

## The Development of Accuracy Maintenance Method for Mobile Mapping System (MMS) Data at GPS Invisible Area

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& Koichi Tsukahara

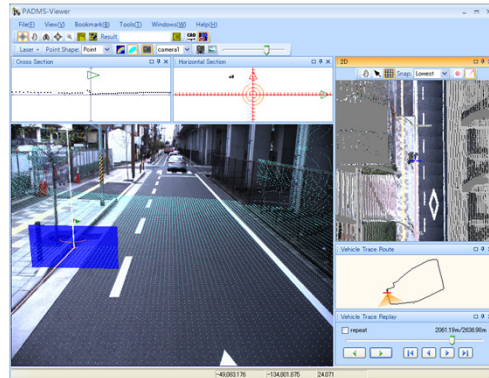
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## Mobile Mapping System



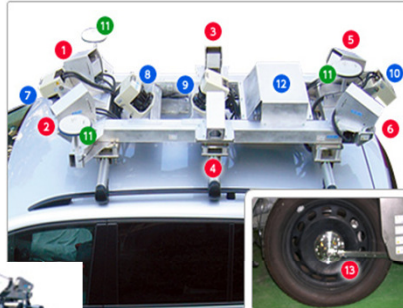
MMS (TYPE-S)

- High accurate 3D measurements
- Very dense imagery & laser points
- Easy & Safety operation



## MMS Sensor-unit installed on Vehicle

MMS (Type-X)



- 1 Camera(front; right)
- 2 Camera(front; left)
- 3 Camera(side; right)
- 4 Camera(side; left)
- 5 Camera(rear; right)
- 6 Camera(rear; left)
- 7 Laser scanner(front; downward)
- 8 Laser scanner(rear; upward)
- 9 Laser scanner(front; upward)
- 10 Laser scanner(rear; downward)
- 11 GPS antenna
- 12 IMU
- 13 Odometer



In-vehicle equipment



Operation screen



- Computer screen composition of operation
- ① Main screen
  - ② Error monitor
  - ③ GPS signal status

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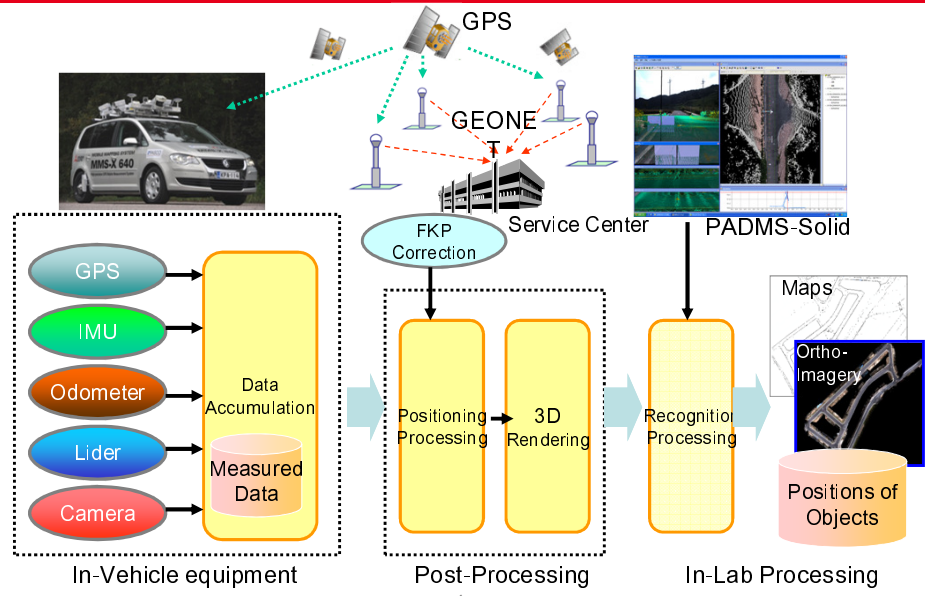
## MMS Specifications

