Examination of application of pavement repair work by utilizing (utilization) of data acquired in other fields

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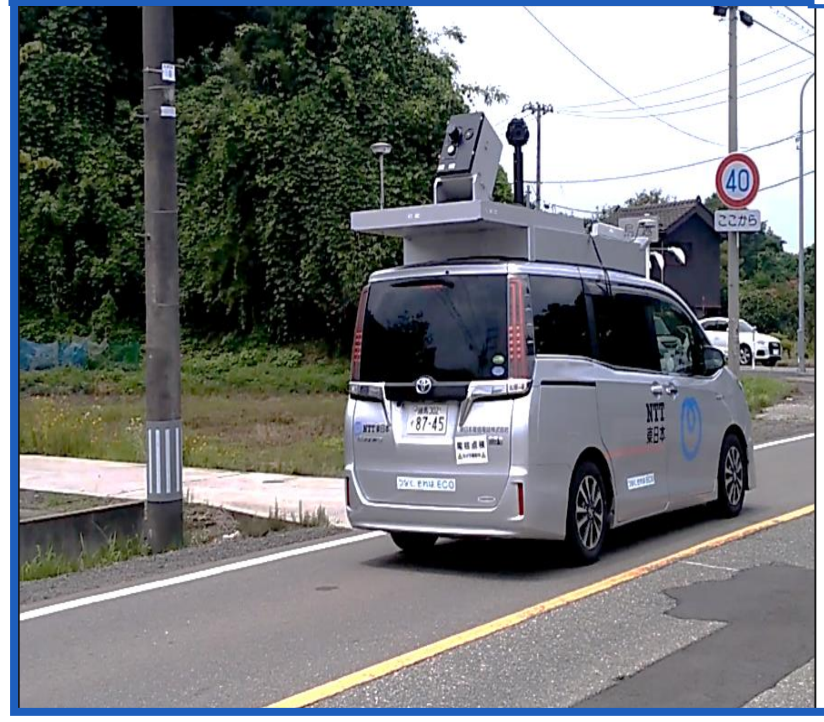
Background of the Initiative

In ICT pavement work (repair work)

①	3D groundbreaking surveying
②	Creation of 3D design data
③	Construction with ICT construction machinery (Construction Management System)
④	Construction management such as 3D as-built management
⑤	Submission of 3D data

TLS	Challenges
	・Installation space is required on the sidewalk or shoulder of the road. ・It takes time to change. ・Not suitable for routes with heavy traffic. ・Variation in measurement density.

MMS	Challenges
	・It takes a lot of time to installation of a fixed point. ・Not suitable for sections where GNSS reception conditions are poor.

There are many issues to improve the essential productivity of ICT pavement work (repair work).

Background of the Initiative

Example of utilization of 3D point cloud data on roads

01	Groundbreaking survey of pavement repair work.
02	Highways, bridges, tunnels, etc. Inspection of deterioration of infrastructure facility.
03	High-precision mapping for autonomous driving.
04	Confirmation of damage in the event of a disaster.
05	Creation of electronic map data.

Acquired data is used for a single purpose only ,not horizontally deployed

Background of the Initiative

Challenge!!

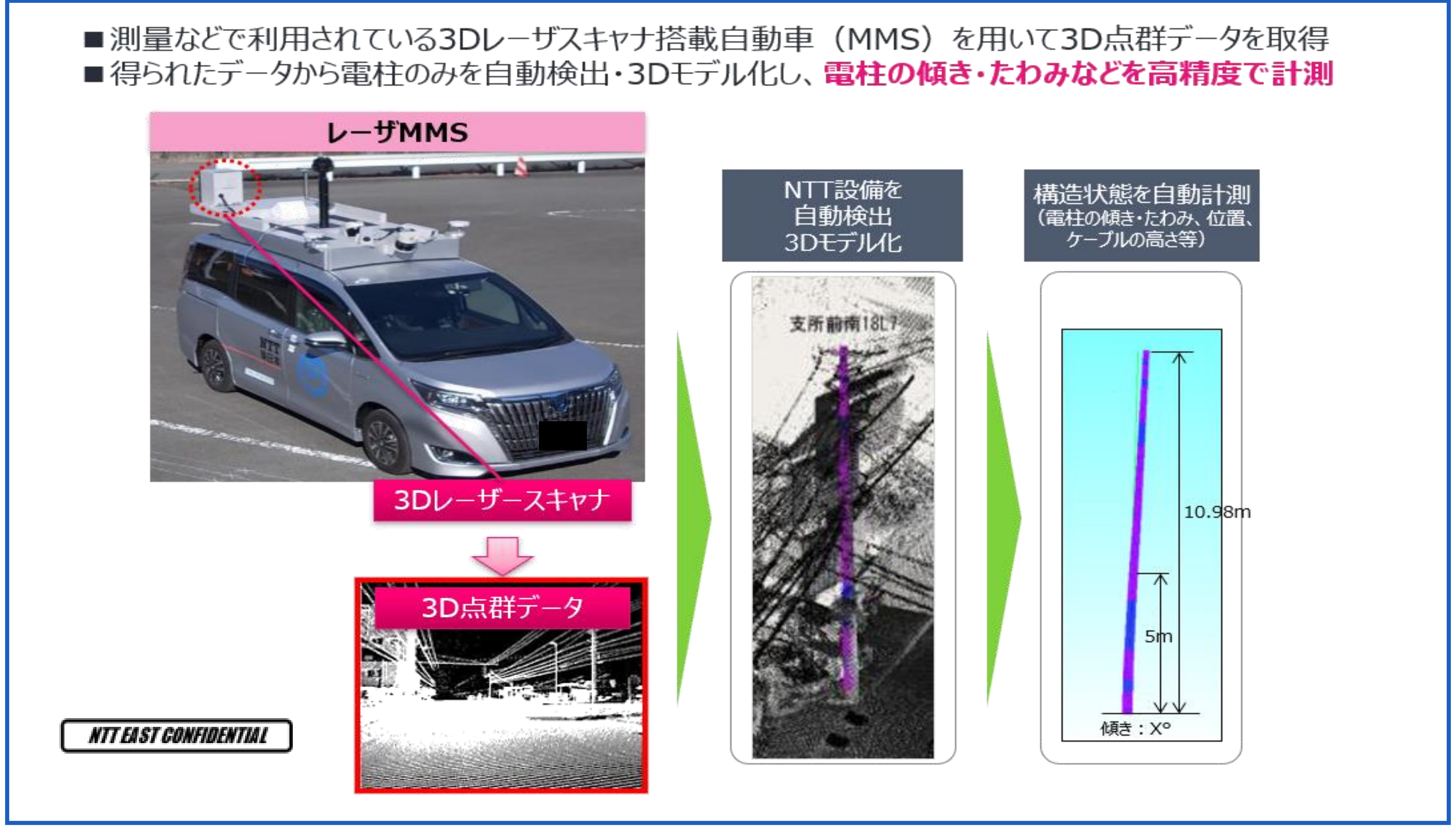
1. Solving the problem of 3D groundbreaking survey in ICT pavement work (repair work).
2. Effective use of 3D point cloud data acquired in other projects beyond the field.

Devised a method to apply “3D point cloud data” acquired in other projects to “groundbreaking survey data of pavement repair work".

Outline of the Initiatives

Regularly acquire 3D information on road space for inspection of its own infrastructure equipment.

