

- when it has to be **right**



Leica Geosystems Leica CityMapper Calibration Certificate

Product	Leica CityMapper
Serial Number	95522
Date	09 March 2021
Inspector	Kevin Spruill





1. System Components

Component	Type	Serial Number
Pod	CityMapper Pod	95522
GNSS/IMU	Litef LCI-100C 500 Hz	1239
LiDAR Unit	Hyperion II	5520
Camera Head	CH82	82636
Lens	NAT-D 2.8/80	80239
Camera Head	CH81m	81792
Lens	SAT-D 4.0/150	150200
Camera Head	CH81m	81793
Lens	SAT-D 4.0/150	150201
Camera Head	CH81m	81794
Lens	SAT-D 4.0/150	150202
Camera Head	CH81m	81795
Lens	SAT-D 4.0/150	150203

2. Estimation Process

		Passed	Date	Inspector
Image Flight	completed	ok	08.12.2018	Philip Benz
Image Quality Check	checked	ok	13.12.2018	Bernhard Riedl
Image Calibration	completed	ok	17.12.2018	Cesar Mendoza
Image Misalignment Update	completed	ok	09.03.2021	Kevin Spruill
LiDAR Flight	completed	ok	08.12.2018	Philip Benz
LiDAR Quality Check	checked	ok	12.12.2018	Rene Heierli
LiDAR Calibration and Accuracy	completed	ok	19.12.2018	Michael Vetter
LiDAR Misalignment Update	completed	ok	09.03.2021	Kevin Spruill

3. Inspectors

Name	Bernhard Riedl	20.12.2018	
Position	Production Manager		
Name	Robert Bosch	20.12.2018	
Position	Support Engineer		
Name	Michael Vetter	20.12.2018	
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	-0.032457	degree
	Φ	0.052422	degree
	κ	-0.483847	degree
Boresight		Value	Unit
	Θ	-0.014032	degree
	Φ	-0.012436	degree
Receiver 1		Value	Unit
Range	Δ Offset	0.000000	meters
Wedge 0		Value	Unit
Wedge	Δ Alpha	-0.005555	degree
Wedge Position	Δ Offset	-0.136448	degree
Position Correction	X	0.013656	degree
	Y	0.060141	degree
Mount	Roll	0.436611	degree
	Pitch	0.870240	degree
Rotation Axis	Roll	0.518921	degree
	Pitch	-0.090063	degree
Wedge 1		Value	Unit
Wedge	Δ Alpha	-0.006312	degree
Wedge Position	Δ Offset	-0.545016	degree
Position Correction	X	-0.023006	degree
	Y	0.003534	degree
Mount	Roll	0.022630	degree
	Pitch	-0.108686	degree
	Speed Pitch	1.50E-06	degree/rps ²
Rotation Axis	Roll	0.006082	degree
	Pitch	-0.062358	degree

LiDAR Geometric Calibration File

HYPERION_GEOMETRY_LIDARUNIT-5520-C-855570-DATETIME-20181213-083618.XML

	Date	13.12.2018
LiDAR Misalignment Flight	Date	27.01.2021
LiDAR Misalignment Update Completed	Date	09.03.2021

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

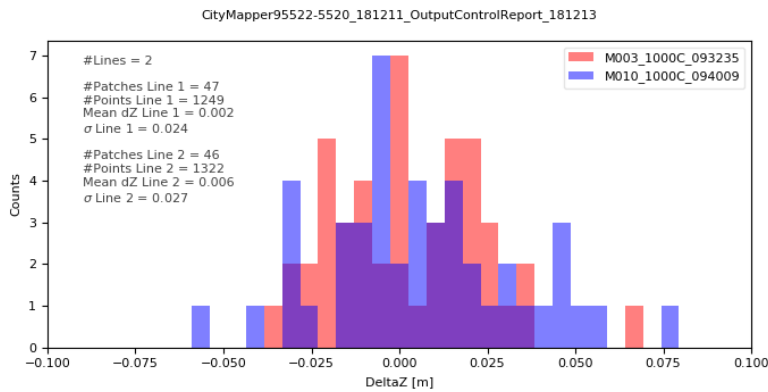


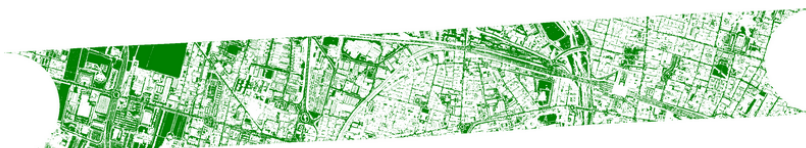
Figure 1 Vertical distance to ground control points at 1000 m AGL.