Spec Item		MMS - X	MMS - S
Laser Scanner	Pulse Rate	13,500 points per second	
	Range	80 m	
	Scanning	75 per second	
	Sweep angle	180 degrees	
Camera	Pixel	5 Megapixels(2400x2000)	2 Megapixels(1600x1200)
	Shot interval	Up to 10 shots per second	Up to 11 shots per second
System	Laser Scanner	0,2,4 (selective)	0,2 (selective)
	Camera	0,2,4,6 (selective)	0,2 (selective)
	Vehicle	Volkswagen Golf Touran	TOYOTA Alphard Hybrid
Accuracy	Planimetric	Within 10 cm rms (absolute) Within 1 cm rms (relative)	
	Vertical	Within 15 cm rms (absolute)	
Data	Data capacity	Up to 8 hours	
	Imagery data	Up to 90,000 shots/camera	

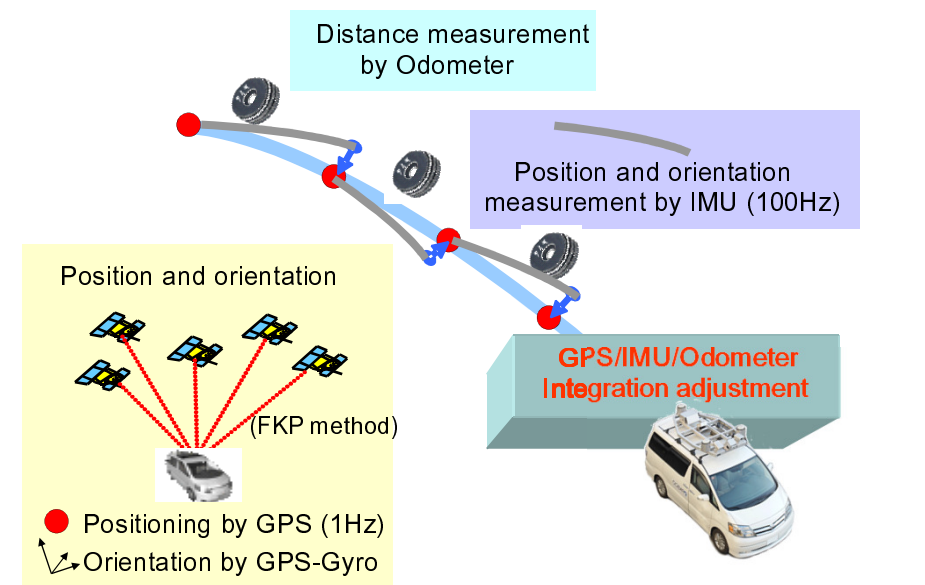
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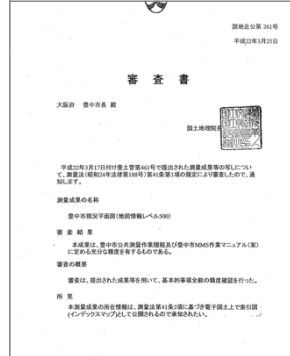
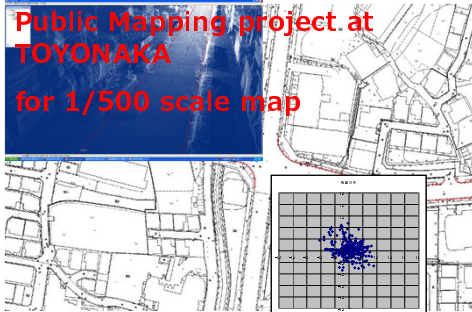
# MMS Data Processing Flow