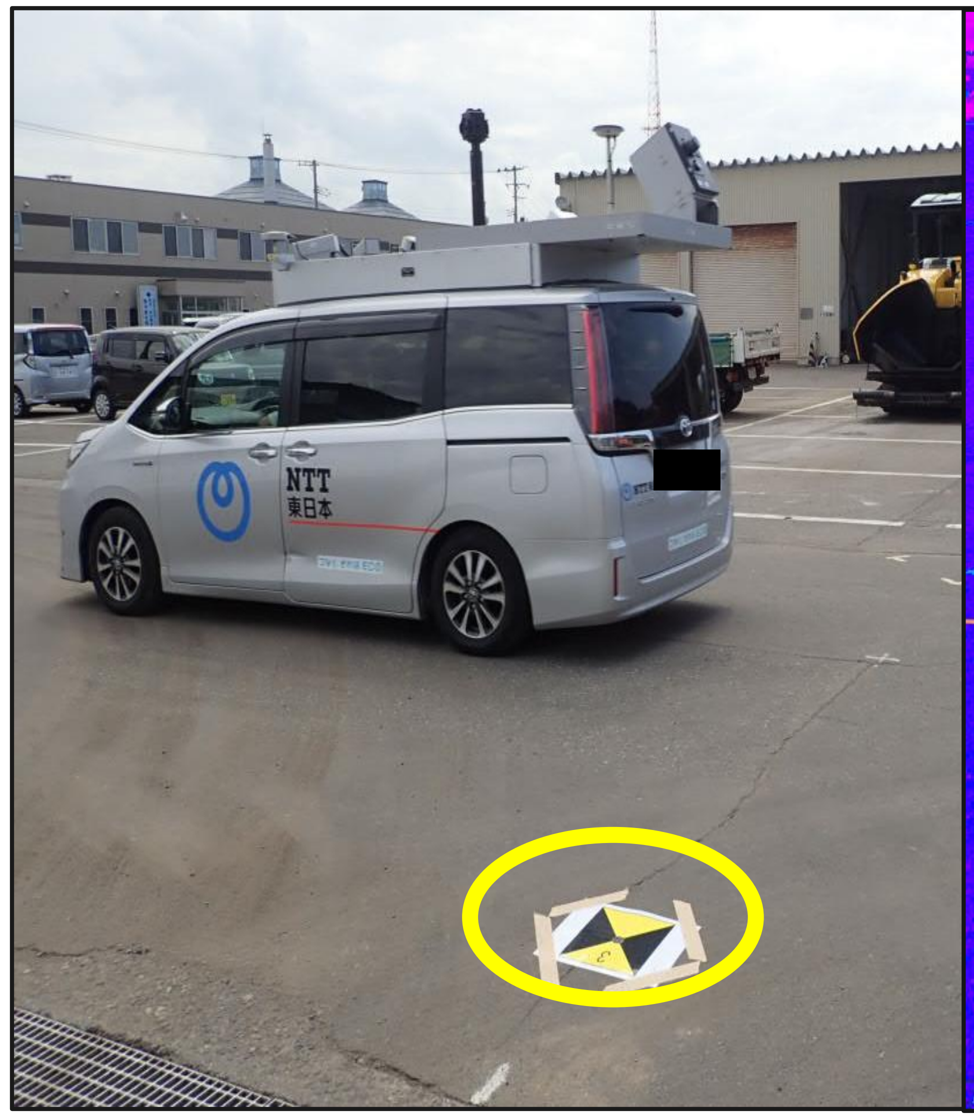
MMS for Infrastructure Equipment Inspection



Can it be applied to paving work?

Toward the Application of Data for Inspection of Infrastructure Facilities

As is



Ground control points are installed to correct errors in the planar and vertical directions.

When inspecting infrastructure

Installation at the time of infrastructure inspection is impractical.

It is necessary to have a mechanism that can be applied to pavement repair work without correction by installing ground control points.

Verification (STEP1)

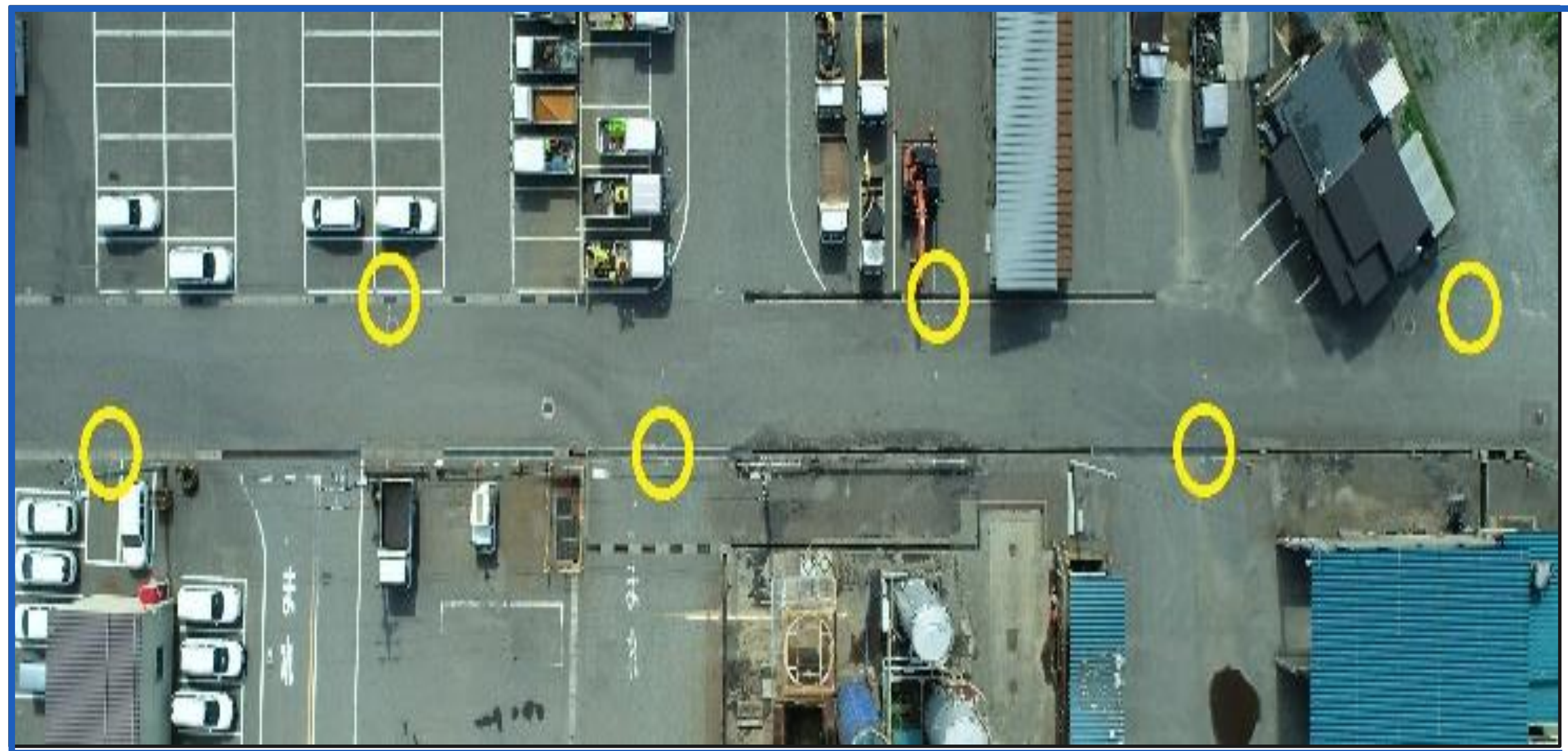
If the required accuracy of 3D point cloud data acquired by MMS for infrastructure equipment inspection can be confirmed, pavement repair work can be planned without correction by installing ground control points.

Accuracy comparison tests were conducted on the following items.

