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Overview of KOMPSAT-3 Geometric Calibration & Accuracy

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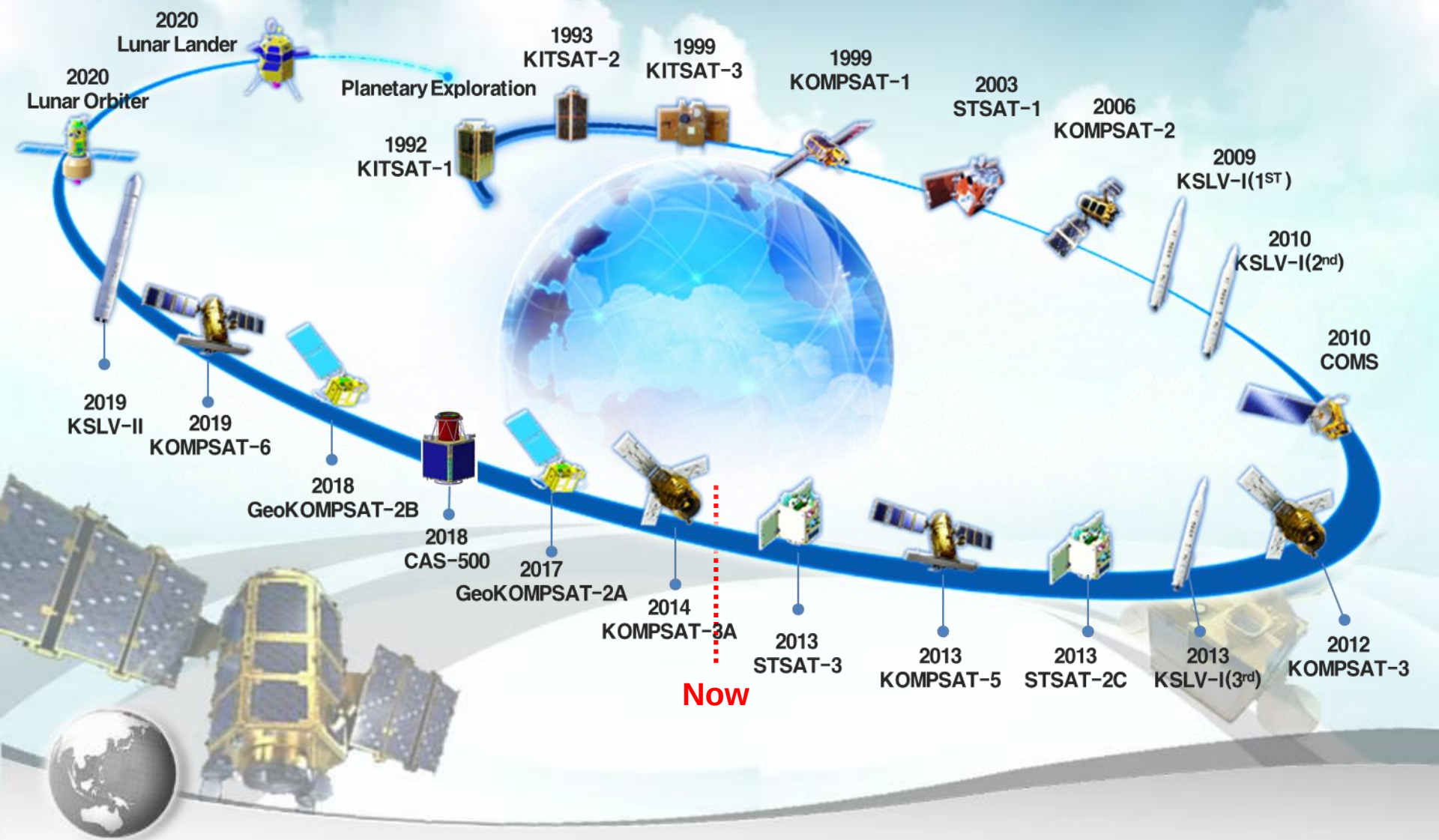
Agenda

- **KARI Space Program**
- **KOMPSAT-3 Characteristics & Geometric Cal/Val Framework**
- **Location Accuracy**
  - KOMPSAT-3 Sensor Model
  - KOMPSAT-3 Direct Geo-Referencing Model
  - Rational Function Model
- **Geometric Quality Assessment**
  - Length Distortion
  - Planimetric Accuracy
  - Ortho-image Accuracy
- **Conclusion**

Space Program of Korea



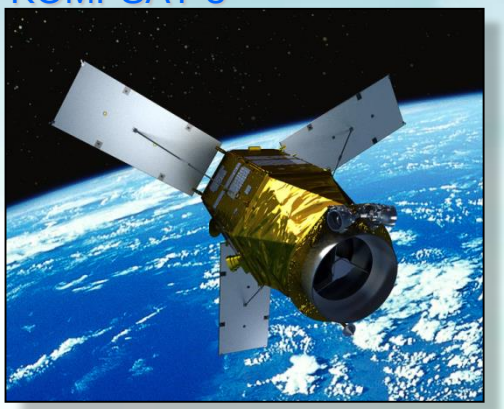
KARI Proprietary

Earth Observation Satellite

KOMPSAT-2

- Multi-Spectral Camera
- Resolution (PAN/MS : 1/4m)
- Launch : July 2006

KOMPSAT-3

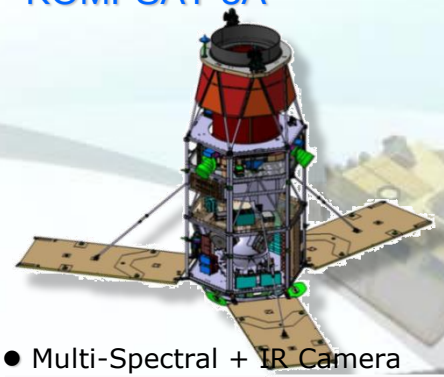


- Multi-Spectral Camera
- Resolution (PAN/MS : 0.7/2.8m)
- Launch : May 2012

KOMPSAT-5

- SAR (Synthetic Aperture Radar)
- Resolution : 1/3/20m
- Launch : Aug. 22, 2013

KOMPSAT-3A



- Multi-Spectral + IR Camera
- Resolution (PAN/MS/IR : 0.55/2.2/5.5m)
- Launch : 2014 (Planned)

KOMPSAT-3 Characteristics

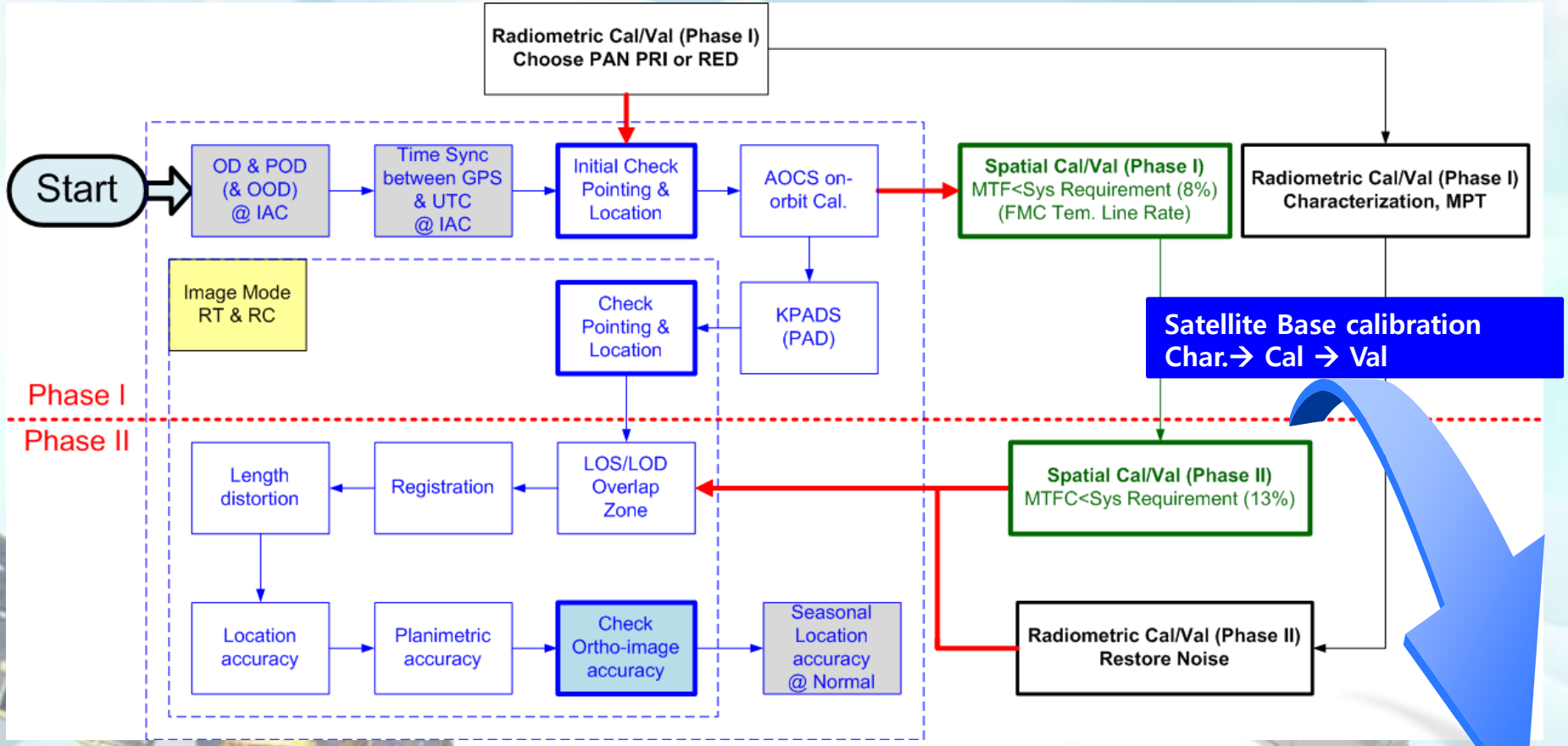
Ground Sampling Distance	PAN : **0.7 m** @altitude 685km(nadir) MS : 2.8 m @altitude 685km(nadir)	
Swath Width	16 km (nadir)	
Spectral Bands	PAN	: 450 ~ 900 nm
	MS1 (Blue)	: 450 ~ 520 nm
	MS2 (Green)	: 520 ~ 600 nm
	MS3 (Red)	: 630 ~ 690 nm
	MS4 (NIR)	: 760 ~ 900 nm
Dynamic Range	**14 bits / pixel**	
Modulation Transfer Function	PAN : 8%	MS : 12%
Signal to Noise	> 100	
Location Accuracy	< 70 m CE90 **(< 30 m RMSE is expected)**	
Orbit	Sun Synchronous Orbit • Altitude : 685.13 ± 1km • Inclination : 98.14 ± 0.05 degree • **MLTAN : 13:30** +10/-15 min	