# Positioning Processing



# Performance of MMS surveying

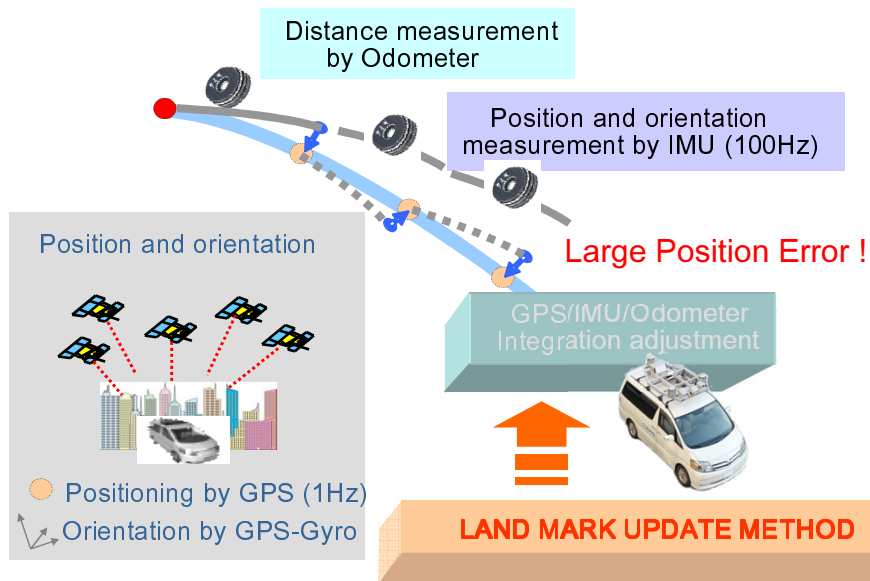


Certification of the authorized public survey result issued by GSI

By using MMS,

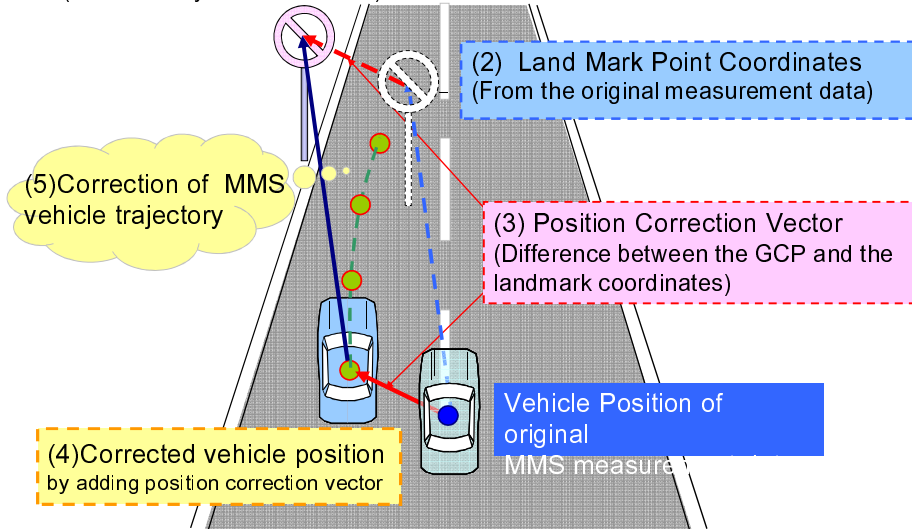
- Reduce cost and time of surveying tasks drastically
- Reduce risks of accident and/or trouble during field works

# Problems at Satellite Invisible Areas



## Land Mark Update Method

(1) 3D Coordinates of GCP  
(Observed by GPS and/or TS)



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## Outlines of Researches

### ■ Accuracy Investigation with LMU Method

Objective :

to make clarify the characteristics and accuracy of LMU Method, by

- ① Estimation of the accuracy by EPE
- ② Accuracy Investigation at Check Points

### ■ Optimal Assignment of Land Marks

to develop optimal assignment method of land marks to maintain the required accuracy for mapping scale of 1/500

### ■ Accuracy Investigation of Mapping Data

to check the accuracy of mapping results adjusted by LMU method

Estimated Posterior Error (EPE) :