STEP1. Accuracy Comparison Test (Test Field)

	Verification items	Contents
①	Verification point range	・Confirmation of accuracy in the planar direction. ・Compare the distance between intersections of each test point coordinate.
②	Cross-sectional shape	・Accuracy confirmation in the vertical direction. ・TLS as ground truth and MMS shapes are compared.
③	Volume	・Confirmation of accuracy of cross-sectional shapes. ・Compare the milling volume of MMS with TLS as ground truth.
④	Profile shape	・Accuracy confirmation in the vertical direction. ・TLS as ground truth and MMS shapes are compared.
⑤	IRI / Standard deviation	・The longitudinal profile meter is set to ground truth, compare TLS and MMS calculated by software.

Accuracy Comparison Verification Overview



Installation of verification points

- Establishment of verification points at the measurement point of 20 m interval on the test field (100 m) .
- Acquisition of verification point center coordinates with total station.
- Measurement and comparison using TLS and MMS.

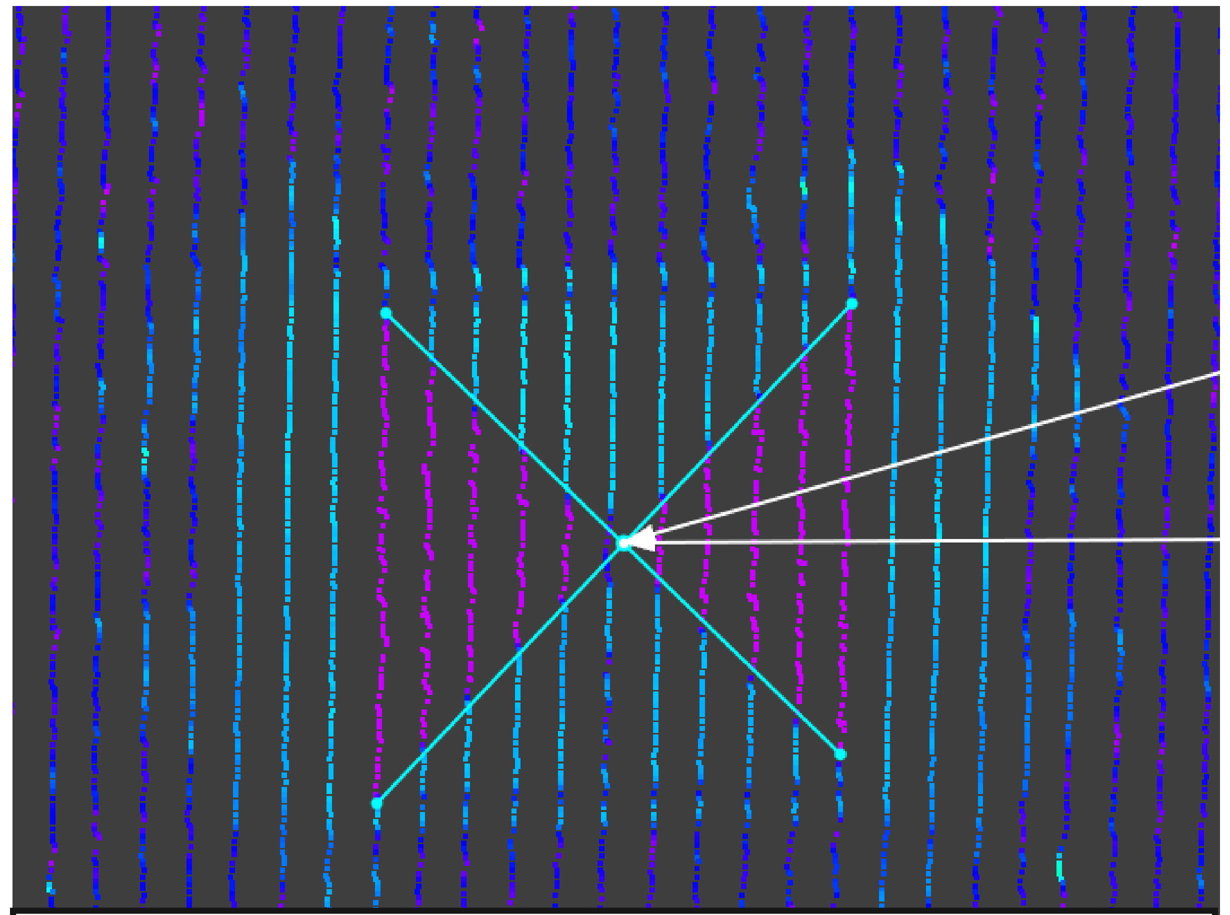
Test field measurement

- Scan rate ：100 rpm/sec
- Number of points acquired：1,000,000 points/sec
- Vehicle speed：30 ㎞/h

Accuracy Comparison Verification①
【Confirmation of validation point range】

【Comparison Overview】

- Compare the verification point range to confirm the accuracy in the plane direction.
- The distance between the intersections of the verified point coordinates by TS as ground truth, compare the distance between intersections of each verification point on the point cloud acquired by TLS and MMS.

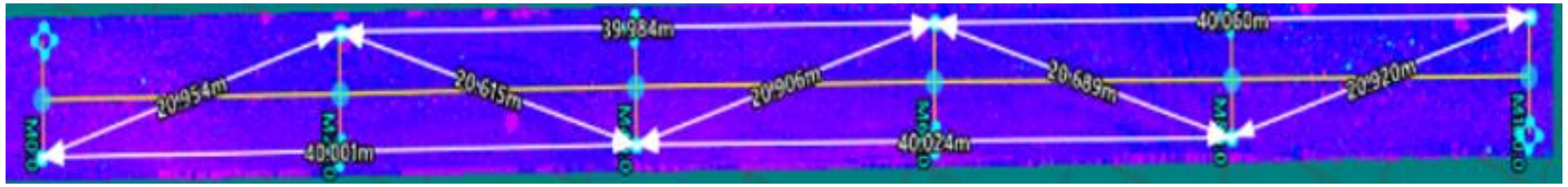


How to find the coordinates of the intersection point

【Result】

- For all intersection distances, the relative accuracy was good.

(※Satisfaction with the required accuracy of the accuracy confirmation test ±within 10 ㎜ of the flat surface.)