KARI Proprietary

KOMPSAT-3 (2014.03.20) Louisville KY USA

KOMPSAT-3
Dubai, UAE

Geometric Cal/Val Framework of KOMPSAT-3



* Blue box: Geometric Cal/Val, Black box: Radiometric Cal/Val, Green box: Spatial Cal/Val

Image Base calibration
Calibration → Validation

KOMPSAT-3 Geometric Sensor Model & Geometric Cal/Val

- **KOMPSAT-3 Direct Geo-Referencing Model & Geometric Cal/Val**
  - Backward model

$$\begin{bmatrix} X - X_s \\ Y - Y_s \\ Z - Z_s \end{bmatrix}_{ECEF} = \frac{1}{\lambda} \cdot M_{ECI}^{ECEF} \cdot M_{Sensor}^{ECI} \begin{bmatrix} -y \\ -x \\ f \end{bmatrix}_{Sensor}$$

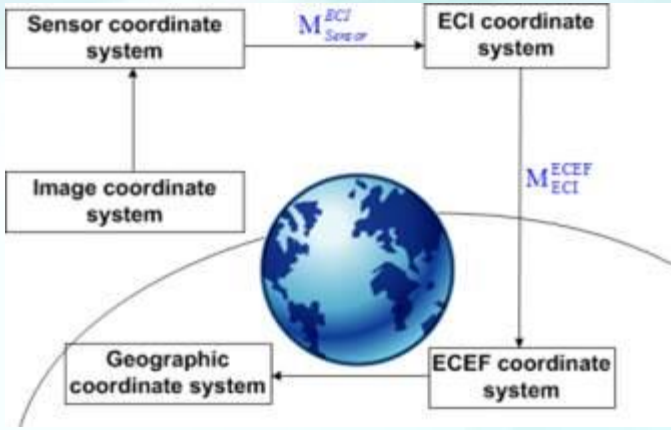
Cal/Val Phase I

Exterior Orientation
- Satellite Position
- Satellite Attitude

Time Sync
- Satellite Position
- Satellite Attitude
- Image Line Time

Cal/Val Phase II

Interior Orientation
- Focal Length
- CCD Alignment
- CCD Distortion



  - Foreword Model

$$\begin{bmatrix} -y \\ -x \\ f \end{bmatrix}_{Sensor} = \frac{1}{\lambda} \cdot M_{ECI}^{Sensor} \cdot M_{ECEF}^{ECI} \cdot \begin{bmatrix} X - X_s \\ Y - Y_s \\ Z - Z_s \end{bmatrix}_{ECEF}$$

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KOMPSAT-3 Geometric Sensor Model

- Sensor model is relationship between object coordinate system to image coordinate system.

- KOMPSAT-3 sensor model
  - Direct Geo-Referencing Model
    - It is based on collinearity condition.
    - It uses satellite ancillary data.
  - Rational function Model
    - It is a generalized sensor model.
    - It uses a pair of rations of two polynomials.

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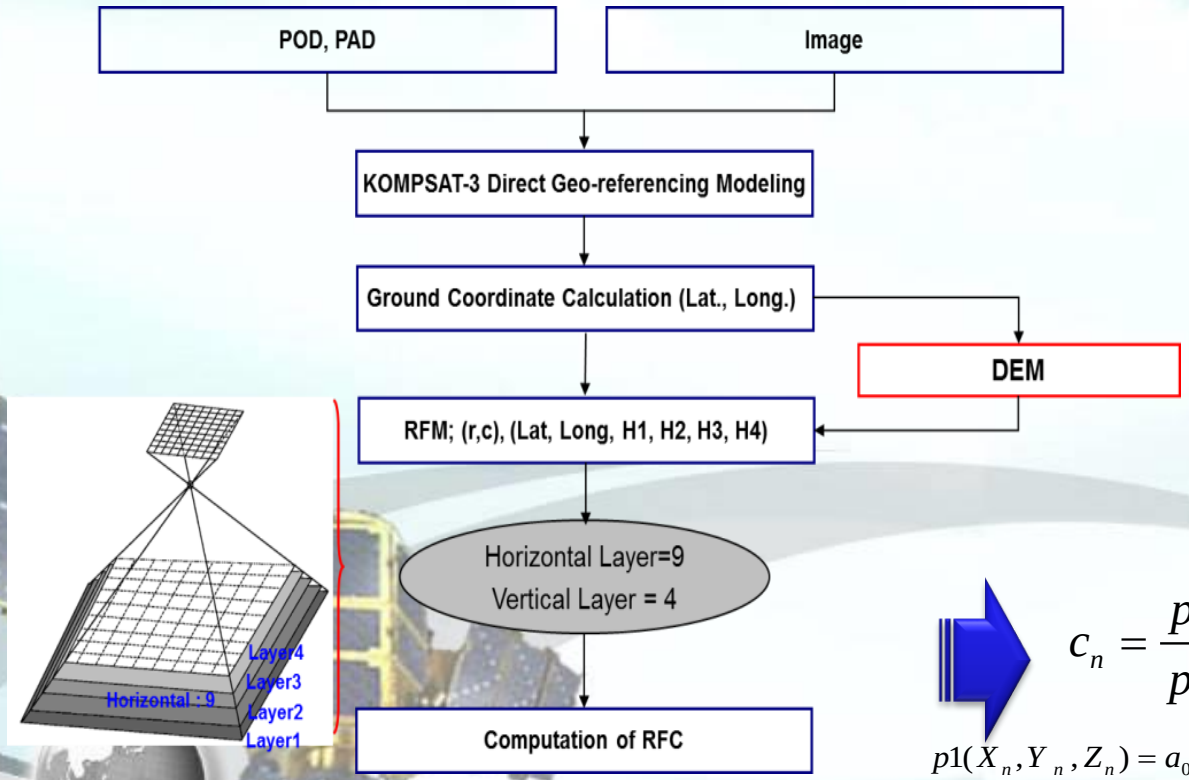
KOMPSAT-3 Geometric Sensor Model

- **Rational Function Model**
  - RPC is generated from the result of KOMPSAT-3 direct geo-referencing model.



$$c_n = \frac{p3(X_n, Y_n, Z_n)}{p4(X_n, Y_n, Z_n)} \qquad r_n = \frac{p1(X_n, Y_n, Z_n)}{p2(X_n, Y_n, Z_n)}$$

$$p1(X_n, Y_n, Z_n) = a_0 + a_1 X + a_2 Y + a_3 Z + a_4 X^2 + a_5 XY + a_6 XZ + a_7 Y^2 + a_8 YZ + a_9 Z^2 + a_{10} X^3 + a_{11} X^2 Y + a_{12} X^2 Z + a_{13} XY^2 + a_{14} XYZ + a_{15} XZ^2 + a_{16} Y^3 + a_{17} Y^2 Z + a_{18} YZ^2 + a_{19} Z^3$$