5.2.2 Difference of forward and backward scan of one line

M010_1000C_094009

317910 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	317385	99.83
Bright Green	0.04-0.07	490	0.15
Yellow	0.07-0.1	25	0.01
Red	>0.1	10	0.00



Vertical difference

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

5.2.3 Multi-line accuracy between two perpendicular lines

M003_1000C_093235_vs_M010_1000C_094009

32483 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	32444	99.88
Bright Green	0.04-0.07	35	0.11
Yellow	0.07-0.1	2	0.01
Red	>0.1	2	0.01



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

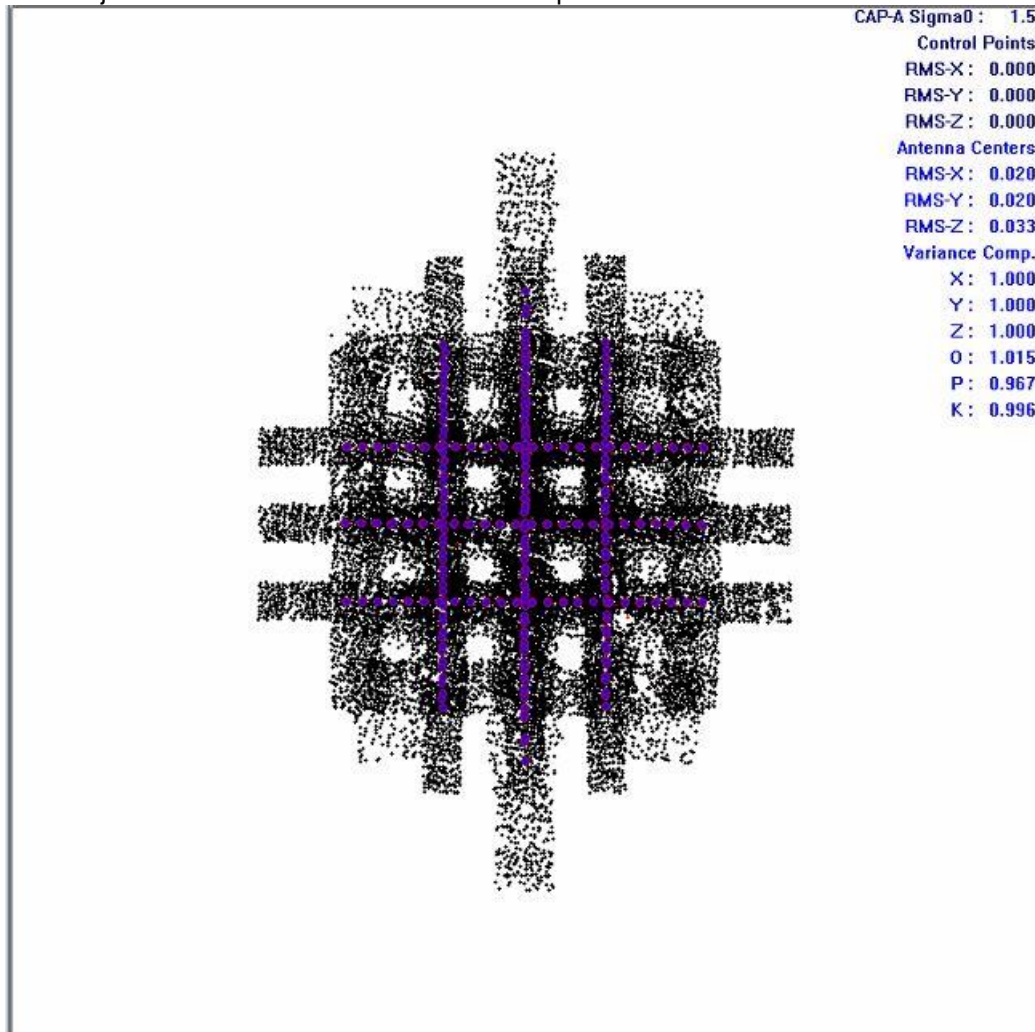
Reference band (green)