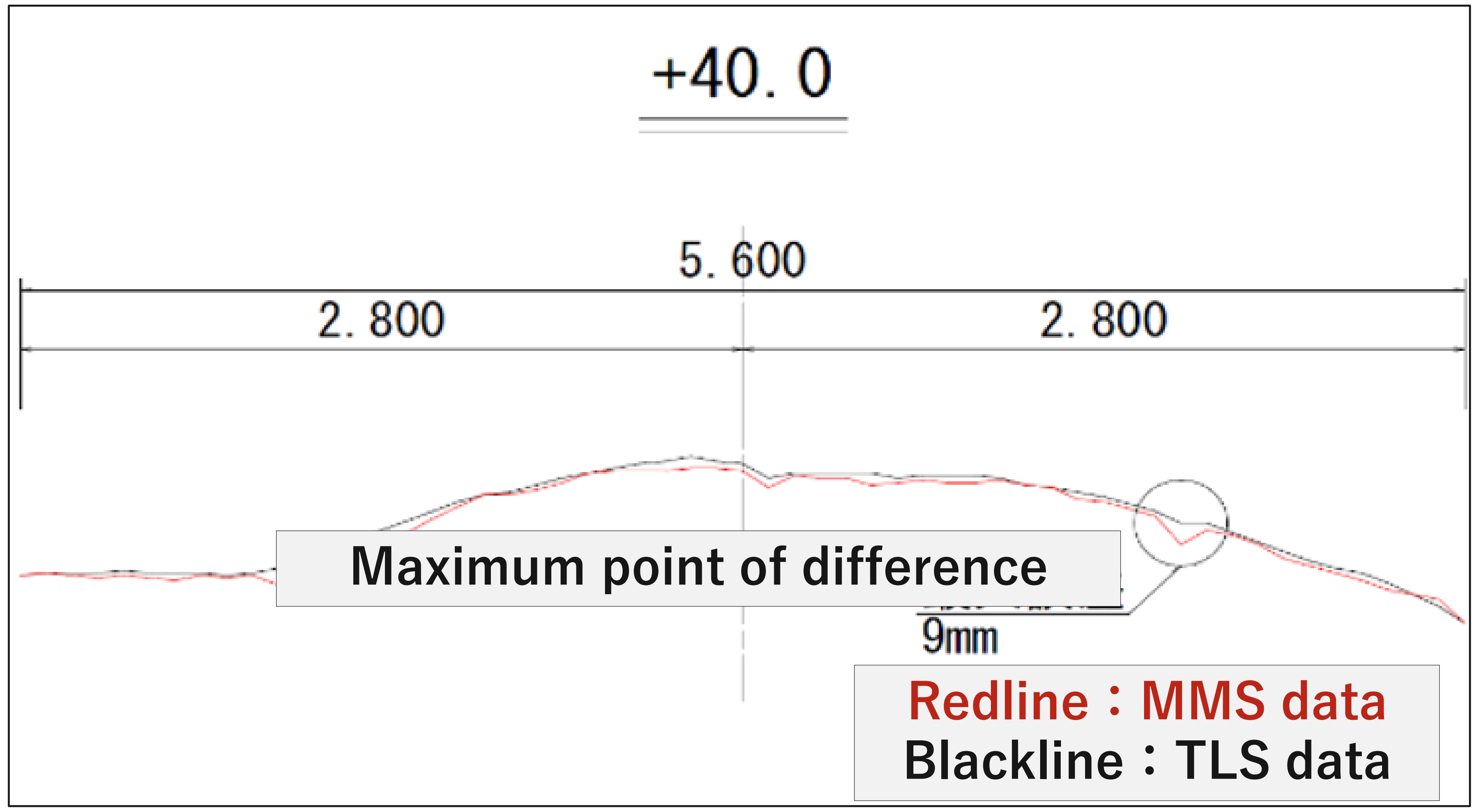


Section distance（m）	TS（True Value）	TLS（TS and TLS Diff）	MMS（TS and MMS Diff）
0～20	20.945	20.943 (0.002)	20.954 (-0.009)
20～40	20.624	20.632 (-0.008)	20.615 (0.009)
40～60	20.898	20.896 (0.002)	20.906 (-0.008)
60～80	20.698	20.702 (-0.004)	20.689 (0.009)
80～100	20.916	20.920 (-0.004)	20.920 (-0.004)
Average value		-0.002 m	-0.001 m
Standard deviation		0.004 m	0.008 m

Accuracy Comparison Verification②
【 Confirmation of cross-sectional shape 】

【 Comparison Overview 】

・Compare the accuracy of vertical (cross sectional shape) of MMS using TLS as positive.
・Extract point clouds at intervals 10 ㎝ for the cross-sectional shape of each station with a 20m pitch.
・In order to compare relative shapes, the height of both ends was matched.

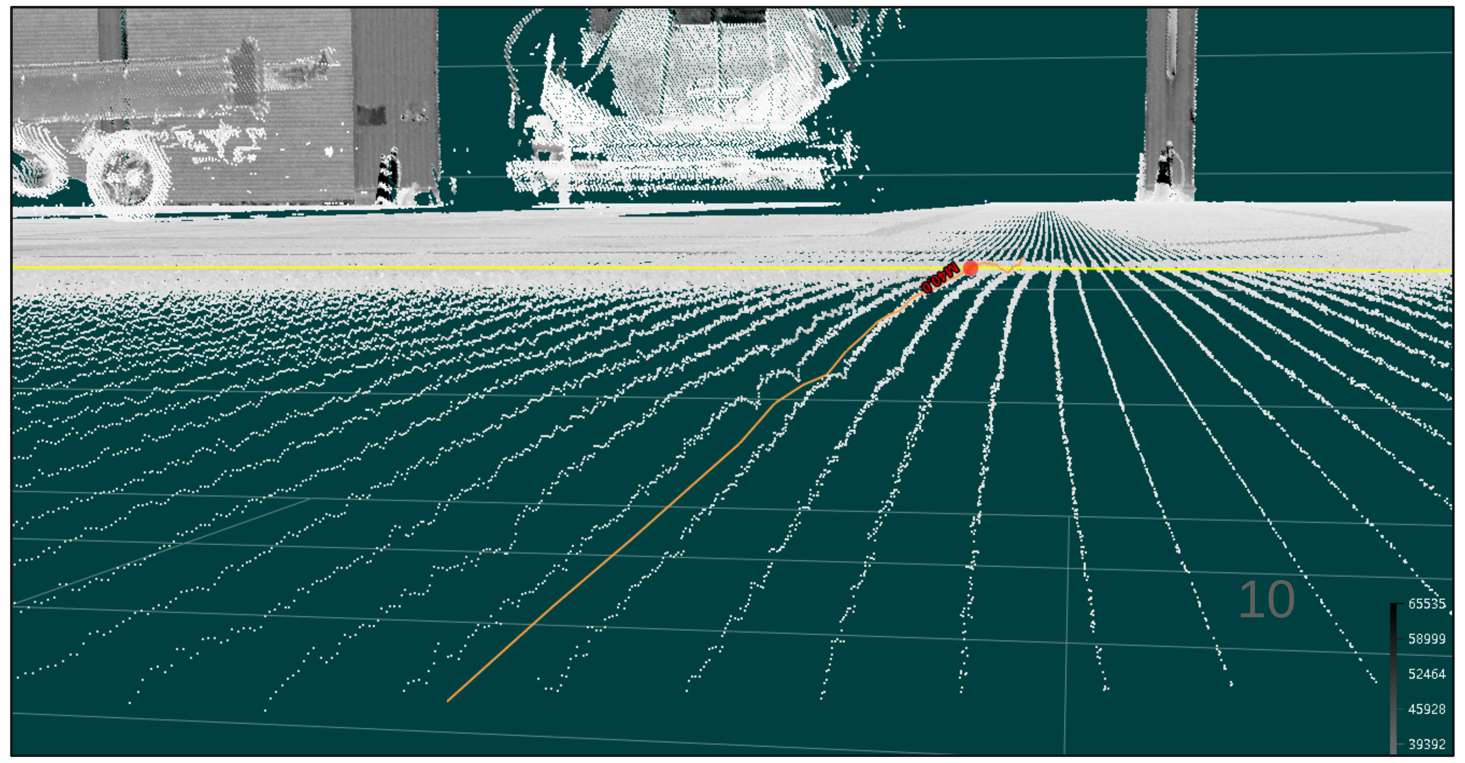


【Result】

・The average error value at all points (N = 330) is －1.8 ㎜.
・No significant divergence in the cross-section shape was observed at all stations.
（※ Satisfaction with the accuracy required for accuracy confirmation tests ± vertical within 4 ㎜. ）

