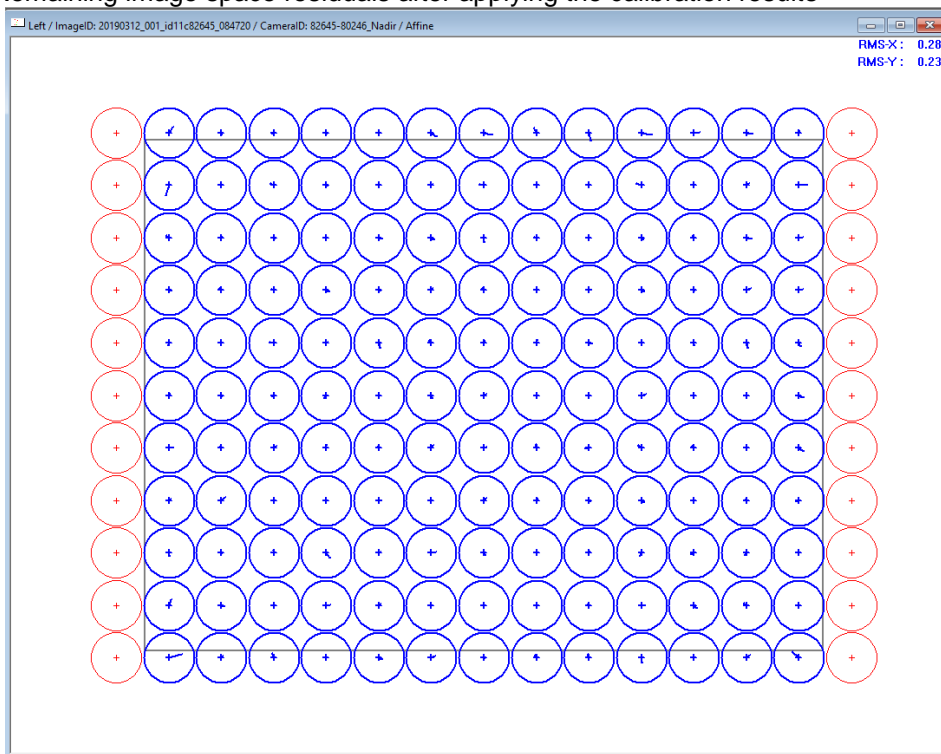


Radius of circles is 0.0010 mm

6.4 Estimation Results for Forward Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81808
Lens	SAT-D 4.0/150	150216
View Direction in Pod Position	Forward	
IMU Misalignment	Angle [degree]	
	ω	-0.15308
	Φ	0.12982
	κ	0.00152
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81808-D-842157_LensSystem-150216-B-819435_DateTime-20190324-090515.xml		
Geometric Calibration	Date	24.03.2019
Radiometric Calibration	Date	09.01.2019
Misalignment Flight	Date	-
Misalignment Update Completed	Date	-