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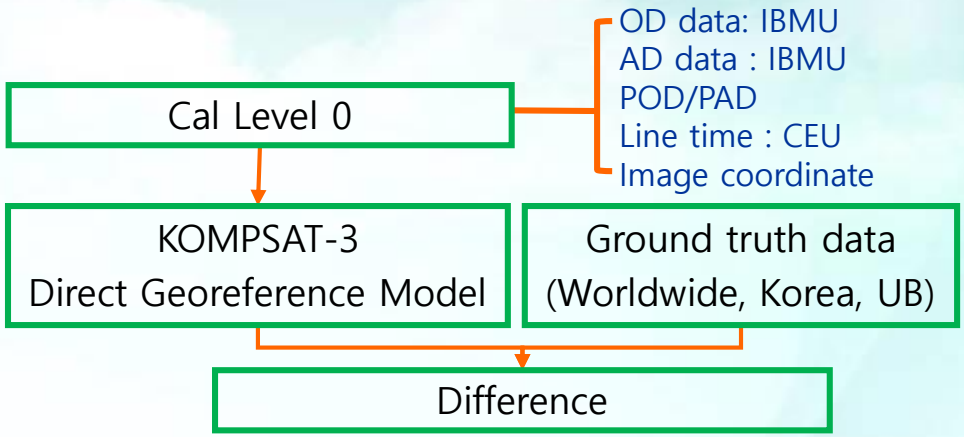
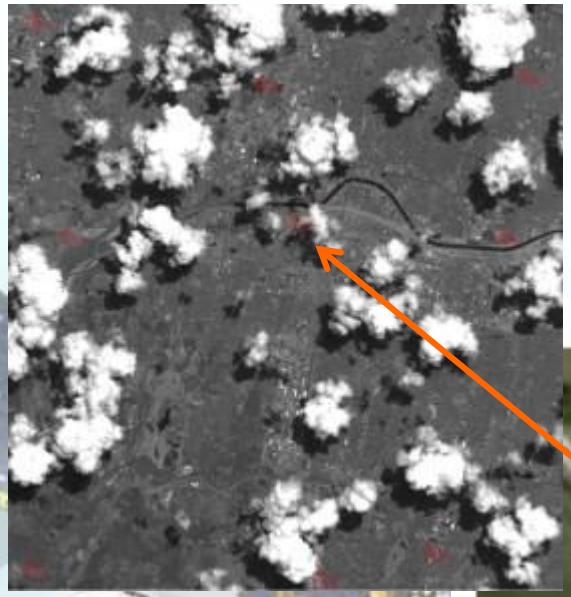
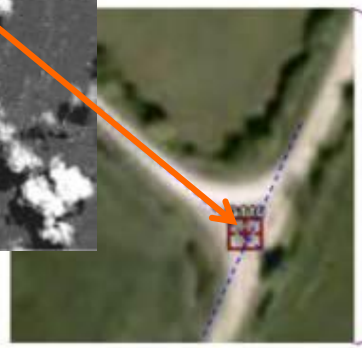
Quality Assessment

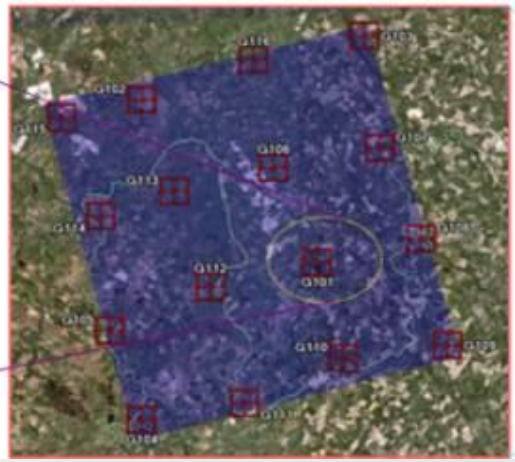
-Location Accuracy-

- **Definition**
  - Distance difference between K3 Direct Geo-Referencing Model with ancillary data and Ground truth data (GCPs)









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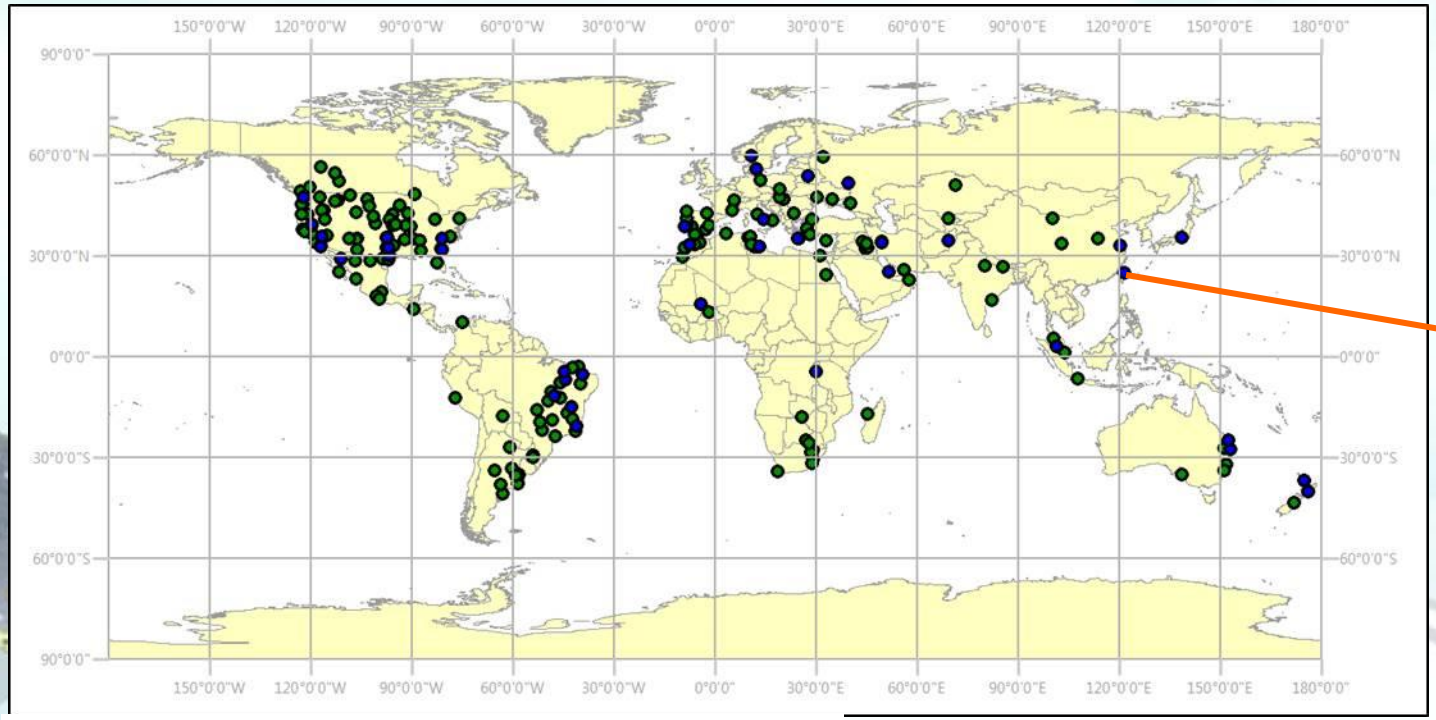
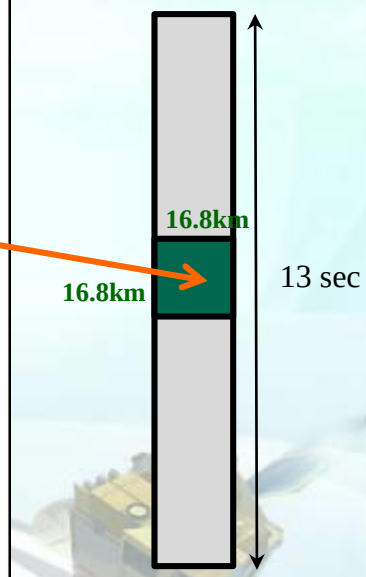
Quality Assessment

-Location Accuracy (LEOP, 2012 year)-

- **Location Accuracy in LEOP**
  - Tested image data (Cloud >C) : 2012.07.12 ~ 2012.07.30 (239 scenes)
  - Latitude range : -43.5°~ 59.8°