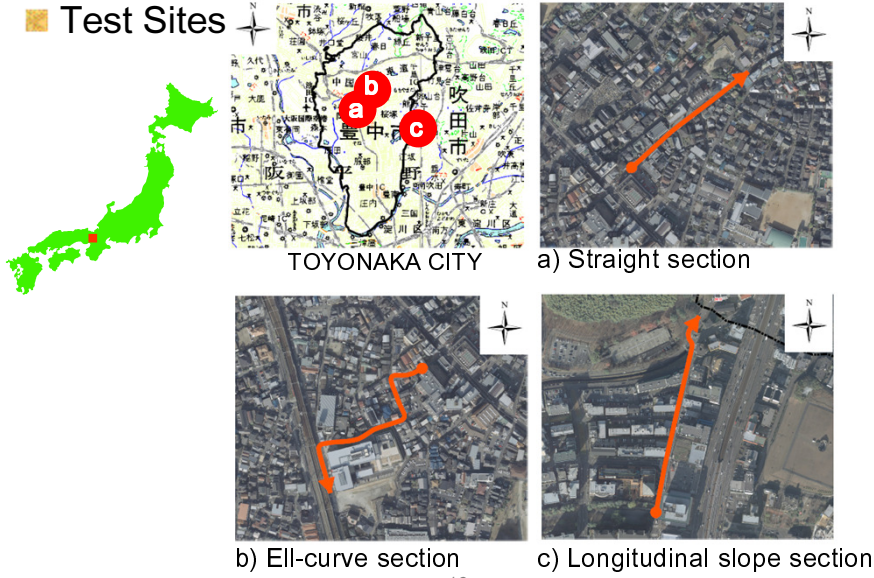
Estimated error of position coordinates calculated in the positioning processing by using kalman filter with GPS data, IMU data and odometer data.

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# Accuracy Investigation with LMU Method

## Test Sites



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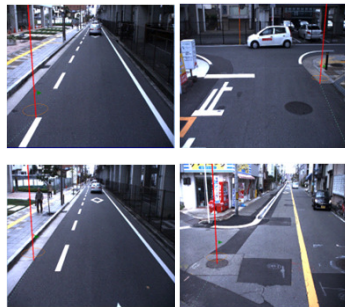
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# Accuracy Investigation with LMU Method

## Land Marks and Check Points

selected to identify clearly in the imagery captured by MMS;

- ✓ Corners of parcel lines
- ✓ Manholes
- ✓ Corners or edges of gutters



## Outline of Field measurement (Average vehicle speed :40km/h)

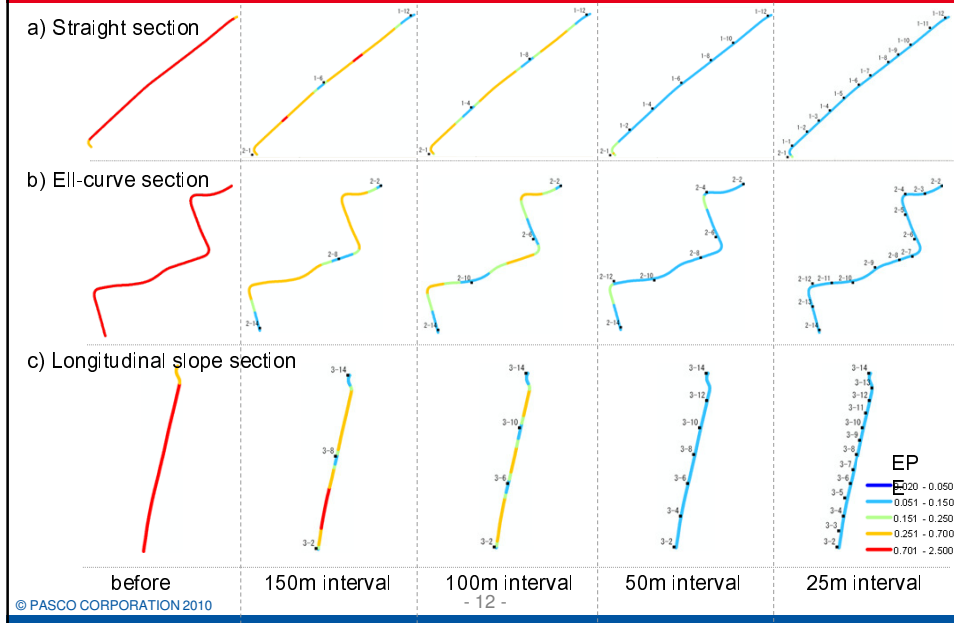
Test Field	Measurement Date	Route	Measurement Time	Estimated Posterior Error(EPE)
TOYONAKA CITY	18.Dec.2009	straight section	13 :07 :47 ~ 13 :08 :23	1.718m
		ell-curve section	12 :50 :02 ~ 12 :51 :15	1.710m
		longitudinal slope section	10 :35 :58 ~ 10 :37 :32	2.390m