【Discussion】

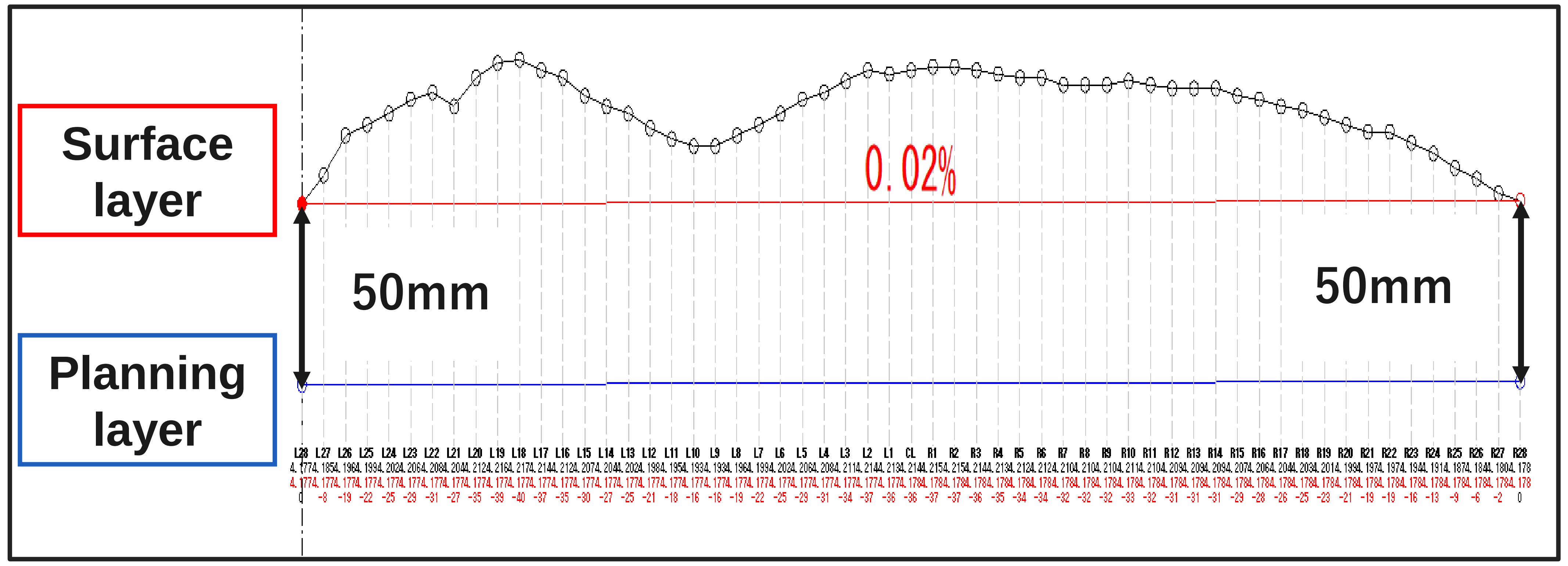
For some stations, errors of up to －9 ㎜ are confirmed.
① MMS is easier to read cracks deeply because laser enters the measurement surface in the vertical direction.
② MMS is less likely to overlap the ejection position of the measured point and the position of the measurement point group.



Accuracy Comparison Verification③ 【Confirmation of volume】

【Comparison Overview】

- Compare milling volumes to confirm vertical direction (cross-sectional shape) accuracy.
- For the cross-sectional shape in which both ends are connected with straight line at each measurement point, create a plan to mill 50 ㎜ at the end.
- As a base for comparison, measurement accuracy in the vertical direction in groundbreaking surveys uses ±4 ㎜.



【Result】

- At the test field (A= 750 ㎡), an error resulted in ＋2% (0.75 ㎥).

	Cutting thickness	Calculated volume	Differential
Compare MMS values with TLS as truth	–	38.3㎥ (Design value＋0.75㎥)	＋2.0%
Calculation results	46㎜ (Design value－4㎜)	34.5㎥ (Design value－3.0㎥)	－8.0%
	50㎜ (Design value±0㎜)	37.5㎥ (Design value±0㎥)	±0%
	54㎜ (Design value＋4㎜)	40.5㎥ (Design value＋3.0㎥)	＋8.0%

【Discussion】

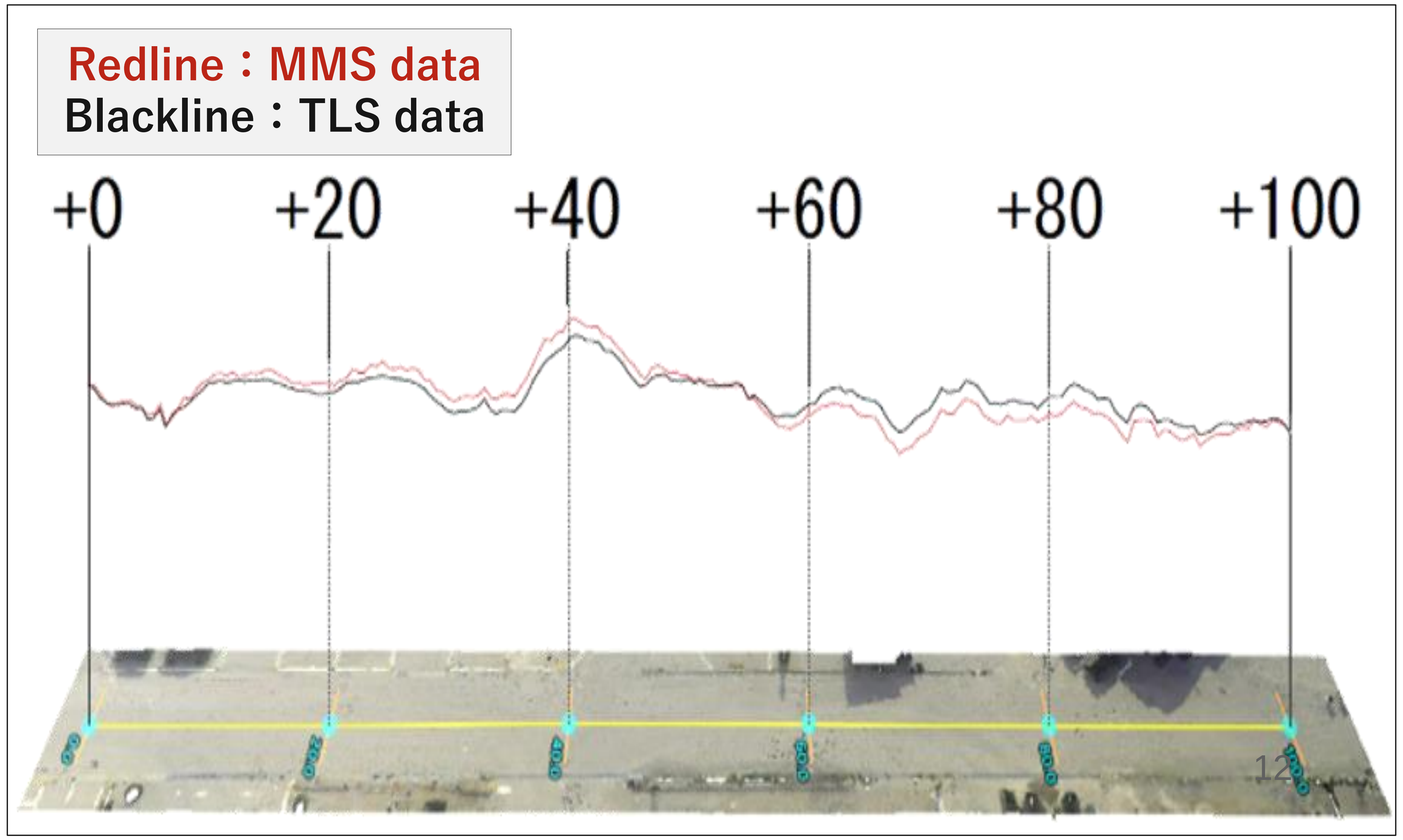
- When the milling thickness of one layer is 50 ㎜, assuming that an error of ±4 ㎜ occurs, the volume error is up to ±8%.→＋2% is a fully acceptable range.
- Measurement of the cross-sectional shape is formed by instantaneous laser emission. →The influence of error factors on each cross-sectional shape is small.