Distance [mm]

Resulting sigma naught of bundle adjustment:

0.0015

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:

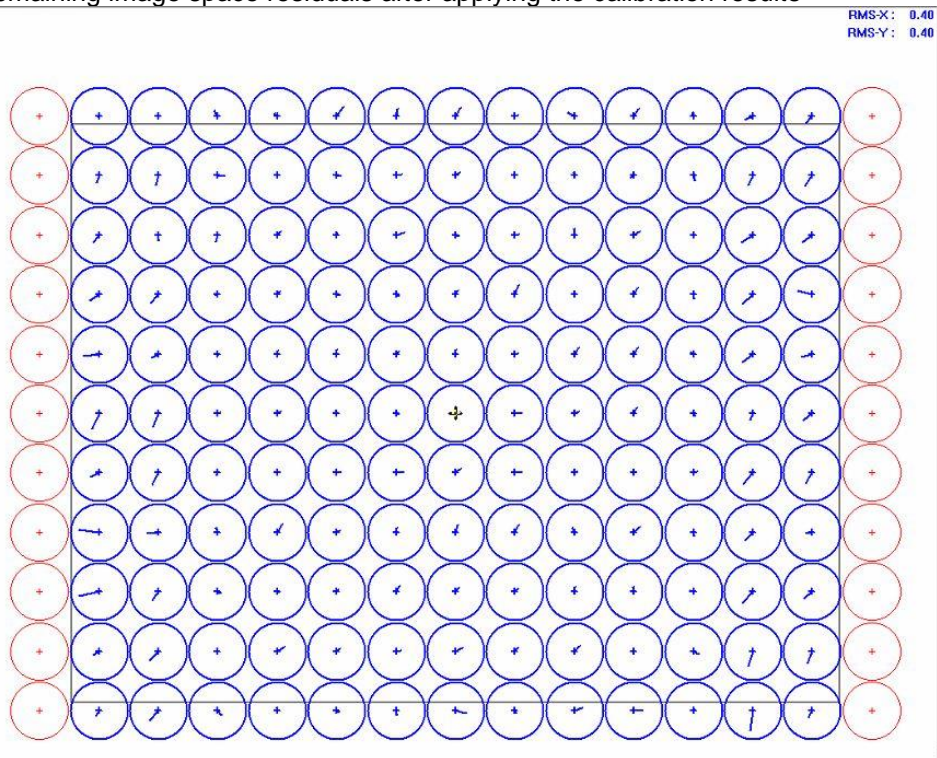
0.002

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	82636
Lens	NAT-D 2.8/80	80239
View Direction in Pod Position	Nadir	
IMU Misalignment	Angle [degree]	
	ω	-0.16186
	Φ	0.05651
	κ	0.11477
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
	c	83.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-82636-E-798528_LensSystem-80239-B-785423_DateTime-20181220-174537.xml		
Geometric Calibration	Date	20.12.2018
Radiometric Calibration	Date	14.11.2018
Misalignment Flight	Date	27.01.2021
Misalignment Update Completed	Date	09.03.2021

