Technical Note NO. 5 (TN - 05)

April, 2023

102S PRO SN:0520102P10265 (Calibrated on 19/03/2023)

รายงานผลการวัดสอบทางเรขาคณิตสำหรับระบบกล้องเฉียงที่ติดตั้งบนยูเอวี

Geometric Camera Calibration Report for UAV-Equipped Small-Format Oblique Camera System

PCV & LS Lab

Department of Survey Engineer,

Faculty of Engineering,

Chulalongkorn University

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จัดทำโดย

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รศ.ดร.ไพศาล สันติธรรมนนท์ Phisan Santitamnont (Dr.-Ing., Leibniz Hannover)

ภาควิชาวิศวกรรมสำรวจ

คณะวิศวกรรมศาสตร์ จุฬาลงกรณ์มหาวิทยาลัย

กิตติกรรมประกาศ

คณะวิจัยขอขอบคุณ บริษัท ไทยสกายวิชั่น จำกัด ซึ่งเป็นผู้สนับสนุนและอนุเคราะห์ข้อมูลภาพถ่ายทางอากาศและข้อมูลสัญญาณจีเอนเอสเอสมาใช้ในการประมวลผลข้อมูลและวิเคราะห์หาค่าพารามิเตอร์และแบบจำลองทางคณิตศาสตร์ของระบบกล้องเฉียง

งานวิจัยครั้งนี้สำเร็จลุล่วงด้วยดี ข้อมูลที่ได้จะถูกนำไปประมวลผล วิจัย พัฒนาองค์ความรู้ด้านการทำแผนที่และแบบจำลองสามมิติทั้งจากระบบถ่ายภาพกล้องเฉียงสำหรับสถาบันการศึกษาและบริษัทที่ปรึกษาการทำแผนที่จากภาพถ่ายทางอากาศต่อไป

คณะวิจัย

Photogrammetric Block Information

Photogrammetrist **UAV Camera Operator**	1. Phisan Santitamnont (Dr.-Ing) 2. Thirawat Bannakulpiphat (M.Eng.) 3. Team Thai Sky Vision (TSV)
Flight Date and Time	19/03/2023 (After 12.00 PM.)
Report Date / Release	10/04/2023
Test Field	Geodetic GNSS and UAV Testing Field, Chulalongkorn University
Location	Saraburi, Thailand (Latitude: 14°.5236N, Longitude: 101°.0235E)
Aircraft	DJI MATRICE 300
Camera	SHARE 102S PRO
Block Name	Full block CU-SBR
Number of Photo	4,135 (827 photo per camera)
Nadir Photo Overlap (%)	80%
Nadir Photo Side-lap (%)	80%
Number of Rig Station	827
Number of Flight-Strip	16
Number of GCP/CP	Total 40
Photogrammetric Processing Software	Pix4D Mapper version 4.7.5

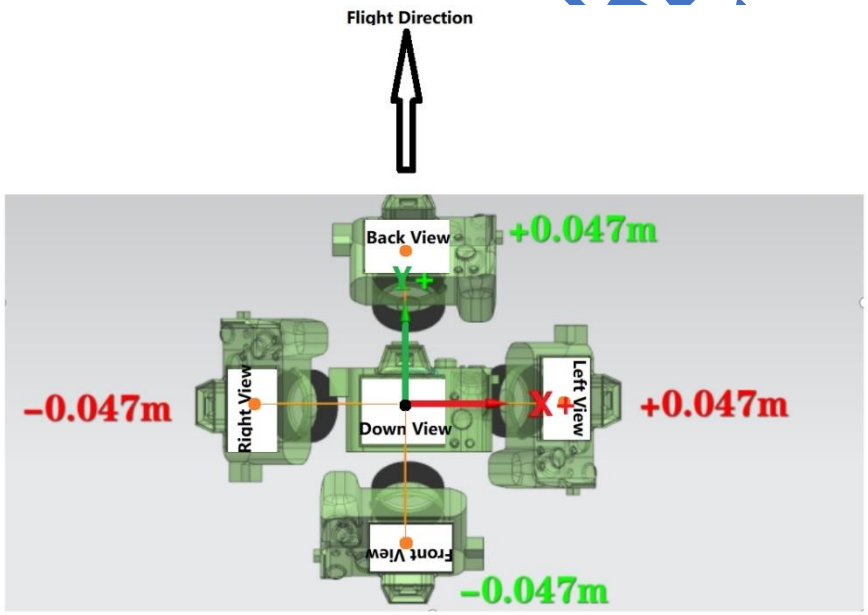
Camera Specification

Parameter	Description
CMOS Size	23.5 x 15.6 mm (APS-C)
Pixel	24.3 MP (Total ≥ 120 MP)
Resolution (Single CCD)	6000 x 4000
Pixel Size	3.9 µm
Exposure Interval	≥ 0.8 s
Focal Length (Nadir/Oblique)	25 mm/ 35 mm
Weight	650 g
Data Storage	1280 GB
Size	140*140*80 mm