<Data set> 2012.08.03: 199 data, 2012.08.08: 239 data

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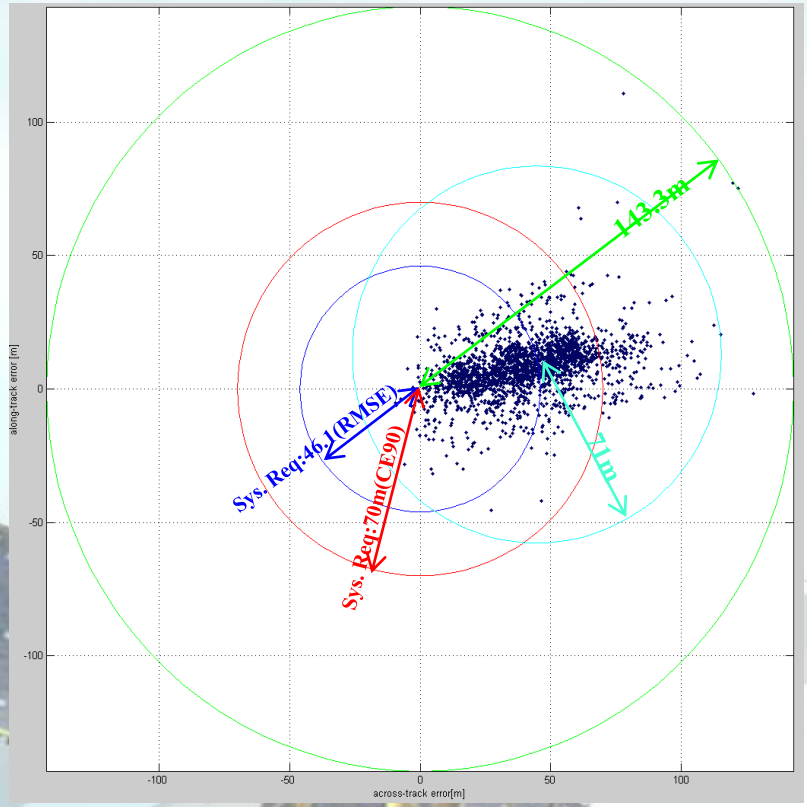
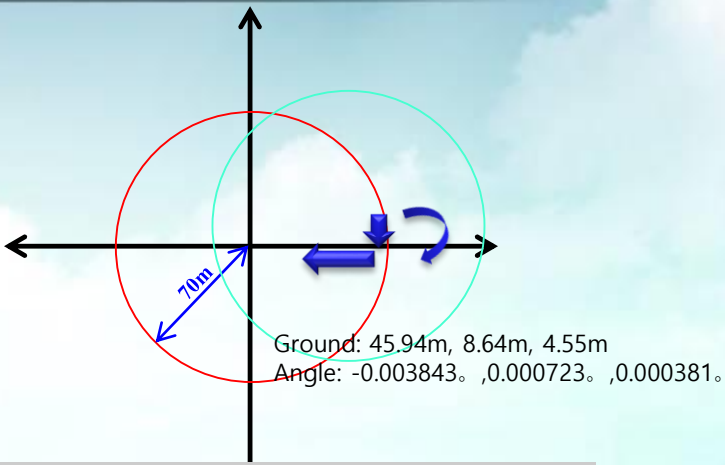
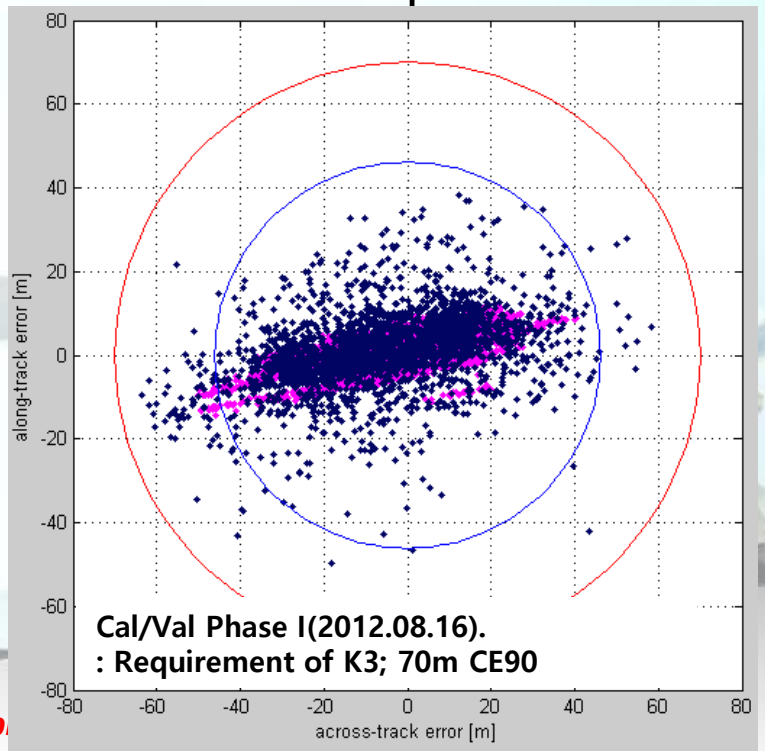
Quality Assessment

-Location Accuracy (LEOP, 2012 year)-

- **Sensor Alignment**

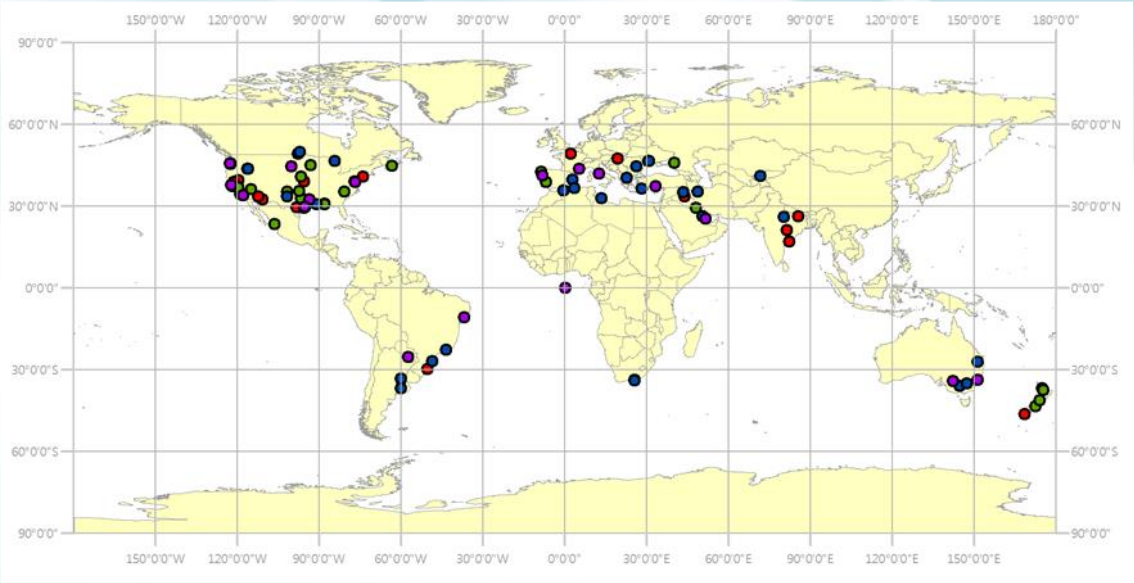




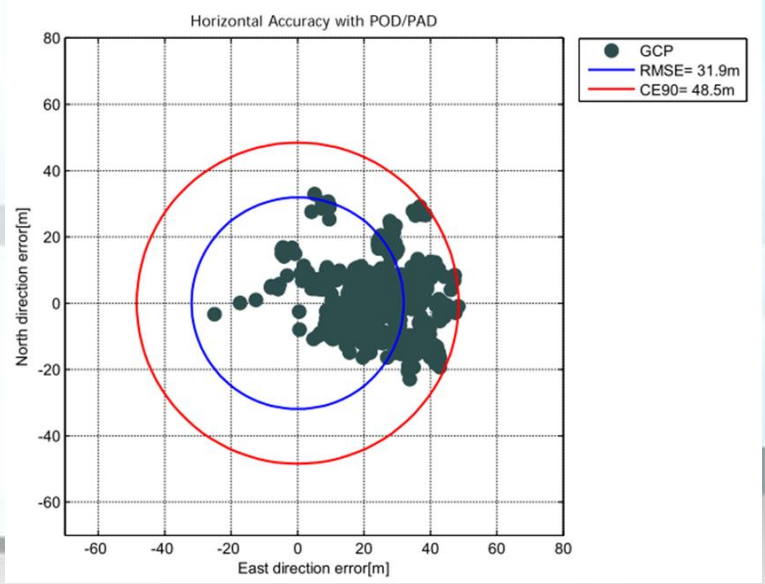


Quality Assessment

-Location Accuracy (2013 year)-



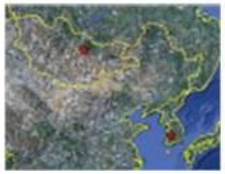
2013.04 2013.05 2013.06 2013.07



Quality Assessment

-Geometric Accuracy-

- **Test Site**
  - KOMPSAT-3 Precision Geometric Calibration Site
  - Kimjae, Ulaanbaatar (Korea, Mongolia)