Remaining image space residuals after applying the calibration results

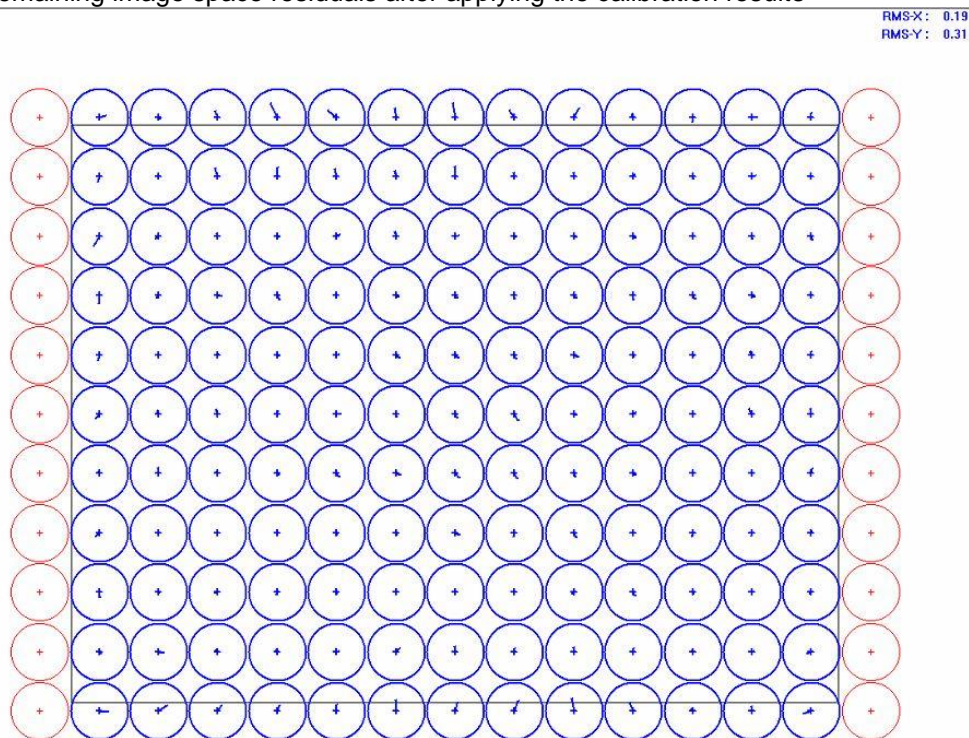


Radius of circles is 0.0010 mm

6.4 Estimation Results for Forward Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81792
Lens	SAT-D 4.0/150	150200
View Direction in Pod Position	Forward	
IMU Misalignment	Angle [degree]	
	ω	-0.12760
	Φ	-0.04249
	κ	0.32482
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81792-D-842157_LensSystem-150200-B-819435_DateTime-20181217-195951.xml		
Geometric Calibration	Date	17.12.2018
Radiometric Calibration	Date	09.11.2018
Misalignment Flight	Date	27.01.2021
Misalignment Update Completed	Date	09.03.2021