Quality Report

1. Camera position from manufacturer note

Camera	X (mm)	Y (mm)	Z (mm)	Camera
102S PRO	???.??	???.??	???.??	Ortho view
	???.??	???.??	???.??	Left view
	???.??	???.??	???.??	Right view
	???.??	???.??	???.??	Forward view
	???.??	???.??	???.??	Backward view



2. Initial and adjusted rig relative parameters

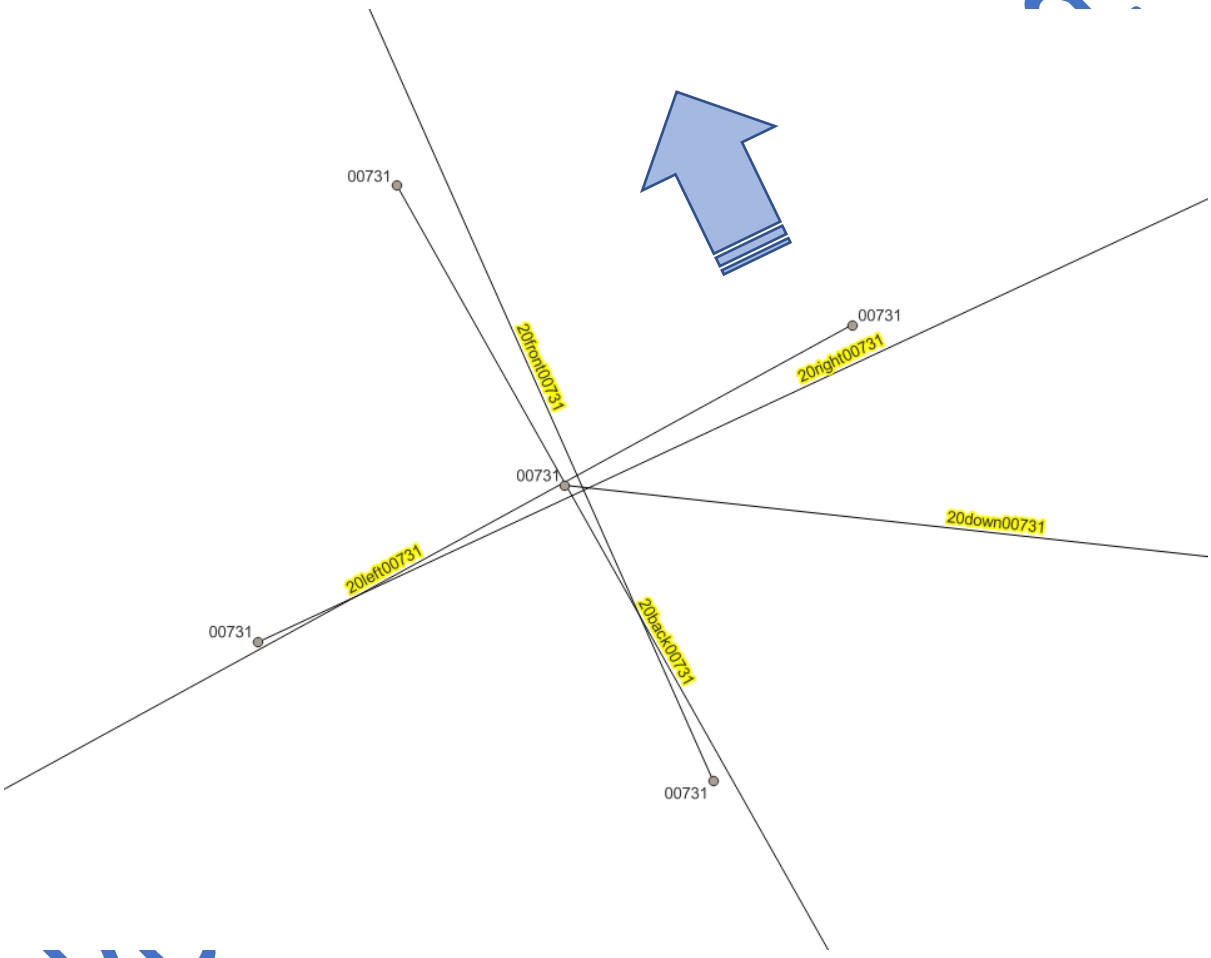
*หมายเหตุ: พารามิเตอร์ที่ใช้ยังไม่ใช่ค่าที่สอดคล้องกับลักษณะทางกายภาพความเป็นจริงของระบบกล้อง หากได้ค่าที่สอดคล้องจะทำการวัดสอบพารามิเตอร์ใหม่