	Geo ID	Date	Roll	Pitch	Yaw
1	Geo_02644	2012-08-02	7.9	0.5	2.5
2	Geo_02953	2012-08-07	3.2	0.3	2.6
3	Geo_03594	2012-08-22	-11.2	-0.3	2.4
4	Geo_03776	2012-08-27	-15.8	-0.5	2.3
5	Geo_03918	2012-08-30	10.3	0.6	2.5
6	Geo_04201	2012-09-04	5.4	0.4	2.5
7	Geo_04304	2012-09-06	-24.3	-0.8	2.1
8	Geo_04702	2012-09-14	-4.7	0.0	2.5
9	Geo_04849	2012-09-17	20.9	1.0	2.2
10	Geo_05459	2012-10-02	6.4	0.5	2.5
11	Geo_05505	2012-10-04	-23.2	-0.8	2.1
12	Geo_05530	2012-10-05	29.4	1.2	1.8
13	Geo_05577	2012-10-07	1.2	0.2	2.6
14	Geo_05682	2012-10-10	25.4	1.1	2.0
15	Geo_06137	2012-10-22	-14.0	-0.4	2.4
16	Geo_06363	2012-10-27	-18.7	-0.6	2.3
17	Geo_06500	2012-10-30	6.2	0.4	2.5
18	GKJ_02700	2012-08-03	16.7	1.0	2.8
19	GKJ_02829	2012-08-05	-19.8	-0.8	2.7
20	GKJ_02985	2012-08-08	11.3	0.8	3.0
21	GKJ_03721	2012-08-26	24.5	1.3	2.5
22	GKJ_03960	2012-08-31	19.4	1.1	2.7
23	GKJ_04238	2012-09-05	13.9	0.9	2.9
24	GKJ_04406	2012-09-08	38.4	1.6	1.8
25	GKJ_04511	2012-09-10	8.0	0.6	3.0
26	GKJ_04991	2012-09-20	-4.3	-0.1	3.1
27	GKJ_05119	2012-09-23	25.9	1.3	2.4
28	GKJ_05472	2012-10-03	15.0	0.9	2.9
29	GKJ_05598	2012-10-08	8.9	0.6	3.0
30	GKJ_06308	2012-10-26	20.4	1.2	2.7
31	GKJ_06402	2012-10-28	-16.2	-0.7	2.9
32	GKJ_06537	2012-10-31	14.5	0.9	2.9

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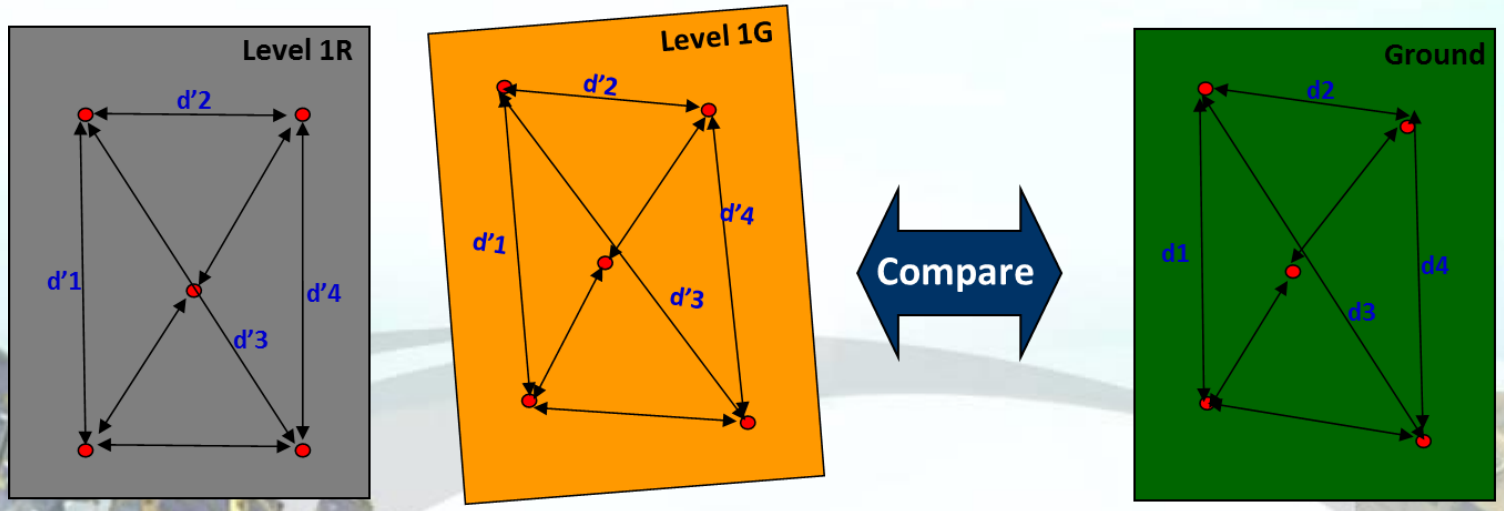
Quality Assessment

-Length Distortion-

- The ratio between the distance difference 2 points on image and the measured distance gives the length alteration.

- Distance differences between two GCPs and the two corresponding points in the image and processed for each pairs of GCPs in a given image.

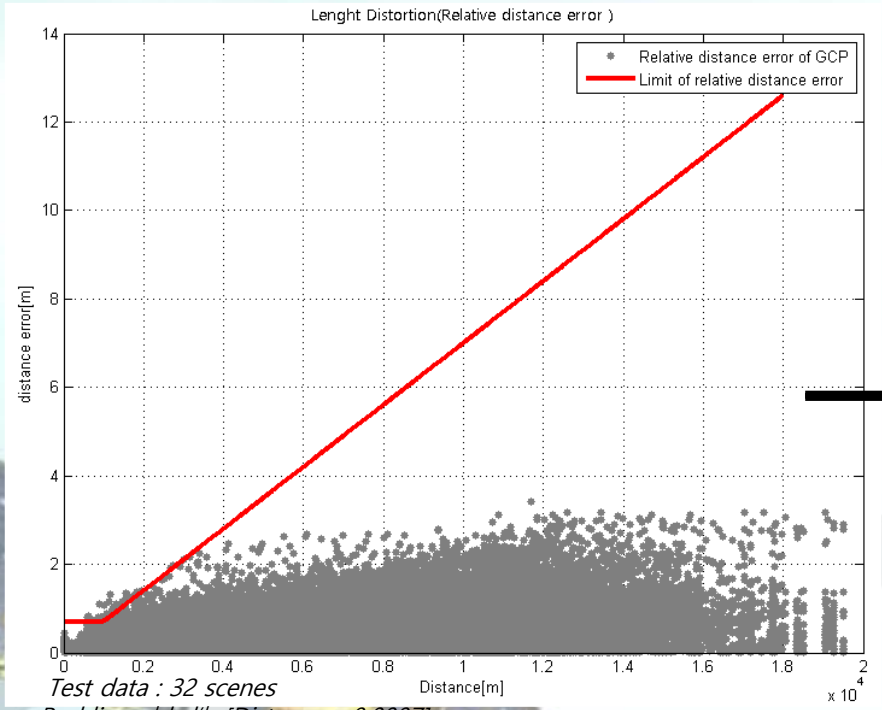


$$\text{Length distortion} = |d - d'| / d$$

Quality Assessment

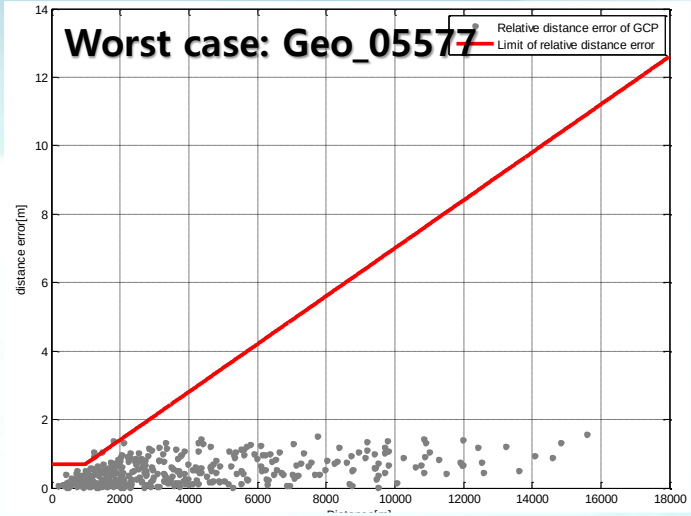
-Length Distortion Accuracy-

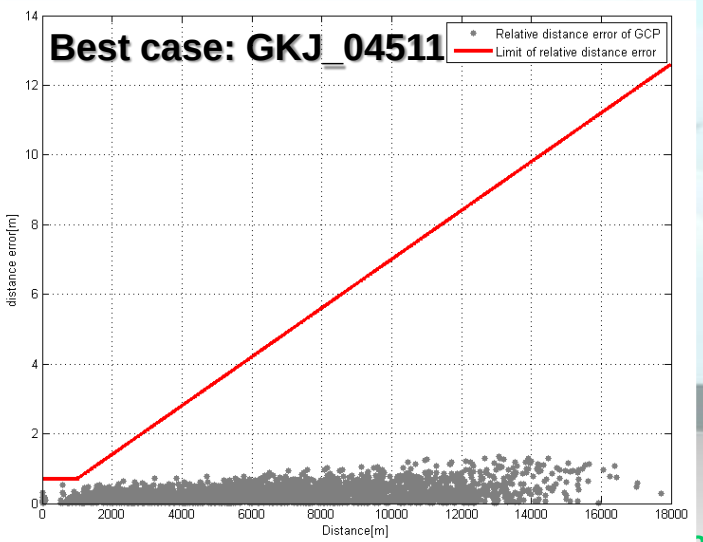
- **Relative Distance Accuracy**
  - Abs [Reference Distance – Image Distance (K3 Direct Geo-referencing model)]



Test data : 32 scenes

Red line : |d-d'|=[Distance x 0.0007]