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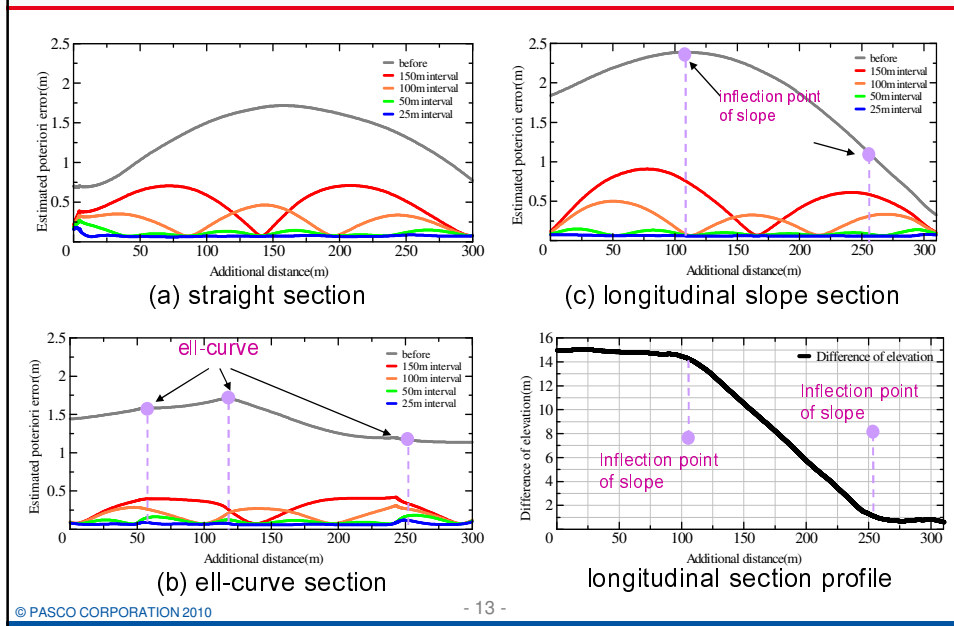
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## Estimation of the accuracy by EPE



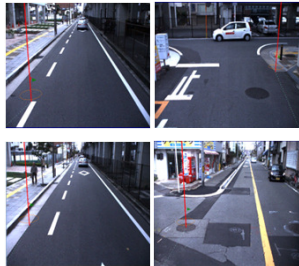
## Characteristics of EPE distribution



# Accuracy Investigation at Check Points

Check Points are settled on the halfway of the land marks

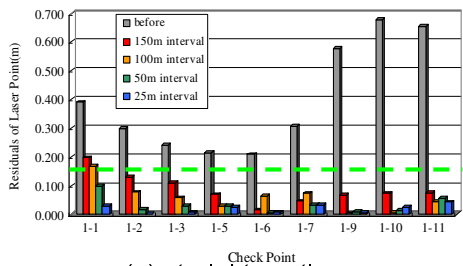
3D Residual =  
(Coord. on MMS cloud data)  
- (Coord. by GPS/TS)