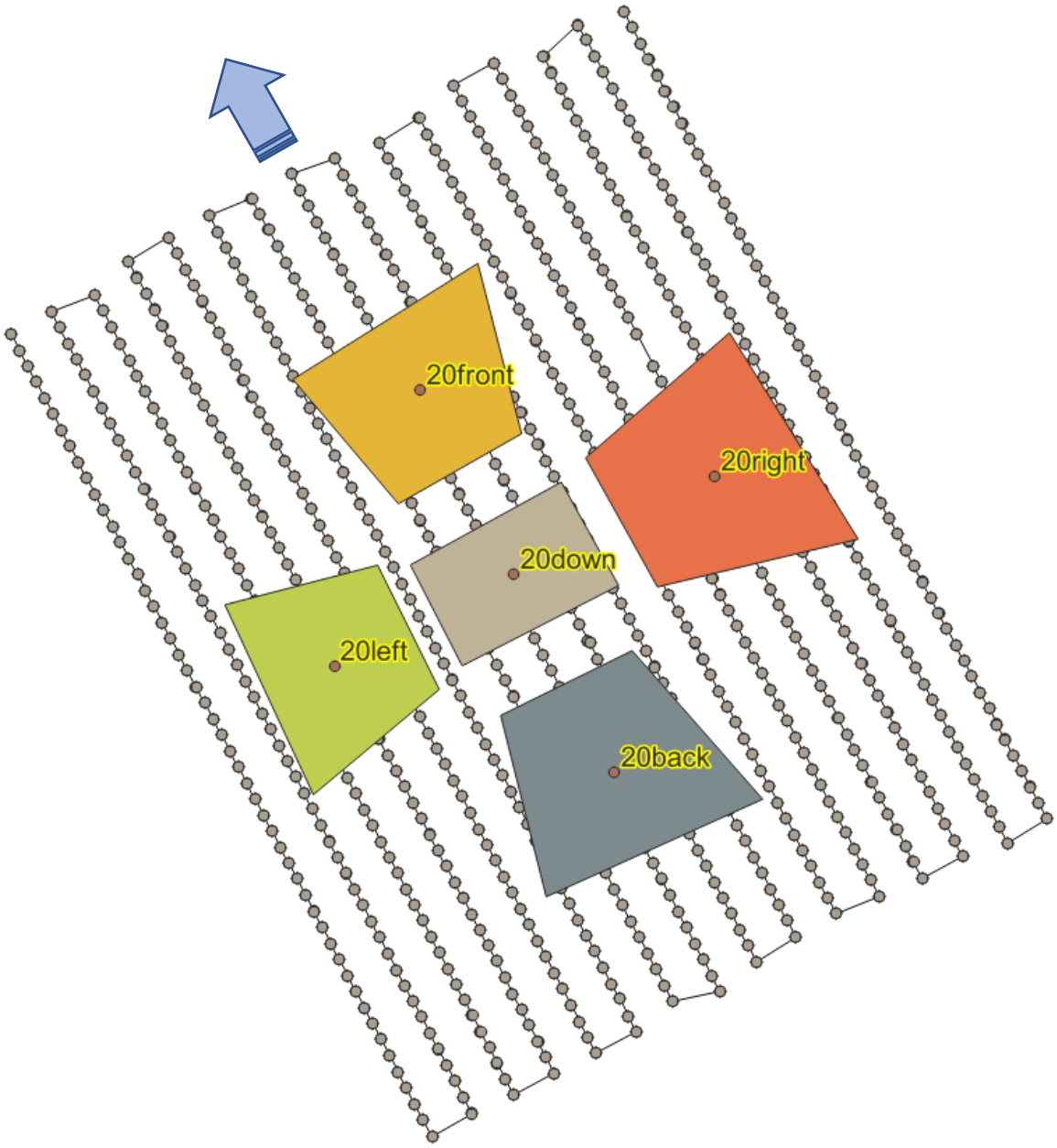
Camera Rig «SHARE_OBQ_RIG» Relatives. Images: 4135