Remaining image space residuals after applying the calibration results

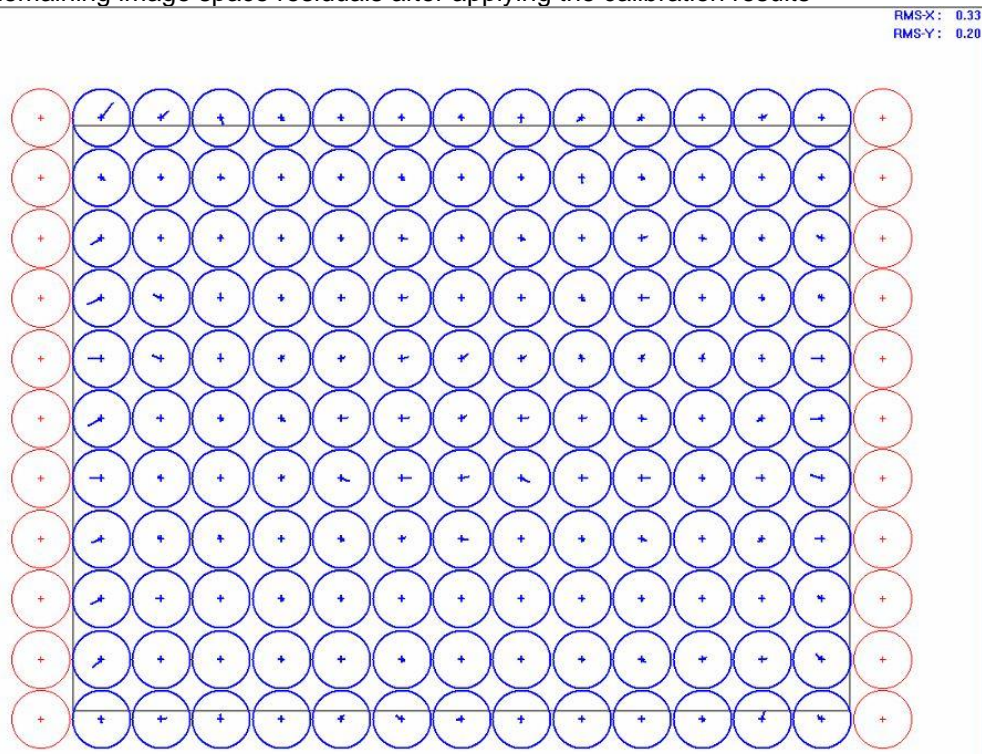


Radius of circles is 0.0010 mm

6.5 Estimation Results for Backward Camera Head and Lens

	Component	Serial Number
Camera Head	CH81m	81793
Lens	SAT-D 4.0/150	150201
View Direction in Pod Position	Backward	
IMU Misalignment	Angle [degree]	
	ω	-0.08253
	Φ	0.03474
	κ	0.03264
Principal Point	Distance [mm]	
	x	0.0000
	y	0.0000
Focal Length	Distance [mm]	
		156.00
Geometric Calibration File		
RCD30_Geometry_CameraHead-81793-D-842157_LensSystem-150201-B-819435_DateTime-20181217-200024.xml		
Geometric Calibration	Date	17.12.2018
Radiometric Calibration	Date	09.11.2018
Misalignment Flight	Date	27.01.2021
Misalignment Update Completed	Date	09.03.2021