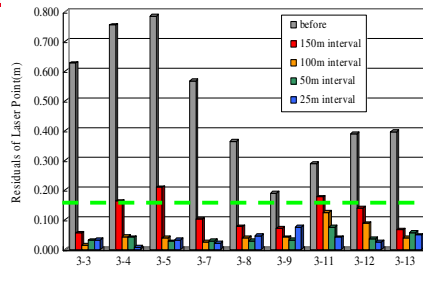
Check points for investigation

Route	Check Point	Before	150m interval	100m interval	50m interval	25m interval	
straight section	1-1	0.391m	0.197m	0.167m	0.099m	0.030m	
	1-2	0.300m	0.129m	0.077m	0.018m	0.003m	
	1-3	0.243m	0.109m	0.057m	0.029m	0.007m	
	1-5	0.215m	0.070m	0.029m	0.028m	0.024m	
	1-6	0.209m	0.015m	0.064m	0.005m	0.008m	
	1-7	0.308m	0.046m	0.073m	0.032m	0.032m	
	1-9	0.577m	0.067m	0.003m	0.010m	0.006m	
	1-10	0.679m	0.074m	0.006m	0.013m	0.025m	
	1-11	0.656m	0.075m	0.044m	0.055m	0.042m	
	ell-curve section	2-3	0.297m	0.113m	0.097m	0.113m	0.012m
		2-4	0.241m	0.189m	0.179m	0.046m	0.021m
2-5		0.061m	0.115m	0.079m	0.097m	0.074m	
2-7		0.178m	0.094m	0.056m	0.077m	0.023m	
2-8		0.166m	0.082m	0.099m	0.071m	0.051m	
2-9		0.181m	0.095m	0.038m	0.040m	0.014m	
2-11		0.305m	0.054m	0.046m	0.050m	0.017m	
2-12		0.494m	0.168m	0.155m	0.007m	0.059m	
2-13		0.518m	0.073m	0.079m	0.040m	0.022m	
longitudinal slope section		3-3	0.628m	0.054m	0.014m	0.030m	0.031m
		3-4	0.756m	0.162m	0.041m	0.041m	0.007m
	3-5	0.787m	0.209m	0.039m	0.026m	0.030m	
	3-7	0.568m	0.101m	0.025m	0.027m	0.020m	
	3-8	0.363m	0.077m	0.038m	0.027m	0.047m	
	3-9	0.189m	0.070m	0.041m	0.031m	0.076m	
	3-11	0.289m	0.176m	0.124m	0.075m	0.040m	
	3-12	0.390m	0.140m	0.087m	0.036m	0.025m	
	3-13	0.395m	0.066m	0.039m	0.057m	0.048m	

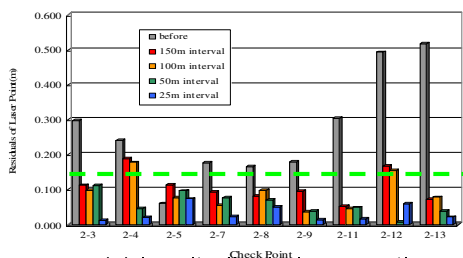
# Residuals of Coordinates at Check Points



(a) straight section



(b) ell-curve section

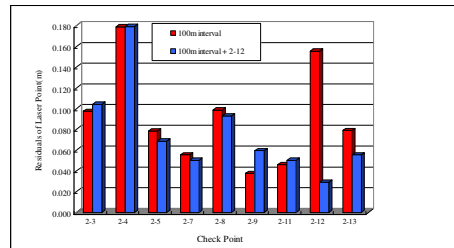
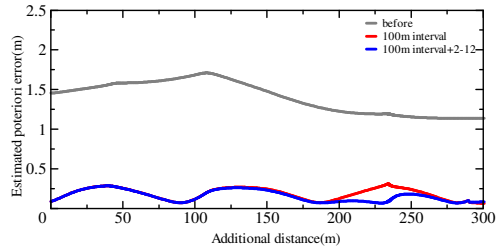
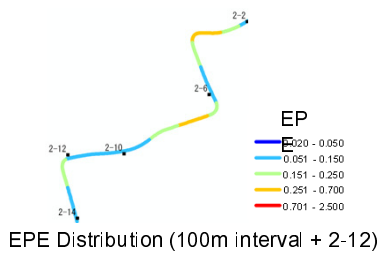
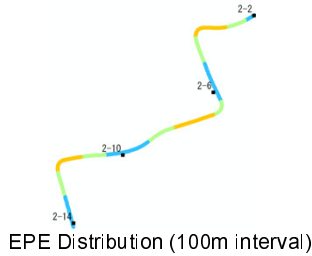