	Transl X [m]	Transl Y [m]	Transl Z [m]	Rot X [degree]	Rot Y [degree]	Rot Z [degree]
SHARE102SPRO265DOWN_25.2_6000x4000 (RGB)	Reference Camera					
SHARE102SPRO265BACK_35.2_6000x4000 (RGB)						
Initial Values	0.000	-0.047	-0.025	-45.000	0.000	0.000
Optimized values	0.000	-0.047	-0.025	-44.623	-0.791	-0.140
Uncertainties (sigma)				0.016	0.002	0.017
SHARE102SPRO265FRONT_35.3_6000x4000 (RGB)						
Initial Values	0.000	0.047	-0.025	45.000	0.000	-180.000
Optimized values	0.000	0.047	-0.025	45.456	0.211	179.954
Uncertainties (sigma)				0.012	0.015	0.002
SHARE102SPRO265LEFT_35.4_6000x4000 (RGB)						
Initial Values	0.047	0.000	-0.025	0.000	-45.000	90.000
Optimized values	0.047	0.000	-0.025	0.984	-45.332	90.944
Uncertainties (sigma)				0.008	0.005	0.013
SHARE102SPRO265RIGHT_35.4_6000x4000 (RGB)						
Initial Values	-0.047	0.000	-0.025	0.000	45.000	-90.000
Optimized values	-0.047	0.000	-0.025	-1.583	45.010	-88.886
Uncertainties (sigma)				0.002	0.003	0.003

Evaluation result passed: (ตรวจสอบอีกครั้งหลังจากแทนค่าพารามิเตอร์ได้ถูกต้อง)

Uncertainty	Tx, Ty, Tz (mm)	Rot X (degrees)	Rot Y (degrees)	Rot Z (degrees)
Criterion	Constraint	0.015	0.015	0.015
Passed	?	?	?	?




20front
20right
20down
20left
20back

3. Internal Camera Parameter

SHARE102SPRO265DOWN_25.2_6000x4000 (RGB). Sensor Dimensions: 22.604 [mm] x 15.069 [mm]

EXIF ID: SHARE102SPRO265DOWN_25.2_6000x4000

	Focal Length	Principal Point x	Principal Point y	R1	R2	R3	T1	T2
Initial Values	6685.710 [pixel] 25.187 [mm]	3002.620 [pixel] 11.312 [mm]	2028.210 [pixel] 7.641 [mm]	-0.053	0.137	-0.047	0.000	0.000
Optimized Values	6423.603 [pixel] 24.200 [mm]	3000.463 [pixel] 11.304 [mm]	2024.668 [pixel] 7.628 [mm]	-0.050	0.120	-0.023	0.000	-0.000
Uncertainties (Sigma)	0.279 [pixel] 0.001 [mm]	0.256 [pixel] 0.001 [mm]	0.193 [pixel] 0.001 [mm]	0.000	0.002	0.005	0.000	0.000

SHARE102SPRO265BACK_35.2_6000x4000 (RGB). Sensor Dimensions: 22.839 [mm] x 15.226 [mm]

EXIF ID: SHARE102SPRO265BACK_35.2_6000x4000

	Focal Length	Principal Point x	Principal Point y	R1	R2	R3	T1	T2
Initial Values	9257.140 [pixel] 35.237 [mm]	3040.020 [pixel] 11.572 [mm]	2014.680 [pixel] 7.669 [mm]	-0.012	0.040	-0.334	-0.000	-0.001
Optimized Values	9015.691 [pixel] 34.318 [mm]	2999.100 [pixel] 11.416 [mm]	1952.867 [pixel] 7.434 [mm]	-0.053	0.265	-1.014	-0.001	0.003
Uncertainties (Sigma)	0.745 [pixel] 0.003 [mm]	2.710 [pixel] 0.010 [mm]	2.493 [pixel] 0.009 [mm]	0.003	0.044	0.178	0.000	0.000