Remaining image space residuals after applying the calibration results

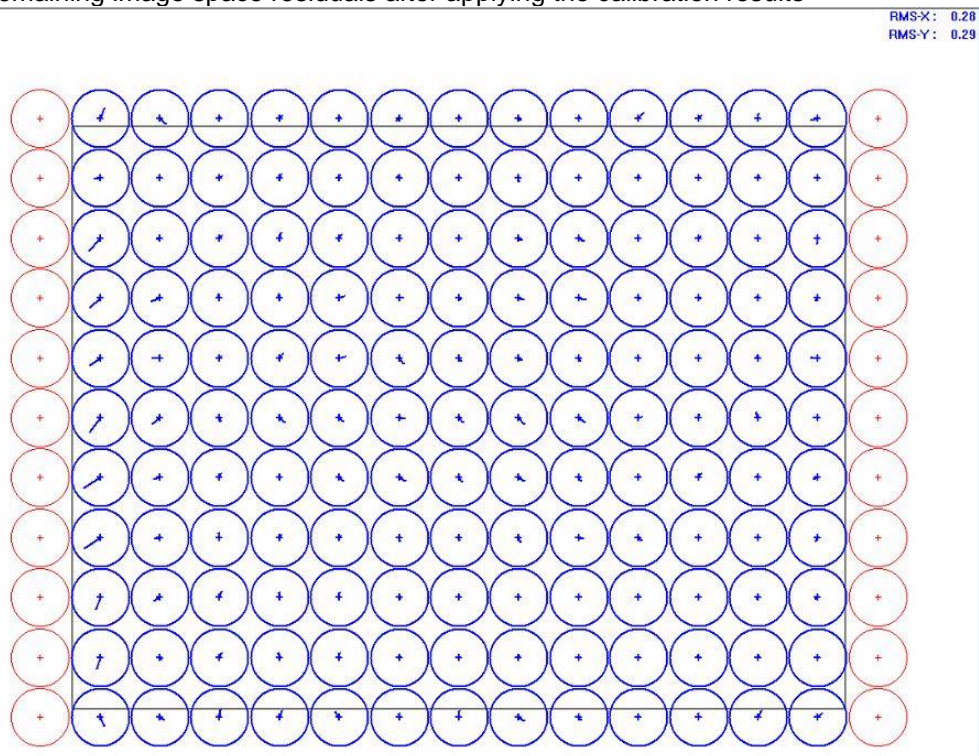


Radius of circles is 0.0010 mm

6.6 Estimation Results for Left Camera Head and Lens

		Component	Serial Number
Camera Head		CH81m	81794
Lens		SAT-D 4.0/150	150202
View Direction in Pod Position		Left	
IMU Misalignment		Angle [degree]	
	ω	-0.01854	
	Φ	0.34535	
	κ	0.12304	
Principal Point		Distance [mm]	
	x	0.0000	
	y	0.0000	
Focal Length		Distance [mm]	
		156.00	
Geometric Calibration File			
RCD30_Geometry_CameraHead-81794-D-842157_LensSystem-150202-B-819435_DateTime-20181217-200045.xml			
Geometric Calibration	Date	17.12.2018	
Radiometric Calibration	Date	13.11.2018	
Misalignment Flight	Date	27.01.2021	
Misalignment Update Completed	Date	09.03.2021	

Remaining image space residuals after applying the calibration results

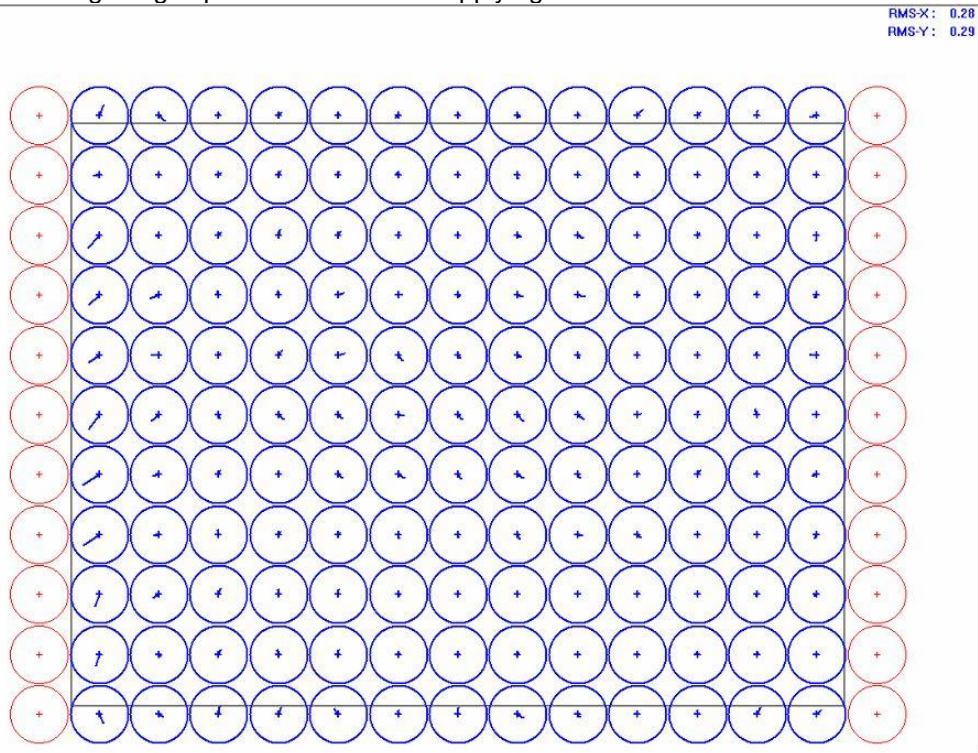


Radius of circles is 0.0010 mm

6.7 Estimation Results for Right Camera Head and Lens

		Component	Serial Number
Camera Head		CH81m	81795
Lens		SAT-D 4.0/150	150203
View Direction in Pod Position		Right	
IMU Misalignment		Angle [degree]	
	ω	0.05641	
	ϕ	0.10777	
	κ	0.06263	
Principal Point		Distance [mm]	
	x	0.0000	
	y	0.0000	
Focal Length		Distance [mm]	
		156.00	
Geometric Calibration File			
RCD30_Geometry_CameraHead-81795-D-842157_LensSystem-150203-B-819435_DateTime-20181217-200054.xml			
Geometric Calibration Date	Date	17.12.2018	
Radiometric Calibration Date	Date	12.11.2018	
Misalignment Flight	Date	27.01.2021	
Misalignment Update Completed	Date	09.03.2021	

Remaining image space residuals after applying the calibration results



Radius of circles is 0.0010 mm