Accuracy Comparison Verification④
【 Confirmation of Profile Shape】

【 Comparison Overview 】
- Comparison of vertical accuracy (profile shape) in the longitudinal direction
- Extract point clouds located in the center of the road at intervals of 50㎝.
- For comparison of relative shapes, the height of the both ends connecting the starting and ending points is adjusted.

【Result】
- The accuracy required for the accuracy confirmation test did not meet within±4 ㎜ vertically.
- There is an error of up to 10 ㎜.

【Discussion】
- Over time, MMS is subject to errors due to IMU performance and GNSS positioning.
- Since the profile shape is affected by the measurement time of the entire cross sections, it is considered that the error has become larger.



Accuracy Comparison Verification⑤ 【Confirmation of IRI and standard deviation(flatness)】

【 Comparison Overview 】

・Comparison of IRI and standard deviation (flatness) for vertical accuracy (profile shape).
・Measure the center position of the test field with a profile meter.
・Compare with TLS and MMS data calculated on the software.

【Result】

・Compared with the IRI and standard deviation of the profiler, both data were equivalent, which was a good result.
・Longitudinal relative shape is approximate

	IRI (m/㎞)	Differential	Standard deviation(㎜)	Differential
profiler	7.179(X̅5)	―	4.48	―
TLS	7.141	－ 0.5%	4.75	＋ 6.0%
MMS	7.090	－ 1.3%	4.57	＋ 2.0%

Summary of Accuracy Comparison Verification

STEP1. Accuracy Comparison Test (Test Field)

	Verification items	Contents	Outcome
①	Verification point range	・Confirmation of accuracy in the planar direction. ・Compare the distance between intersections of each test point coordinate.	○
②	Transverse shape	・Accuracy confirmation in the vertical direction. ・TLS as ground truth and MMS shapes are compared.	○
③	volume	・Confirmation of accuracy of cross-sectional shapes. ・Compare the milling volume of MMS with TLS as ground truth.	○
④	Longitudinal shape	・Accuracy confirmation in the vertical direction. ・TLS as ground truth and MMS shapes are compared.	×
⑤	IRI / Standard deviation	・The longitudinal profile meter is set to ground truth, compare TLS and MMS calculated by software.	○

・Relative plane accuracy and vertical accuracy in the cross-sectional direction can be applied to pavement repair work.
・Relative accuracy relative to vertical accuracy in the longitudinal direction cannot be applied.

Even "3D point cloud data" that does not have accurate elevation values acquired in other projects, it can be applied to "groundbreaking survey data of pavement repair work" if the construction conditions do not require longitudinal correction.

Verification (STEP2)

STEP2. On-site demonstration test

	Verification items	Contents
①	Milling depth	・Comparison of design value and actual measured value of cutting thickness. ※Intended for a position of 2.0 m from the center of the road.
②	Milling quantity	・Compare the actual quantity of milling waste material to the design milling quantity.

At the same time, we are also considering combining it with a milling machine control system using a thickness control method.

Outline of the On-site demonstration test

【Site Overview】

✔ **Client**：
Hokuriku Gas Co.,Ltd.

✔ **Construction details** ：
Pavement restoration work by milling and overlay after gas pipe laying work.

✔ **Construction extension**：
National highway L = 1,180 m(A = 3,445 ㎡) managed by Niigata Prefecture.
※One lane on a two-lane road.

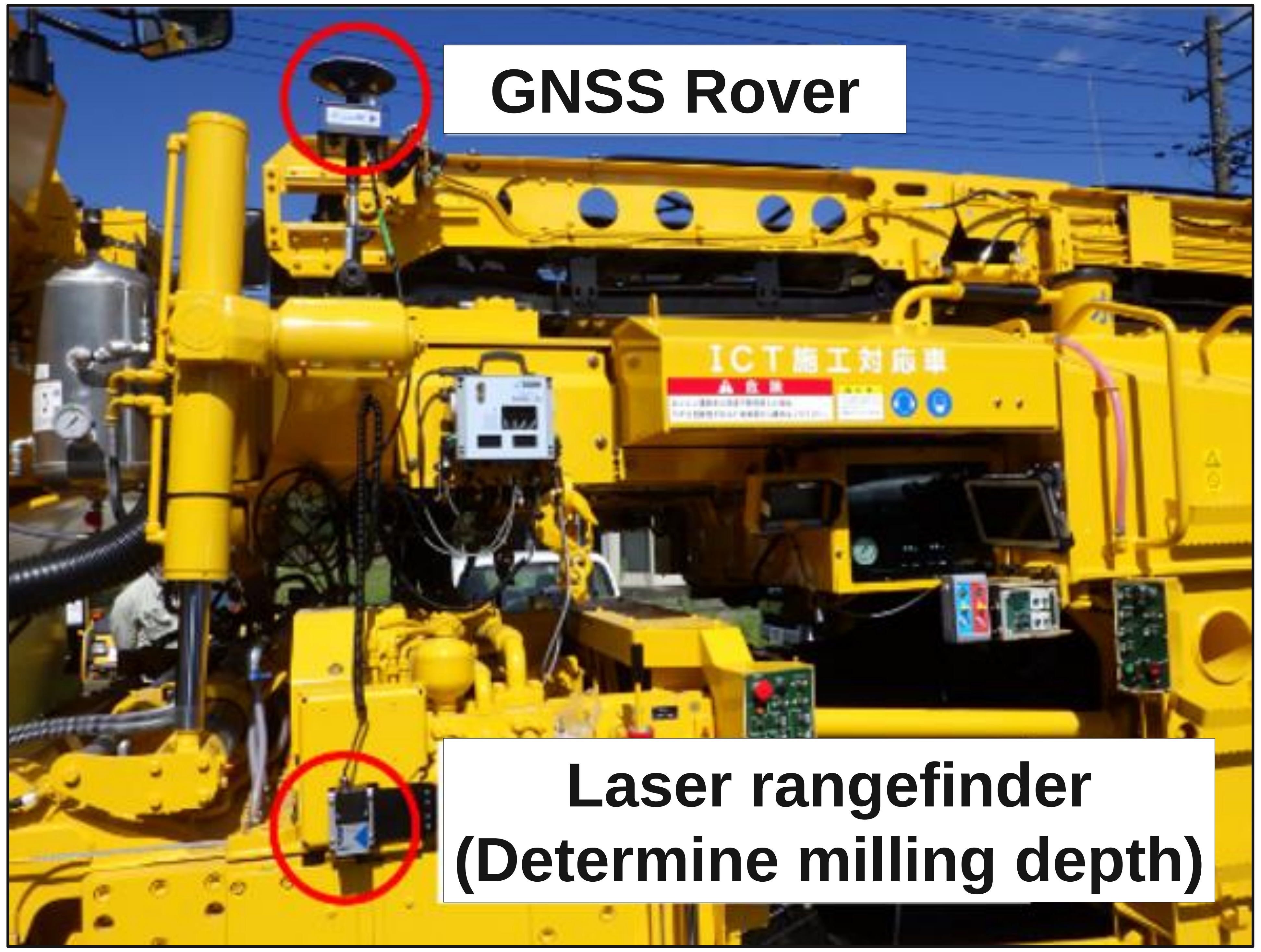
✔ **Construction conditions** ：
・Since the construction is only half width, there is no need to correct the longitudinal section at the time of planning.
・Superelevation is based on the shape of connecting the center side end and the shoulder side end.