SHARE102SPRO265FRONT_35.3_6000x4000 (RGB). Sensor Dimensions: 22.858 [mm] x 15.239 [mm]

EXIF ID: SHARE102SPRO265FRONT_35.3_6000x4000

	Focal Length	Principal Point x	Principal Point y	R1	R2	R3	T1	T2
Initial Values	9257.140 [pixel] 35.266 [mm]	3042.170 [pixel] 11.590 [mm]	1997.070 [pixel] 7.608 [mm]	-0.015	0.135	-0.800	0.000	-0.000
Optimized Values	8999.712 [pixel] 34.286 [mm]	3111.765 [pixel] 11.855 [mm]	1979.437 [pixel] 7.541 [mm]	0.062	-0.975	3.652	0.003	0.002
Uncertainties (Sigma)	0.541 [pixel] 0.002 [mm]	2.302 [pixel] 0.009 [mm]	1.830 [pixel] 0.007 [mm]	0.002	0.032	0.130	0.000	0.000

SHARE102SPRO265LEFT_35.4_6000x4000 (RGB). Sensor Dimensions: 22.968 [mm] x 15.312 [mm]

EXIF ID: SHARE102SPRO265LEFT_35.4_6000x4000

	Focal Length	Principal Point x	Principal Point y	R1	R2	R3	T1	T2
Initial Values	9257.140 [pixel] 35.436 [mm]	3054.980 [pixel] 11.694 [mm]	2016.620 [pixel] 7.720 [mm]	-0.006	-0.005	-0.190	0.000	0.001
Optimized Values	9041.725 [pixel] 34.611 [mm]	3045.577 [pixel] 11.658 [mm]	2054.176 [pixel] 7.863 [mm]	0.003	-0.059	-0.199	0.000	-0.001
Uncertainties (Sigma)	0.430 [pixel] 0.002 [mm]	1.781 [pixel] 0.007 [mm]	0.648 [pixel] 0.002 [mm]	0.002	0.027	0.117	0.000	0.000

SHARE102SPRO265RIGHT_35.4_6000x4000 (RGB). Sensor Dimensions: 22.924 [mm] x 15.283 [mm]

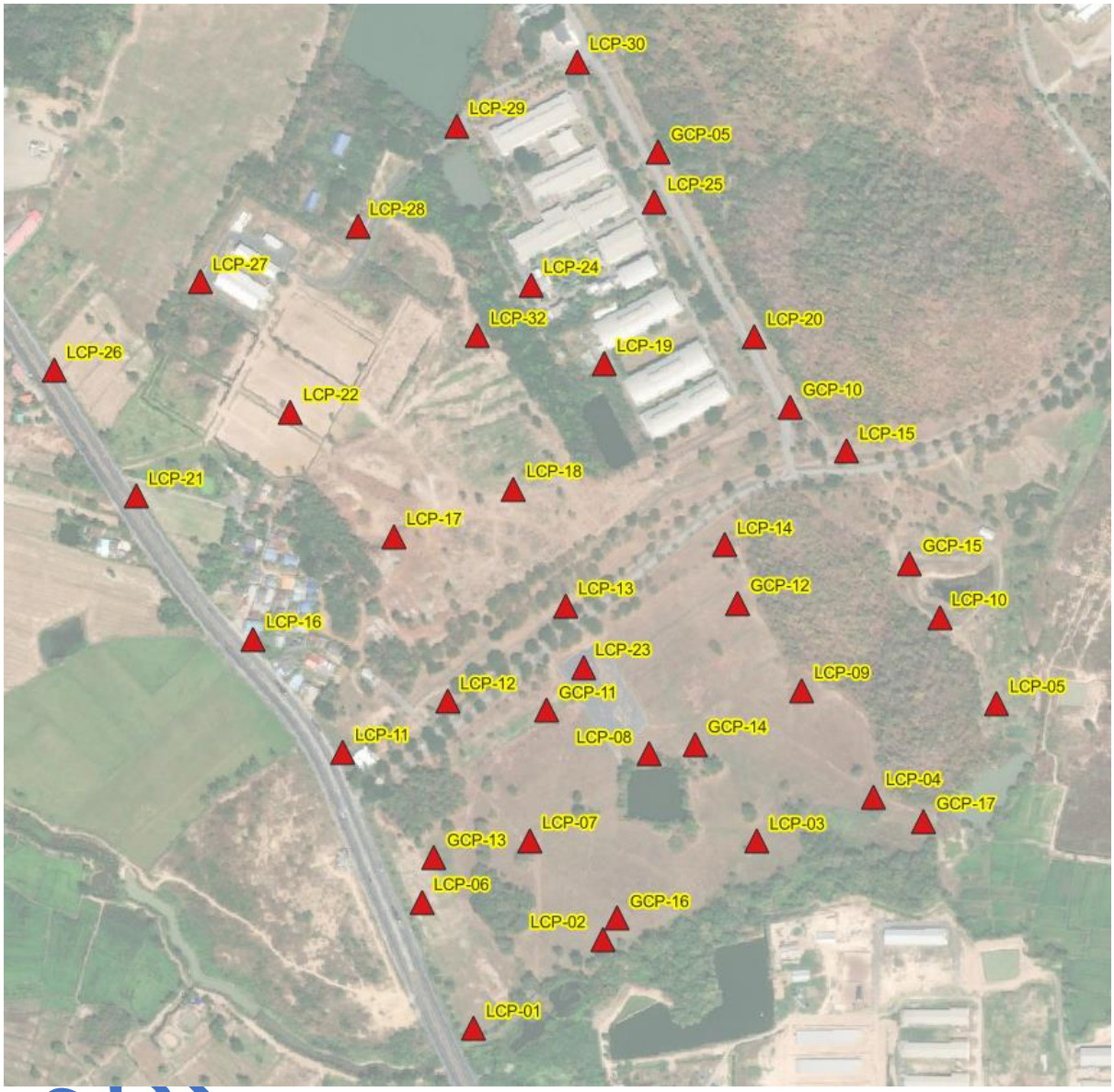
EXIF ID: SHARE102SPRO265RIGHT_35.4_6000x4000