Remaining image space residuals after applying the calibration results

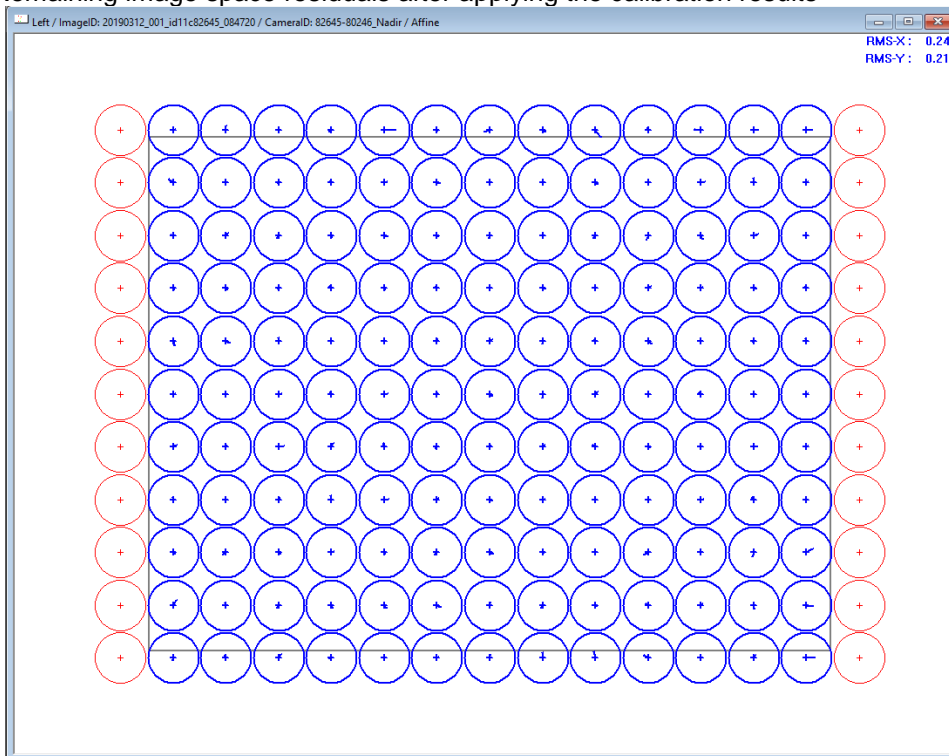


Radius of circles is 0.0010 mm

6.5 Estimation Results for Backward Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81809
Lens	SAT-D 4.0/150	150217
View Direction in Pod Position	Backward	
IMU Misalignment	Angle [degree]	
	ω	-0.09455
	Φ	0.08253
	κ	-0.01839
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81809-D-842157_LensSystem-150217-B-819435_DateTime-20190324-090616.xml		
Geometric Calibration	Date	24.03.2019
Radiometric Calibration	Date	10.01.2019
Misalignment Flight	Date	-
Misalignment Update Completed	Date	-