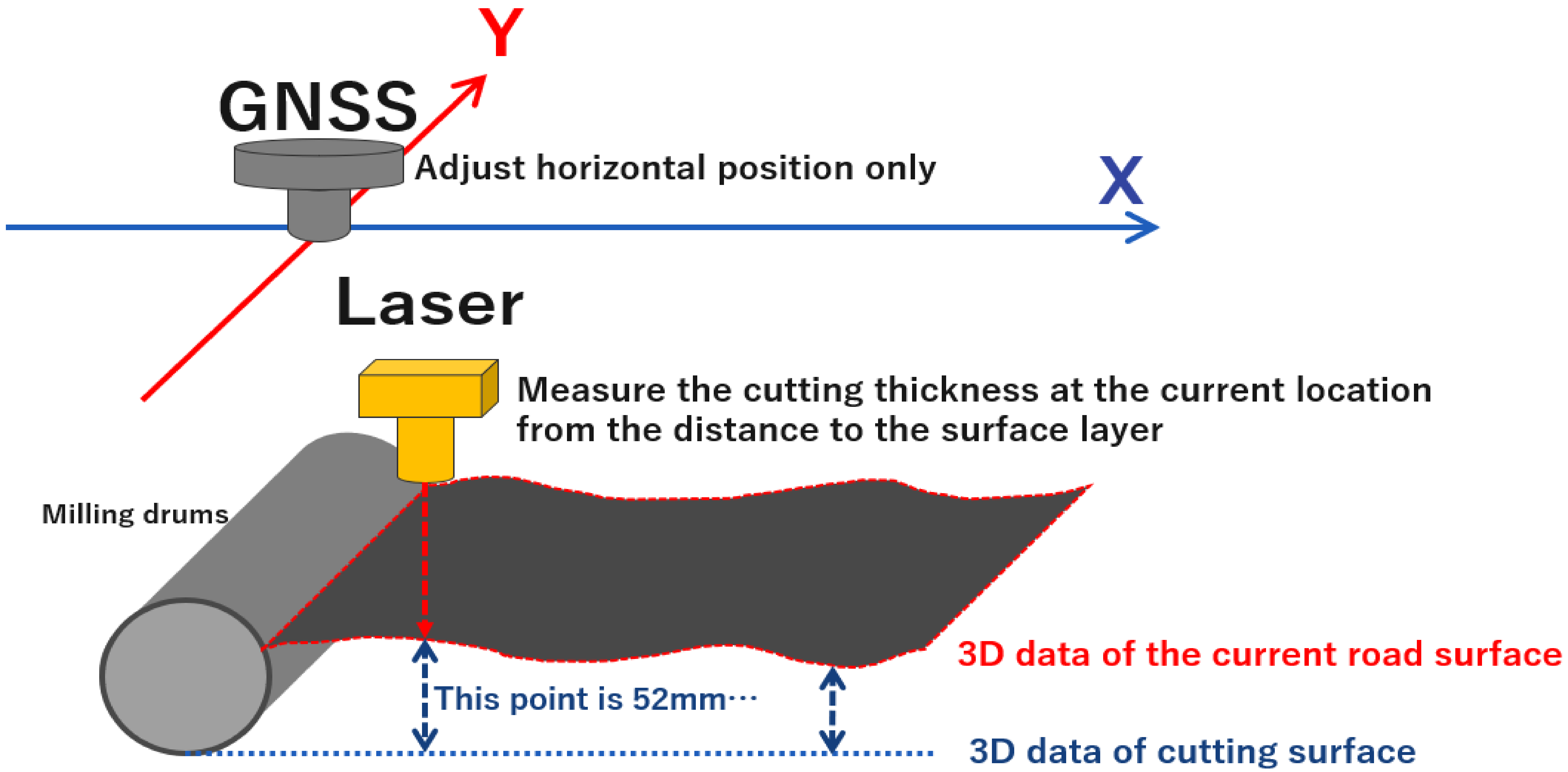
✔ **Data used**：
Measurement conditions are aligned with those at the time of infrastructure inspection, and point cloud data is newly measured by MMS for demonstration.

About the Milling Machine Control System Using Thickness Management Method

【System Overview】

（1） Measure the XY position of the milling machine by GNSS.
（2） Measuring milling thickness with a laser rangefinder.
（3） From the "plane position" of GNSS and the “milling thickness" of the laser, "design milling thickness" at the position is controlled.





Machine control system using two 3D surface data, the current pavement surface and the milled surface

On-site accuracy confirmation【 Confirmation of milling thickness】

【 Comparison target 】

・Comparison of design value and actual measured value of milling thickness.

※Intended for a position of 2.0 m from the center of the road.

【Result】

・The average error of the cutting thickness is －2.0 ㎜ (N=56 points) Good results.

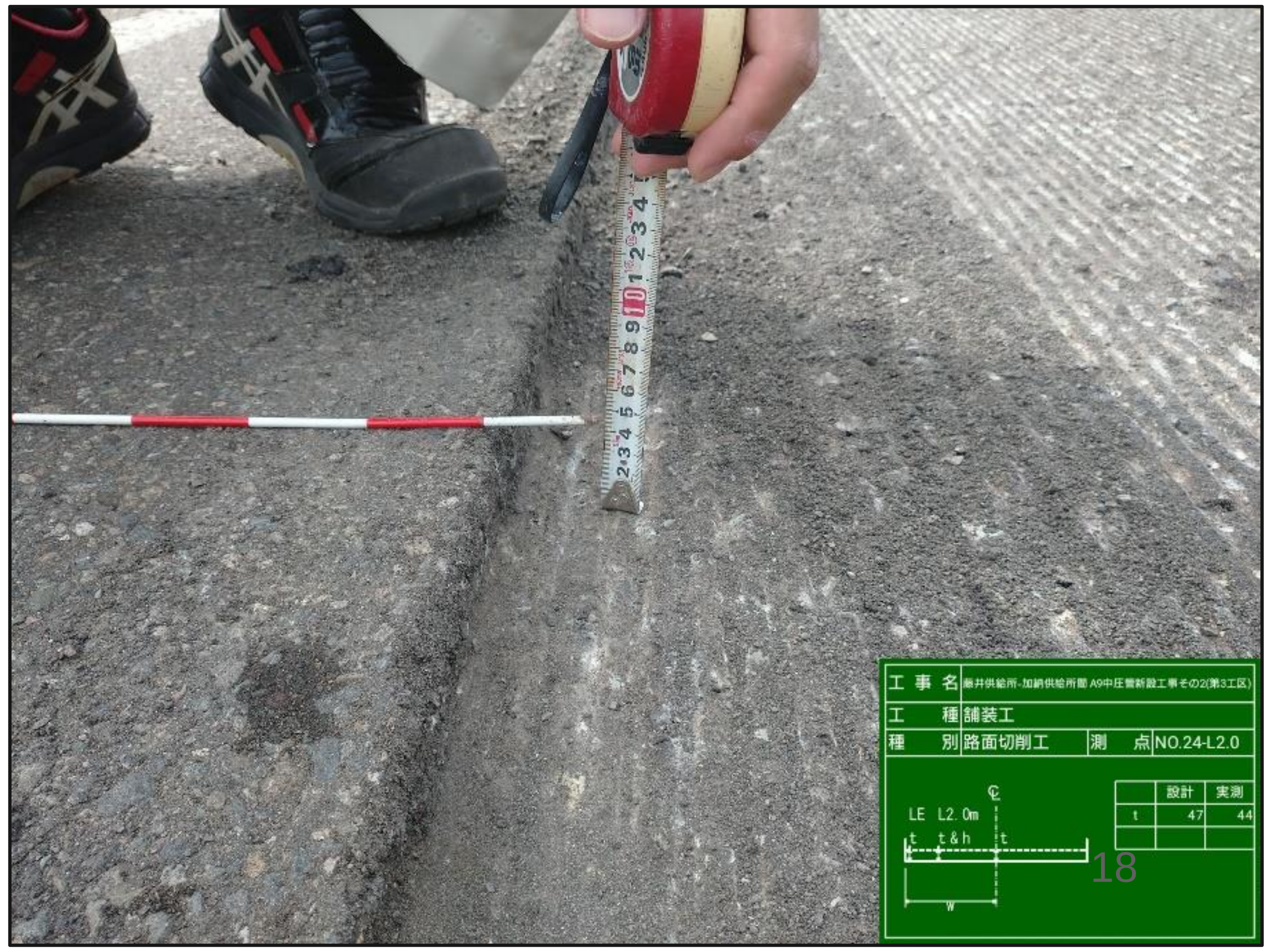
（※ Satisfied within －7.0 ㎜, which is the as-built control standard value）

・On the other hand, an error of up to －7.0 ㎜ occurs.