	Focal Length	Principal Point x	Principal Point y	R1	R2	R3	T1	T2
Initial Values	9257.140 [pixel] 35.368 [mm]	3008.110 [pixel] 11.493 [mm]	2019.280 [pixel] 7.715 [mm]	-0.009	0.009	-0.245	0.000	0.001
Optimized Values	9023.686 [pixel] 34.476 [mm]	2955.669 [pixel] 11.293 [mm]	2008.004 [pixel] 7.672 [mm]	0.000	-0.123	0.289	-0.000	-0.002
Uncertainties (Sigma)	0.389 [pixel] 0.001 [mm]	0.088 [pixel] 0.000 [mm]	0.114 [pixel] 0.000 [mm]	0.002	0.023	0.103	0.000	0.000

Evaluation Results Passed: **(ตรวจสอบอีกครั้งหลังจากแทนค่าพารามิเตอร์ได้ถูกต้อง)**

	f	cx	cy	R1	R2	R3
Criterion	0.005 mm	0.015 mm	0.015 mm	0.005	0.060	0.400
DOWN	?	?	?	?	?	?
FRONT	?	?	?	?	?	?
REAR	?	?	?	?	?	?
LEFT	?	?	?	?	?	?
RIGHT	?	?	?	?	?	?

4. Distribution of Ground Control Points (GCPs) and Check Point (CPs)



5. Aerial Triangulation Result: partial GCP (20 points) vs partial Check Points (20 points)

Ground Control Points

GCP Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
GCP-11 (3D)	0.020/ 0.050	0.008	-0.009	0.021	0.293	20 / 20
LCP-22 (3D)	0.020/ 0.050	-0.020	-0.030	-0.027	0.290	20 / 20
LCP-28 (3D)	0.020/ 0.050	-0.017	-0.014	-0.011	0.240	20 / 20
LCP-30 (3D)	0.020/ 0.050	-0.003	-0.004	-0.026	0.281	20 / 20
LCP-25 (3D)	0.020/ 0.050	-0.009	0.025	-0.023	0.280	20 / 20
LCP-19 (3D)	0.020/ 0.050	0.012	-0.017	-0.018	0.290	20 / 20
LCP-15 (3D)	0.020/ 0.050	0.002	-0.010	0.007	0.303	20 / 20
GCP-10 (3D)	0.020/ 0.050	0.022	0.014	-0.006	0.354	20 / 20
LCP-05 (3D)	0.020/ 0.050	-0.018	0.016	0.048	0.272	20 / 20
LCP-13 (3D)	0.020/ 0.050	0.019	-0.014	0.065	0.297	20 / 20
LCP-32 (3D)	0.020/ 0.050	0.023	-0.000	0.019	0.279	20 / 20
LCP-26 (3D)	0.020/ 0.050	-0.013	0.005	0.032	0.249	20 / 20
LCP-16 (3D)	0.020/ 0.050	-0.013	0.019	0.005	0.333	20 / 20
LCP-01 (3D)	0.020/ 0.050	-0.030	0.024	-0.035	0.282	20 / 20