(c) longitudinal slope section



# Optimal Assignment of Land Marks

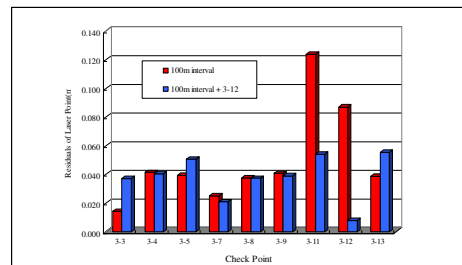
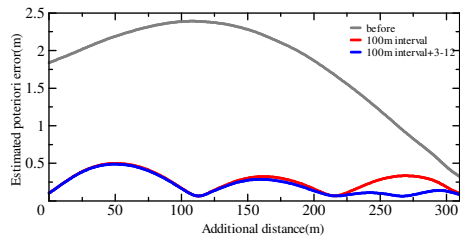
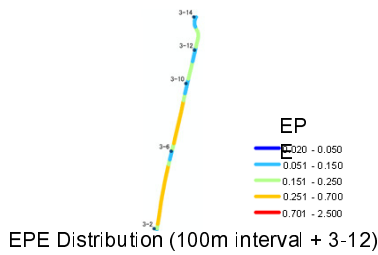
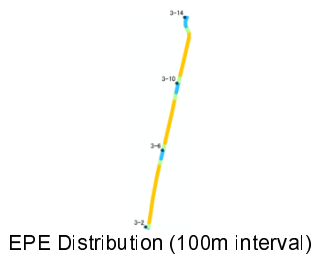
## (1) ell-curve section



3D Residual at Check Point

# Optimal Assignment of Land Marks

## (2) longitudinal slope section



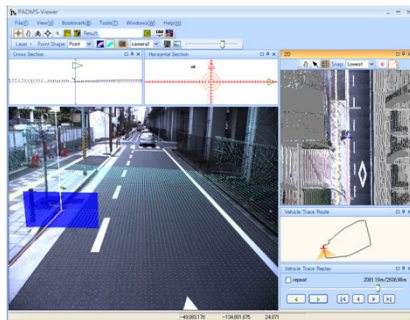
3D Residual at Check Point

## Optimal Assignment of Land Marks

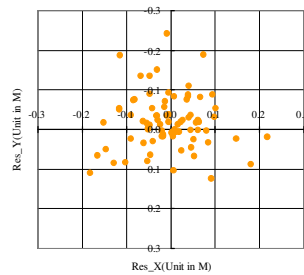
Optimal Assignment Method of Land Marks for GPS  
Invisible Area for MMS

Route	Optimal Assignment Method of Land Marks
Straight section	100m intervals
Ell-curve section	100m intervals and additional points near ell-curve
Longitudinal slope section	100m intervals and additional points at inflection point

## Accuracy Investigation of Mapping Data



Mapping point identification by using PADAMS-Solid



Distribution of mapping point residuals

**MMS data adjusted by LMU method have adequate accuracy for the official mapping project !**

	Res_X	Res_Y	Planimetric
RMS	0.074m	0.070m	0.102m
MAX	0.217m	-0.242m	0.242m
Reference Value			0.250m

## Conclusions and Future Works

Accuracy of MMS data maintenance method at GPS invisible areas was investigated.

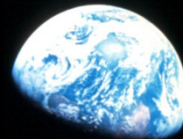
We conclude,

- ✓ In case of standard data capture speed of 40km/h, 100m interval of land marks is sufficient.
- ✓ Additional land mark at inflection point (horizontal curve and slope) is effective to improve laser point cloud data accuracy.
- ✓ 1/500 scale mapping by MMS is available even under GPS invisible area.
- ✓ Optimal assignment method of land mark is useful for mapping of tunnels and other difficult areas for observation.

In order to examine more effective methods of assignment, it will be necessary to take into account of vehicle velocity as our future work.

# Thank You

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