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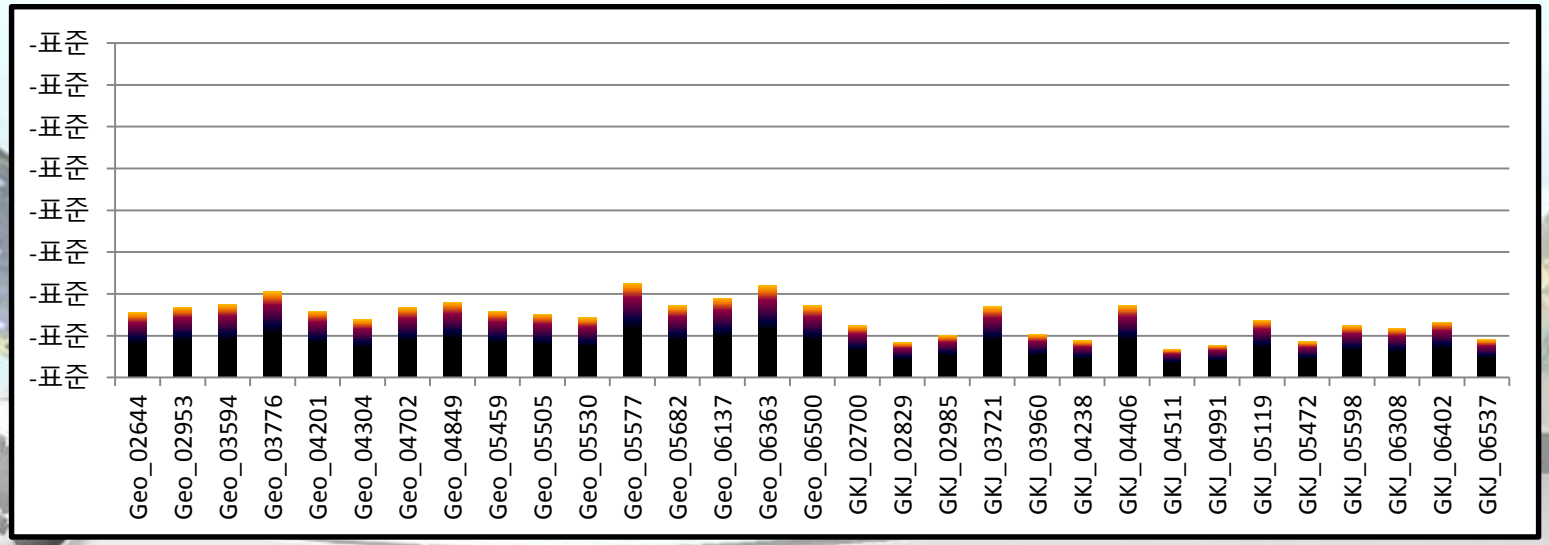
Quality Assessment
-Length Distortion Accuracy-

- **Accuracy of Length distortion**
  - RMSE : 1.44e-4, 0.144m
  - CE90 : 0.218m

Test ID	LD	Test ID	LD	Test ID	LD	Test ID	LD	Test ID	LD
Geo_02644	0.00016	Geo_04702	0.00017	Geo_05682	0.00017	GKJ_02985	0.00010	GKJ_04991	0.00008
Geo_02953	0.00017	Geo_04849	0.00018	Geo_06137	0.00019	GKJ_03721	0.00017	GKJ_05119	0.00014
Geo_03594	0.00017	Geo_05459	0.00016	Geo_06363	0.00022	GKJ_03960	0.00010	GKJ_05472	0.00009
Geo_03776	0.00021	Geo_05505	0.00015	Geo_06500	0.00017	GKJ_04238	0.00009	GKJ_05598	0.00012
Geo_04201	0.00016	Geo_05530	0.00014	GKJ_02700	0.00012	GKJ_04406	0.00017	GKJ_06308	0.00012
Geo_04304	0.00014	Geo_05577	0.00023	GKJ_02829	0.00008	GKJ_04511	0.00007	GKJ_06402	0.00013

*D>1000, Almost same height



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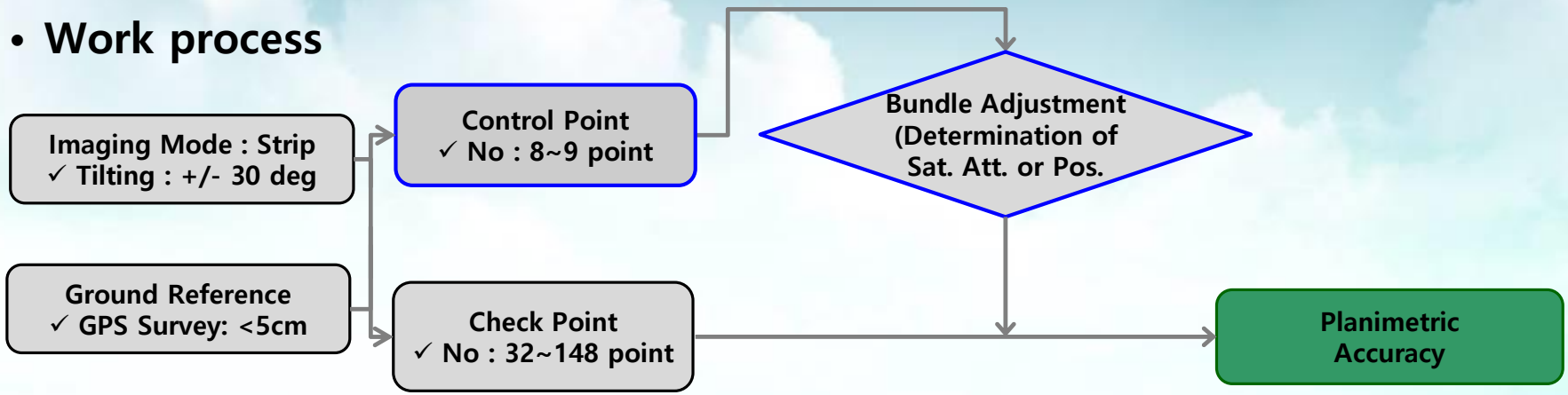
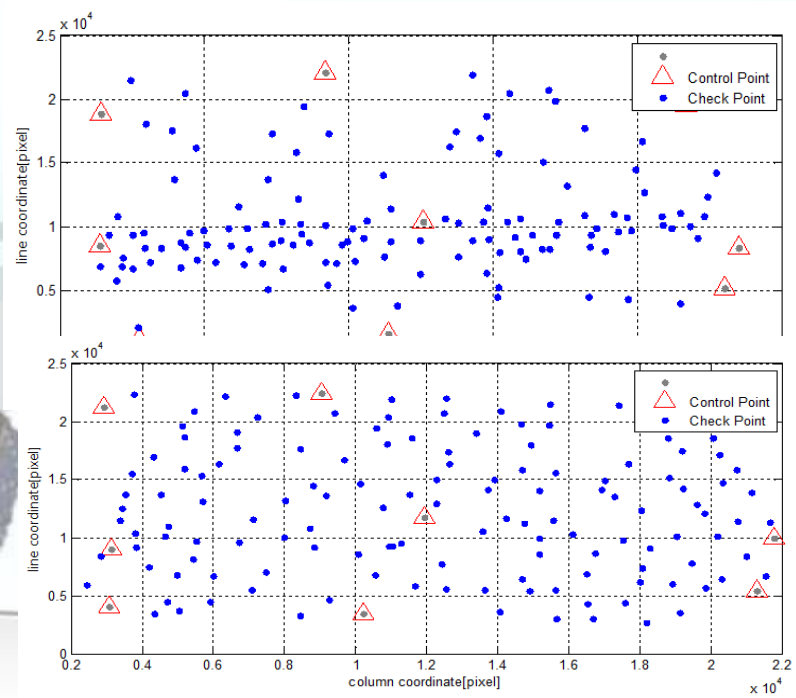
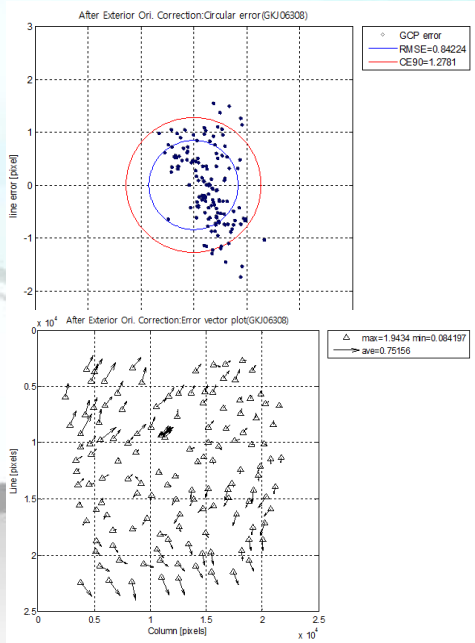
Quality Assessment