LCP-06 (3D)	0.020/ 0.050	0.005	0.026	-0.022	0.422	20 / 20
GCP-13 (3D)	0.020/ 0.050	0.019	0.008	-0.007	0.345	20 / 20
LCP-02 (3D)	0.020/ 0.050	-0.005	-0.004	-0.046	0.274	20 / 20
LCP-03 (3D)	0.020/ 0.050	0.004	-0.009	-0.021	0.271	20 / 20
LCP-09 (3D)	0.020/ 0.050	0.007	-0.014	-0.040	0.284	20 / 20
GCP-16 (3D)	0.020/ 0.020	0.008	-0.012	0.016	0.187	20 / 20
Mean [m]		0.000029	-0.000116	-0.003352		
Sigma [m]		0.014953	0.015799	0.028861		
RMS Error [m]		0.014953	0.015799	0.029055		

Check Point Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
LCP-27		-0.0095	0.0090	-0.0315	0.3037	20 / 20
LCP-29		0.0044	-0.0266	-0.0535	0.1833	20 / 20
GCP-05		-0.0120	0.0763	-0.0011	0.3443	20 / 20
LCP-24		0.0209	0.0039	0.0630	0.2681	20 / 20
LCP-20		0.0217	0.0032	-0.0374	0.3046	20 / 20
GCP-15		0.0654	-0.0079	-0.0789	0.3161	20 / 20
LCP-10		0.0429	0.0312	-0.0479	0.2856	20 / 20
LCP-12		0.0069	-0.0028	0.0190	0.2781	20 / 20
LCP-18		0.0033	-0.0110	0.0167	0.3351	20 / 20
LCP-17		0.0038	-0.0271	-0.0417	0.2724	20 / 20
LCP-21		0.0317	-0.0083	0.0068	0.3001	20 / 20
LCP-11		0.0166	0.0298	0.0735	0.2051	20 / 20
LCP-08		0.0343	-0.0006	0.0196	0.3183	20 / 20
LCP-07		0.0016	-0.0076	-0.0259	0.2645	20 / 20
GCP-17		0.0380	0.0053	-0.0566	0.2828	20 / 20
LCP-04		0.0341	-0.0153	-0.0296	0.3090	20 / 20
GCP-12		0.0210	-0.0037	-0.0314	0.2080	20 / 20
LCP-14		0.0129	-0.0277	-0.0576	0.2756	20 / 20
GCP-14		0.0409	0.0011	-0.0281	0.2823	20 / 20
LCP-23		0.0169	-0.0147	-0.0060	0.2949	20 / 20
Mean [m]		0.019795	0.000326	-0.016427		
Sigma [m]		0.018906	0.023228	0.039003		
RMS Error [m]		0.027373	0.023230	0.042321		

Evaluation Result: (ตรวจสอบอีกครั้งหลังจากแทนค่าพารามิเตอร์ได้ถูกต้อง)

	Error X	Error Y (m)	Error Z (m)	Projection Error
Criterion	0.035 m	0.035 m	0.065 m	0.5 pixel
Partial GCPs	?	?	?	?
Partial CPs	?	?	?	?