【Disucussion】

・Errors occurred immediately after construction avoiding structures such as manholes scattered there.

→There is a high possibility that the raising and lowering of the drum affected the control.



On-site accuracy confirmation【Confirmation of milling volume】

【Comparison outline】
・Compare the actual quantity of waste material to the design milling quantity.

【Result】
・Milling volume was +14.0 t (+3.5%) compared to 394.0 t designed.
→The total results for the three days were relatively good.

【Discussion】
・On the second day of construction, the error is slightly larger at ＋ 8.9 t.
→The construction site is a section where bridges and manholes were located.
This may be due to the fact that the drum of the milling machine was raised and lowered many times.

Construction Day	Design milling quantity（t）	Actual waste materials（t）	Differential（t）
Day 1	138.1	143.6	＋5.5
Day 2	139.1	148.0	＋8.9
Day 3	116.5	116.1	－0.4
Total	393.7	407.7	＋14.0

Summary of on-site demonstration tests and man-hour reduction effect

【On-site Demonstration Summary】

Through on-site verification, even “3D point cloud data" that does not have accurate elevation values acquired in other projects, it can be applied to "groundbreaking survey data of pavement repair work“ if the construction conditions do not require longitudinal correction.

【Man-days reduction effect】

	Reference point / Level survey	Installation, observation and calculation of fixed points every 50m	3D Measurement	Horizontal position adjustment / Confirmations	Point group synthesis・Noise processing	Counter-striking verification point installation	Elevation Adjustments and Checks	3D design data creation / profile planning	Total
Conventional（TLS）	3×1day ＋ 1×1day ＝4 man days	—	2×2day ＝4 man days	—	1×2day ＝2 man days	—	—	1×3day ＝3 man days	13 man days
Conventional（MMS）		2×1day ＝2 man days	2×0.5day ＝1 man days	1×0.5day ＝0.5 man days		2×1day ＝2 man days	1×0.5day ＝0.5 man days		15 man days
New method（MMS）	Unnecessary							1×3day ＝3 man days	3 man days

Compared to measurement using TLS and conventional MMS, it is expected to reduce man-days by about 70% and improve safety.

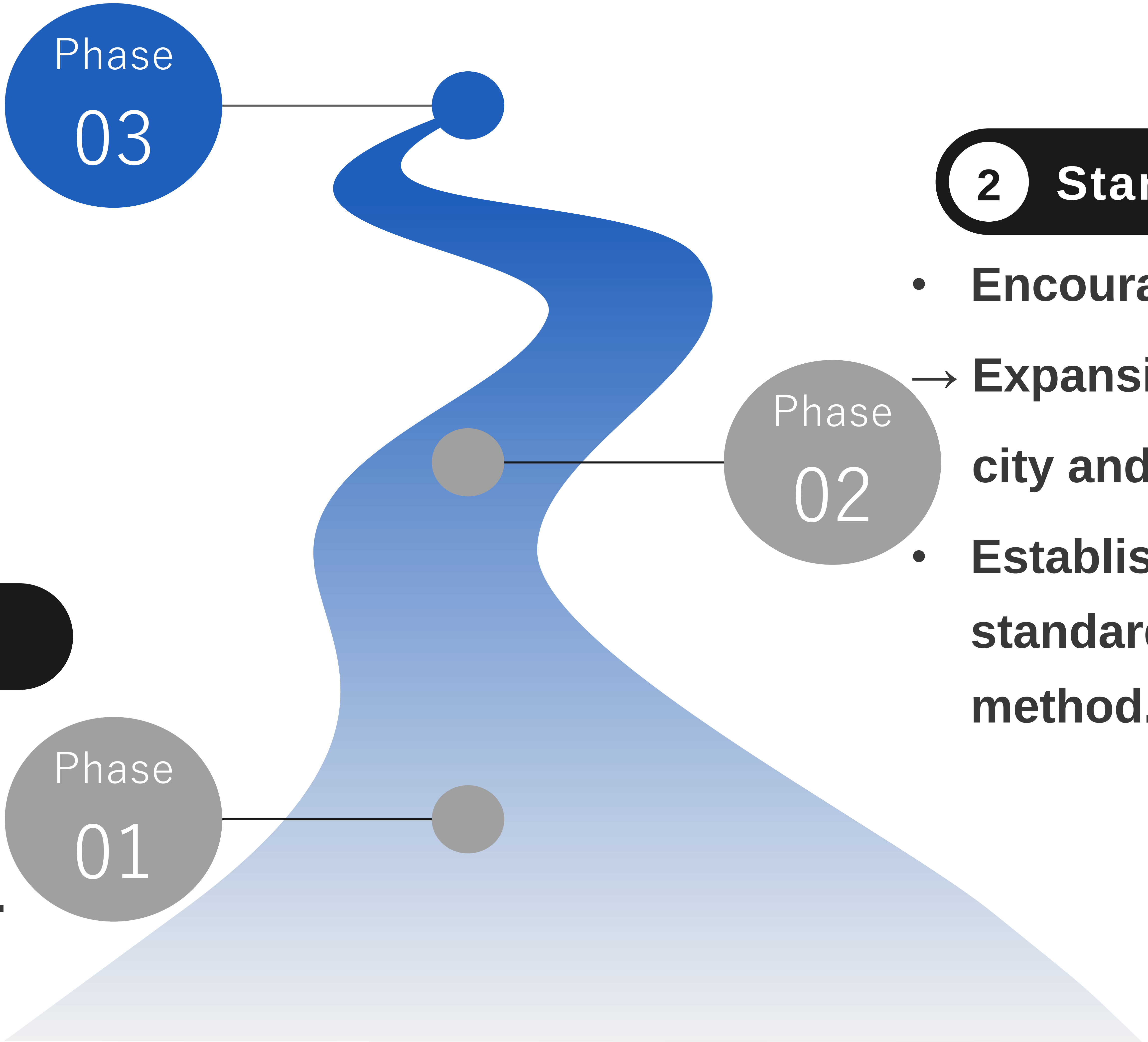
Future Directions

3 Digital Twin Construction/Development

- **Forming a data platform that can be used for the latest and most accurate and versatile purposes.**
- **Providing new value to society to solve regional and construction issues.**

1 Continuation of Verification

- **Verification for expansion of applicable sites.**
- **Service life study of stock data.**



2 Standardization

- **Encouraging governments.**

→ Expansion of performance on city and prefectural roads.

- **Establishment and standardization of the surveying method.**

Achieve outstanding productivity improvement through mutual utilization of 3D point cloud data.

Thank You

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