-Planimetric Accuracy-

- **Work process**



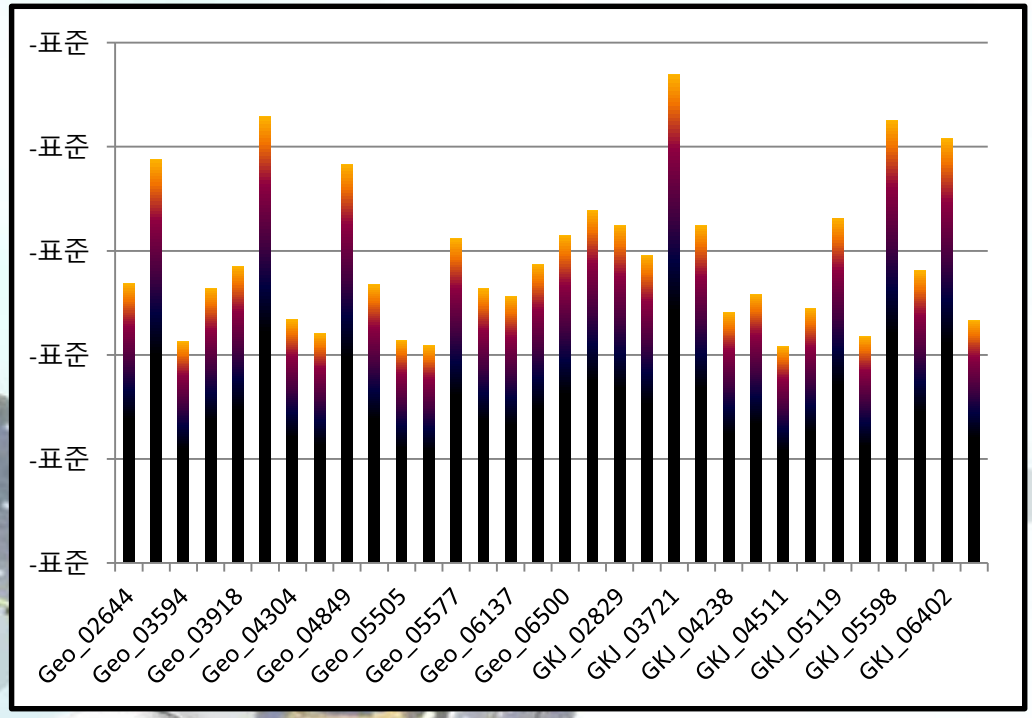




Quality Assessment

-Planimetric Accuracy-

- **Planimetric Accuracy**
  - RMSE : 0.88 pixel
  - CE90 : 1.34 pixel (0.94m)



Geo ID	Tilting Angle			Control Point		Check Point		
	Roll	Pitch	Yaw	RMS X	RMS Y	RMS X	RMS Y	RMSE
Geo_02644	7.94	0.52	2.52	0.76	0.72	0.61	0.53	0.81
Geo_02953	3.22	0.31	2.56	1.58	0.52	1.09	0.41	1.16
Geo_03594	-11.18	-0.32	2.45	0.29	0.51	0.47	0.43	0.64
Geo_03776	-15.78	-0.49	2.34	0.76	0.60	0.61	0.51	0.79
Geo_03918	10.28	0.62	2.46	0.47	1.15	0.45	0.72	0.85
*Geo_04201	5.40	0.41	2.52	1.57	1.15	0.85	0.96	1.29
Geo_04304	-24.26	-0.77	2.08	0.78	0.67	0.46	0.53	0.70
**Geo_04702	-4.68	-0.04	2.54	0.44	0.43	0.40	0.52	0.66
Geo_04849	20.86	1.00	2.16	0.41	0.85	0.66	0.94	1.15
Geo_05459	6.42	0.45	2.51	0.94	0.57	0.55	0.58	0.80
Geo_05505	-23.19	-0.75	2.15	0.64	0.55	0.50	0.41	0.64
Geo_05530	29.43	1.20	1.82	0.79	0.75	0.41	0.47	0.63
Geo_05577	1.24	0.22	2.55	0.47	1.08	0.44	0.82	0.93
Geo_05682	25.40	1.12	2.00	0.90	0.69	0.59	0.52	0.79
Geo_06137	-13.98	-0.43	2.41	0.70	0.48	0.55	0.53	0.77
Geo_06363	-18.73	-0.61	2.28	0.71	1.06	0.47	0.72	0.86
Geo_06500	6.17	0.44	2.53	1.34	0.79	0.78	0.53	0.94
GKJ_02700	16.73	1.02	2.84	0.69	0.57	0.72	0.72	1.02
GKJ_02829	-19.79	-0.82	2.71	0.75	0.51	0.75	0.62	0.97
GKJ_02985	11.33	0.76	2.99	0.66	0.79	0.65	0.60	0.89
*GKJ_03721	24.49	1.31	2.53	1.39	1.07	0.99	1.00	1.41
GKJ_03960	19.44	1.12	2.72	0.52	0.53	0.69	0.68	0.97
GKJ_04238	13.93	0.88	2.90	0.36	0.63	0.49	0.53	0.72
GKJ_04406	38.43	1.55	1.75	0.47	0.74	0.43	0.64	0.77
GKJ_04511	7.99	0.59	3.03	0.61	0.41	0.52	0.34	0.63
**GKJ_04991	-4.30	-0.07	3.09	0.36	0.49	0.33	0.66	0.73
GKJ_05119	25.88	1.33	2.42	0.38	0.69	0.65	0.76	0.99
GKJ_05472	14.97	0.93	2.86	0.52	0.68	0.45	0.48	0.65
GKJ_05598	8.87	0.63	3.01	0.58	1.01	0.92	0.88	1.28
GKJ_06308	20.40	1.16	2.68	0.46	0.70	0.46	0.70	0.84
GKJ_06402	-16.18	-0.67	2.87	0.57	1.28	0.45	1.14	1.23
GKJ_06537	14.51	0.91	2.89	0.53	0.73	0.42	0.56	0.70
					RMSE	0.59	0.64	0.88
					CE90 (PAN pixel)	1.34		
					CE90 (m)	0.94		

*Geo_04201/GKJ_03721 : Ortho-image 생성
**Geo_04702/GKJ_04991 : Ortho-image 생성

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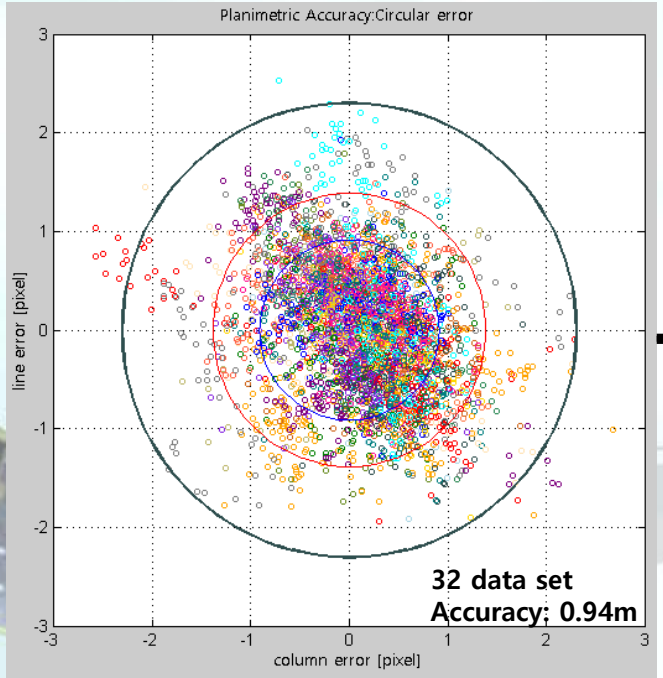
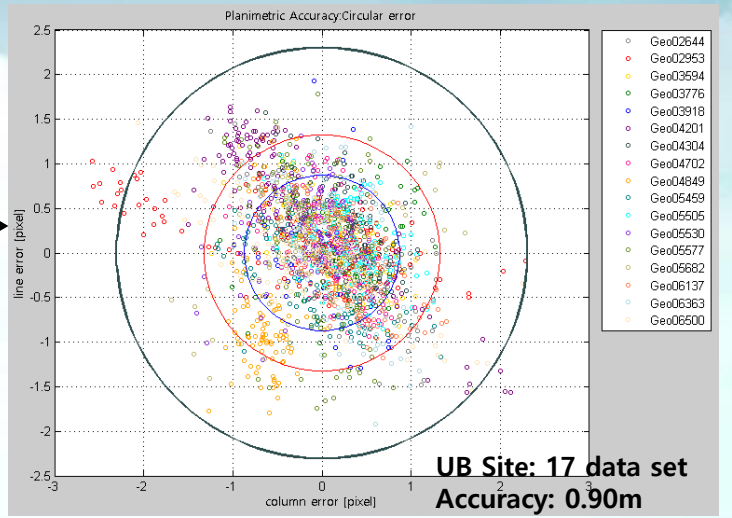
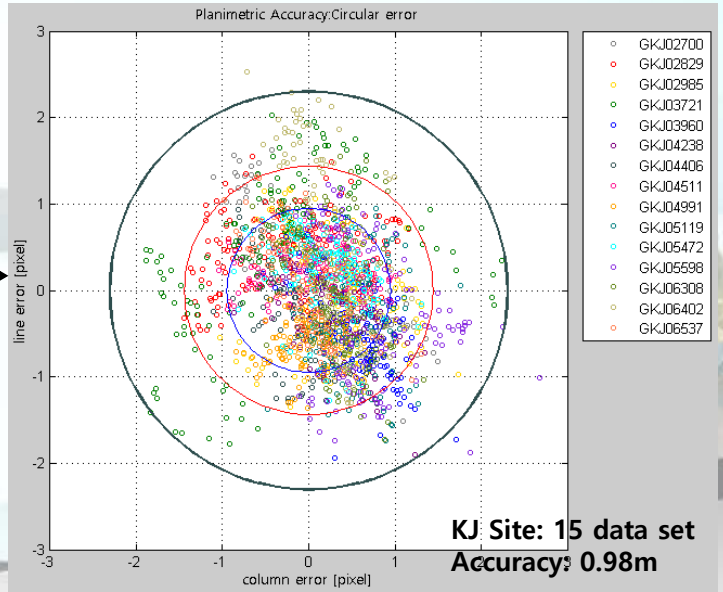
Quality Assessment