Remaining image space residuals after applying the calibration results

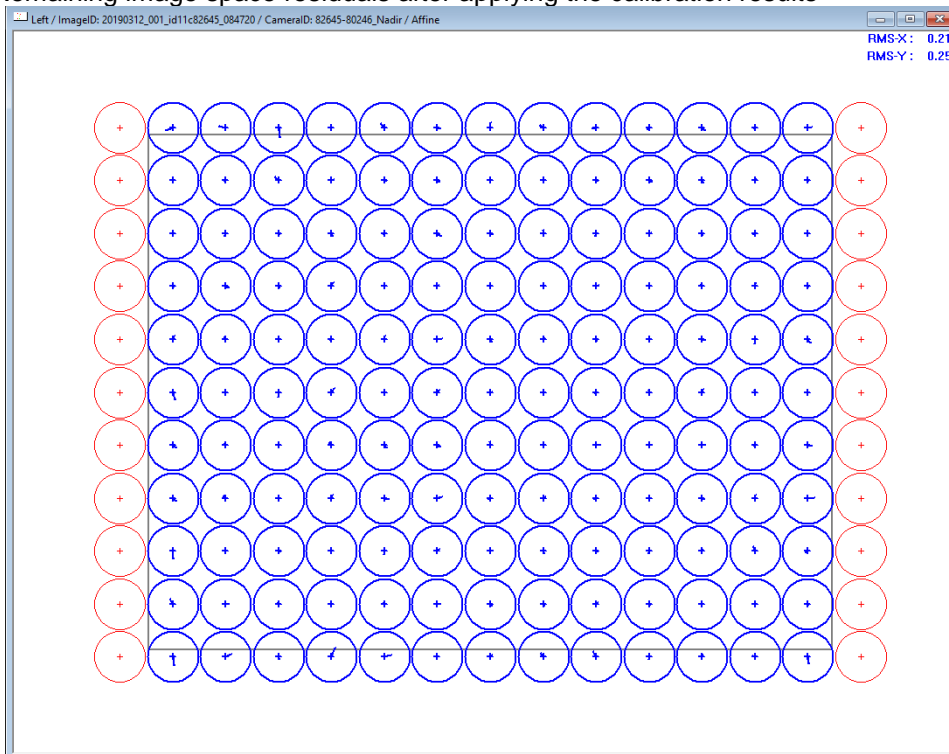


Radius of circles is 0.0010 mm

6.6 Estimation Results for Left Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81810
Lens	SAT-D 4.0/150	150218
View Direction in Pod Position	Left	
IMU Misalignment	Angle [degree]	
	ω	-0.09804
	Φ	0.13641
	κ	-0.01382
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81810-D-842157_LensSystem-150218-B-819435_DateTime-20190324-090724.xml		
Geometric Calibration	Date	24.03.2019
Radiometric Calibration	Date	15.01.2019
Misalignment Flight	Date	-
Misalignment Update Completed	Date	-

Remaining image space residuals after applying the calibration results

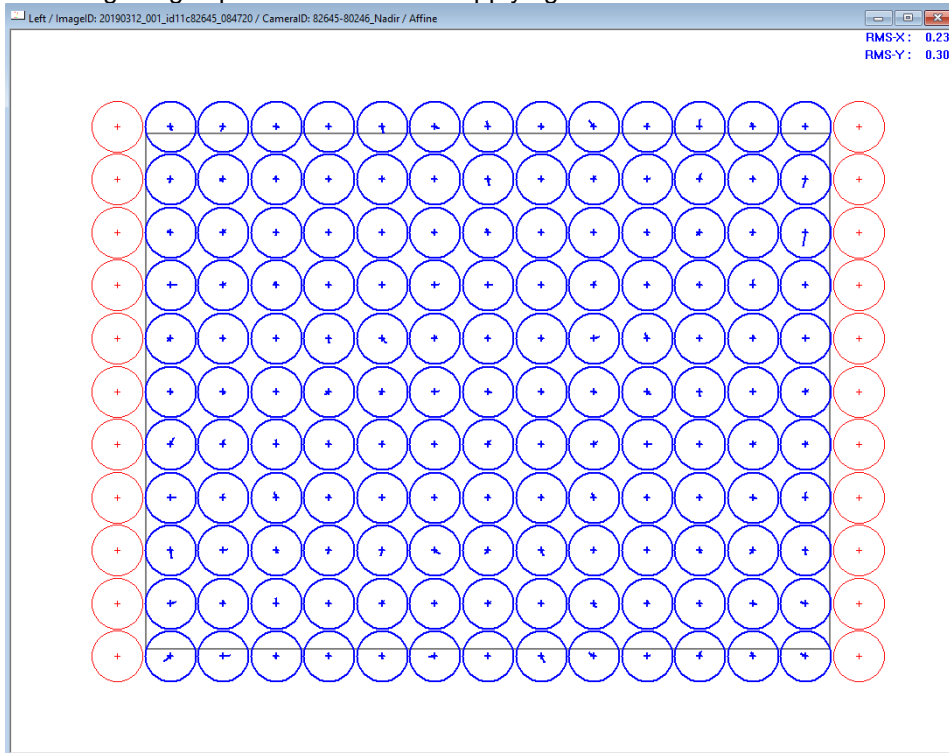


Radius of circles is 0.0010 mm

6.7 Estimation Results for Right Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81820
Lens	SAT-D 4.0/150	150228
View Direction in Pod Position	Right	
IMU Misalignment	Angle [degree]	
	ω	-0.03436
	Φ	-0.18071
	κ	-0.00080
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81820-D-842157_LensSystem-150228-B-819435_DateTime-20190324-090752.xml		
Geometric Calibration Date	Date	24.03.2019
Radiometric Calibration Date	Date	20.02.2019
Misalignment Flight	Date	-
Misalignment Update Completed	Date	-

Remaining image space residuals after applying the calibration results



Radius of circles is 0.0010 mm