6. Aerial Triangulation Result: full GCP (40 points)

Ground Control Points

GCP Name	Accuracy XY/Z [m]	Error X [m]	Error Y [m]	Error Z [m]	Projection Error [pixel]	Verified/Marked
GCP-11 (3D)	0.020/ 0.050	-0.001	-0.007	0.021	0.297	20 / 20
LCP-27 (3D)	0.020/ 0.050	-0.009	0.008	-0.010	0.303	20 / 20
LCP-22 (3D)	0.020/ 0.050	-0.023	-0.026	-0.025	0.284	20 / 20
LCP-28 (3D)	0.020/ 0.050	-0.019	-0.013	-0.002	0.244	20 / 20
LCP-29 (3D)	0.020/ 0.050	0.006	-0.021	-0.032	0.180	20 / 20
LCP-30 (3D)	0.020/ 0.050	0.003	-0.008	-0.018	0.288	20 / 20
GCP-05 (3D)	0.020/ 0.050	-0.008	0.047	0.002	0.358	20 / 20
LCP-25 (3D)	0.020/ 0.050	-0.011	0.007	-0.016	0.287	20 / 20
LCP-24 (3D)	0.020/ 0.050	0.016	0.001	0.047	0.274	20 / 20
LCP-19 (3D)	0.020/ 0.050	0.003	-0.020	-0.023	0.301	20 / 20
LCP-15 (3D)	0.020/ 0.050	-0.014	-0.013	0.025	0.308	20 / 20
LCP-20 (3D)	0.020/ 0.050	0.008	0.000	-0.024	0.320	20 / 20
GCP-10 (3D)	0.020/ 0.050	0.009	0.012	0.004	0.357	20 / 20
GCP-15 (3D)	0.020/ 0.050	0.033	-0.013	-0.028	0.314	20 / 20
LCP-10 (3D)	0.020/ 0.050	0.009	0.025	-0.001	0.299	20 / 20
LCP-05 (3D)	0.020/ 0.050	-0.041	0.017	0.077	0.278	20 / 20
LCP-13 (3D)	0.020/ 0.050	0.008	-0.012	0.070	0.303	20 / 20
LCP-12 (3D)	0.020/ 0.050	0.001	-0.003	0.006	0.289	20 / 20
LCP-18 (3D)	0.020/ 0.050	-0.003	-0.006	0.016	0.339	20 / 20
LCP-17 (3D)	0.020/ 0.050	-0.003	-0.019	-0.035	0.276	20 / 20
LCP-32 (3D)	0.020/ 0.050	0.021	0.000	0.016	0.280	20 / 20
LCP-26 (3D)	0.020/ 0.050	-0.017	0.009	0.039	0.246	20 / 20
LCP-21 (3D)	0.020/ 0.050	0.017	-0.002	0.002	0.309	20 / 20
LCP-16 (3D)	0.020/ 0.050	-0.023	0.018	-0.006	0.345	20 / 20
LCP-11 (3D)	0.020/ 0.050	0.007	0.021	0.043	0.204	20 / 20
LCP-08 (3D)	0.020/ 0.050	0.017	0.003	0.025	0.317	20 / 20
LCP-01 (3D)	0.020/ 0.050	-0.028	0.026	-0.042	0.280	20 / 20
LCP-06 (3D)	0.020/ 0.050	0.003	0.024	-0.032	0.422	20 / 20
GCP-13 (3D)	0.020/ 0.050	0.016	0.006	-0.016	0.346	20 / 20
LCP-07 (3D)	0.020/ 0.050	-0.004	-0.005	-0.024	0.268	20 / 20
LCP-02 (3D)	0.020/ 0.050	-0.008	0.000	-0.043	0.274	20 / 20
LCP-03 (3D)	0.020/ 0.050	-0.010	-0.006	-0.006	0.271	20 / 20
GCP-17 (3D)	0.020/ 0.050	0.010	0.008	-0.020	0.288	20 / 20
LCP-04 (3D)	0.020/ 0.050	0.010	-0.012	-0.002	0.305	20 / 20
LCP-09 (3D)	0.020/ 0.050	-0.010	-0.012	-0.019	0.292	20 / 20
GCP-12 (3D)	0.020/ 0.050	0.004	-0.001	-0.009	0.204	20 / 20
LCP-14 (3D)	0.020/ 0.050	-0.001	-0.022	-0.033	0.272	20 / 20
GCP-14 (3D)	0.020/ 0.050	0.023	0.003	-0.015	0.286	20 / 20
LCP-23 (3D)	0.020/ 0.050	0.004	-0.011	-0.002	0.294	20 / 20
GCP-16 (3D)	0.020/ 0.020	0.003	-0.008	0.018	0.191	20 / 20
Mean [m]		0.000007	-0.000044	-0.001868		
Sigma [m]		0.014826	0.015214	0.028236		
RMS Error [m]		0.014826	0.015214	0.028298		

Evaluation Result: **(ตรวจสอบอีกครั้งหลังจากแทนค่าพารามิเตอร์ได้ถูกต้อง)**

	Error X	Error Y (m)	Error Z (m)	Projection Error
Criterion	0.035 m	0.035 m	0.065 m	0.5 pixel
Full GCPs	?	?	?	?