-Planimetric Accuracy-

- **Circular error of Planimetric Accuracy**







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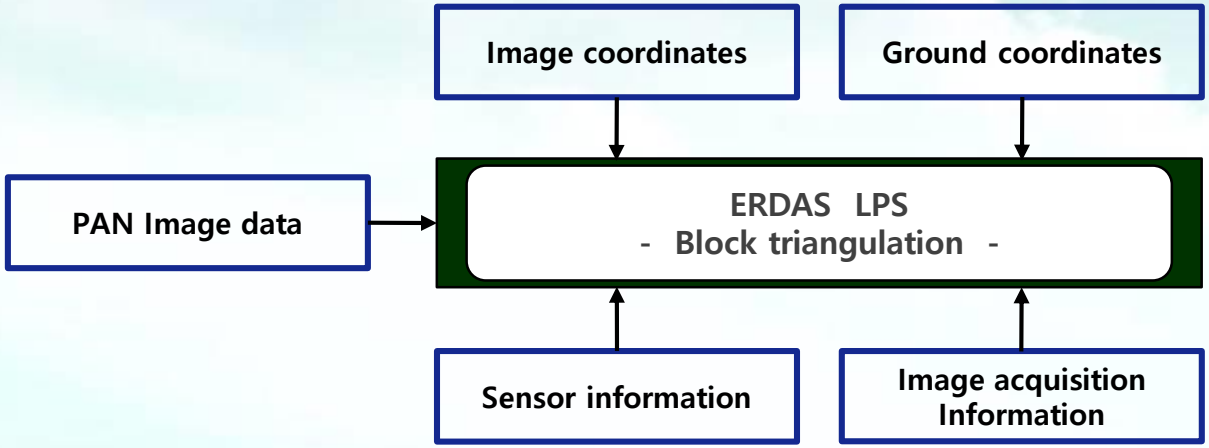
Quality Assessment

-Ortho-image Accuracy-

- **Ortho-image Generation**



* Processing software : ERDAS 9.2 LPS

Geo ID	Tilting Angle			Control Point		Check Point		
	Roll	Pitch	Yaw	RMS X	RMS Y	RMS X	RMS Y	RMSE
Geo_02644	7.94	0.52	2.52	0.76	0.72	0.61	0.53	0.81
Geo_02953	3.22	0.31	2.56	1.58	0.52	1.09	0.41	1.16
Geo_03594	-11.18	-0.32	2.45	0.29	0.51	0.47	0.43	0.64
Geo_03776	-15.78	-0.49	2.34	0.76	0.60	0.61	0.51	0.79
Geo_03918	10.28	0.62	2.46	0.47	1.15	0.45	0.72	0.85
*Geo_04201	5.40	0.41	2.52	1.57	1.15	0.85	0.96	1.29
Geo_04304	-24.26	-0.77	2.08	0.78	0.67	0.46	0.53	0.70
**Geo_04702	-4.68	-0.04	2.54	0.44	0.43	0.40	0.52	0.66
Geo_04849	20.86	1.00	2.16	0.41	0.85	0.66	0.94	1.15
Geo_05459	6.42	0.45	2.51	0.94	0.57	0.55	0.58	0.80
Geo_05505	-23.19	-0.75	2.15	0.64	0.55	0.50	0.41	0.64
Geo_05530	29.43	1.20	1.82	0.79	0.75	0.41	0.47	0.63
Geo_05577	1.24	0.22	2.55	0.47	1.08	0.44	0.82	0.93
Geo_05682	25.40	1.12	2.00	0.90	0.69	0.59	0.52	0.79
Geo_06137	-13.98	-0.43	2.41	0.70	0.48	0.55	0.53	0.77
Geo_06363	-18.73	-0.61	2.28	0.71	1.06	0.47	0.72	0.86
Geo_06500	6.17	0.44	2.53	1.34	0.79	0.78	0.53	0.94
GKJ_02700	16.73	1.02	2.84	0.69	0.57	0.72	0.72	1.02
GKJ_02829	-19.79	-0.82	2.71	0.75	0.51	0.75	0.62	0.97
GKJ_02985	11.33	0.76	2.99	0.66	0.79	0.65	0.60	0.89
*GKJ_03721	24.49	1.31	2.53	1.39	1.07	0.99	1.00	1.41
GKJ_03960	19.44	1.12	2.72	0.52	0.53	0.69	0.68	0.97
GKJ_04238	13.93	0.88	2.90	0.36	0.63	0.49	0.53	0.72
GKJ_04406	38.43	1.55	1.75	0.47	0.74	0.43	0.64	0.77
GKJ_04511	7.99	0.59	3.03	0.61	0.41	0.52	0.34	0.63
**GKJ_04991	-4.30	-0.07	3.09	0.36	0.49	0.33	0.66	0.73
GKJ_05119	25.88	1.33	2.42	0.38	0.69	0.65	0.76	0.99
GKJ_05472	14.97	0.93	2.86	0.52	0.68	0.45	0.48	0.65
GKJ_05598	8.87	0.63	3.01	0.58	1.01	0.92	0.88	1.28
GKJ_06308	20.40	1.16	2.68	0.46	0.70	0.46	0.70	0.84
GKJ_06402	-16.18	-0.67	2.87	0.57	1.28	0.45	1.14	1.23
GKJ_06537	14.51	0.91	2.89	0.53	0.73	0.42	0.56	0.70
					RMSE	0.59	0.64	0.88
					CE90 (PAN pixel)		1.34	
					CE90 (m)		0.94	

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Quality Assessment

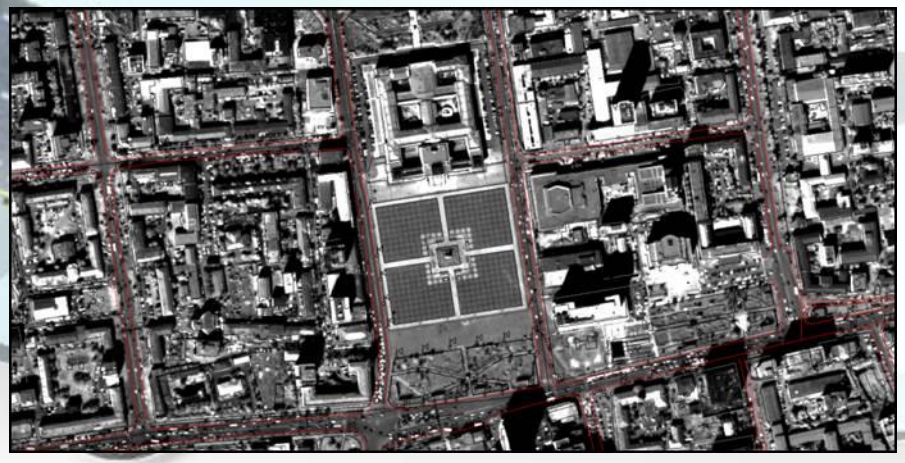
-Ortho-image Accuracy-

- **Overlay : 1:5,000 digital map + generated ortho-image map**

Geo_04201
- ✓ Planimetric accuracy
- ✓ 1.29 pixel/0.90m

Road Area

Downtown Area



Mountain Area

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Conclusion

- **Location Accuracy (<70m, CE90, Sys Req.)**
  - Test data : 649 seta, Worldwide Area (2012 years : 428 Level 1R image data, 2013 : 221 Level 1R image data)
  - Accuracy : 31.9 m RMSE
- **Length Distortion**
  - Test data : 31 set, KOMPSAT-3 Precision Geometric Cal/Val site (Kimjae, UB)
  - RMSE : 1.44e-4, 0.218m CE 90
- **Planimetric Accuracy**
  - Test data : 31 set, KOMPSAT-3 Precision Geometric Cal/Val site (Kimjae, UB)
  - Accuracy : 1.34 pixel (0.94m) CE90
- **Ortho-image (1:5,000, 3.5m CE90, Sys Req.)**
  - Test data : 31 set, KOMPSAT-3 Precision Geometric Cal/Val site (Kimjae, UB)
  - meet the geometric specification of 3.5m corresponding to 1:5,000 digital ortho-image

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