Advanced LiDAR-UAV Surveying Technology at Patimban Port Development Project

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Ides

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LiDAR-UAV Surveying @ Patimban Port

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【LiDAR UAV】
Light Detection and Ranging system UAV

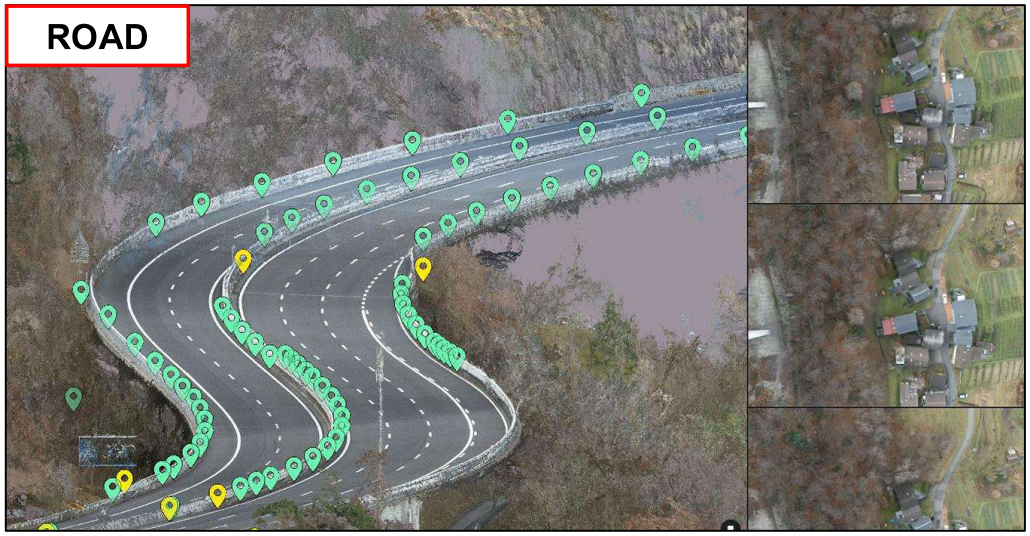
- Enable large and distant target area
- Automatic Operation
- Short-time and Less-manpower surveying

Many construction site are considering implementation of LiDAR UAV

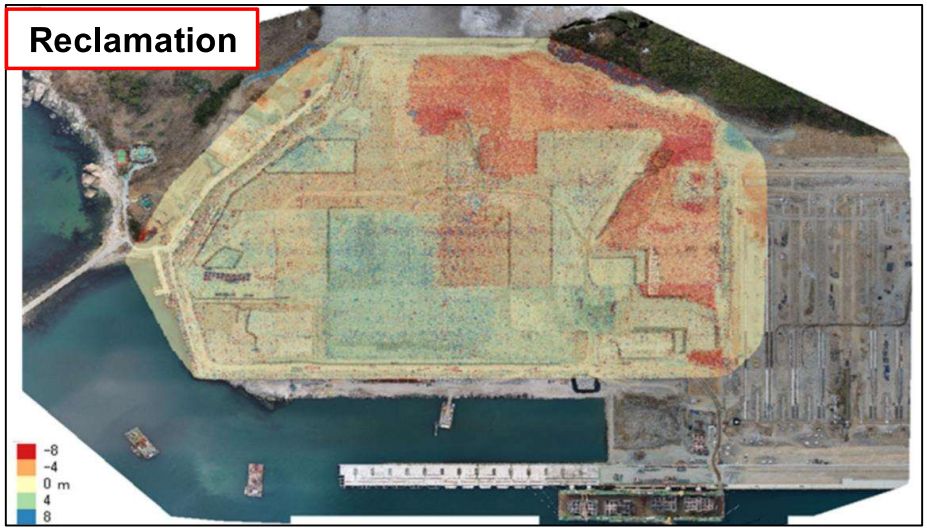
⇒Replace Contemporary Measurement (Total Station, Traverse)

Examples of Utilization LiDAR UAV in Construction Field

ROAD



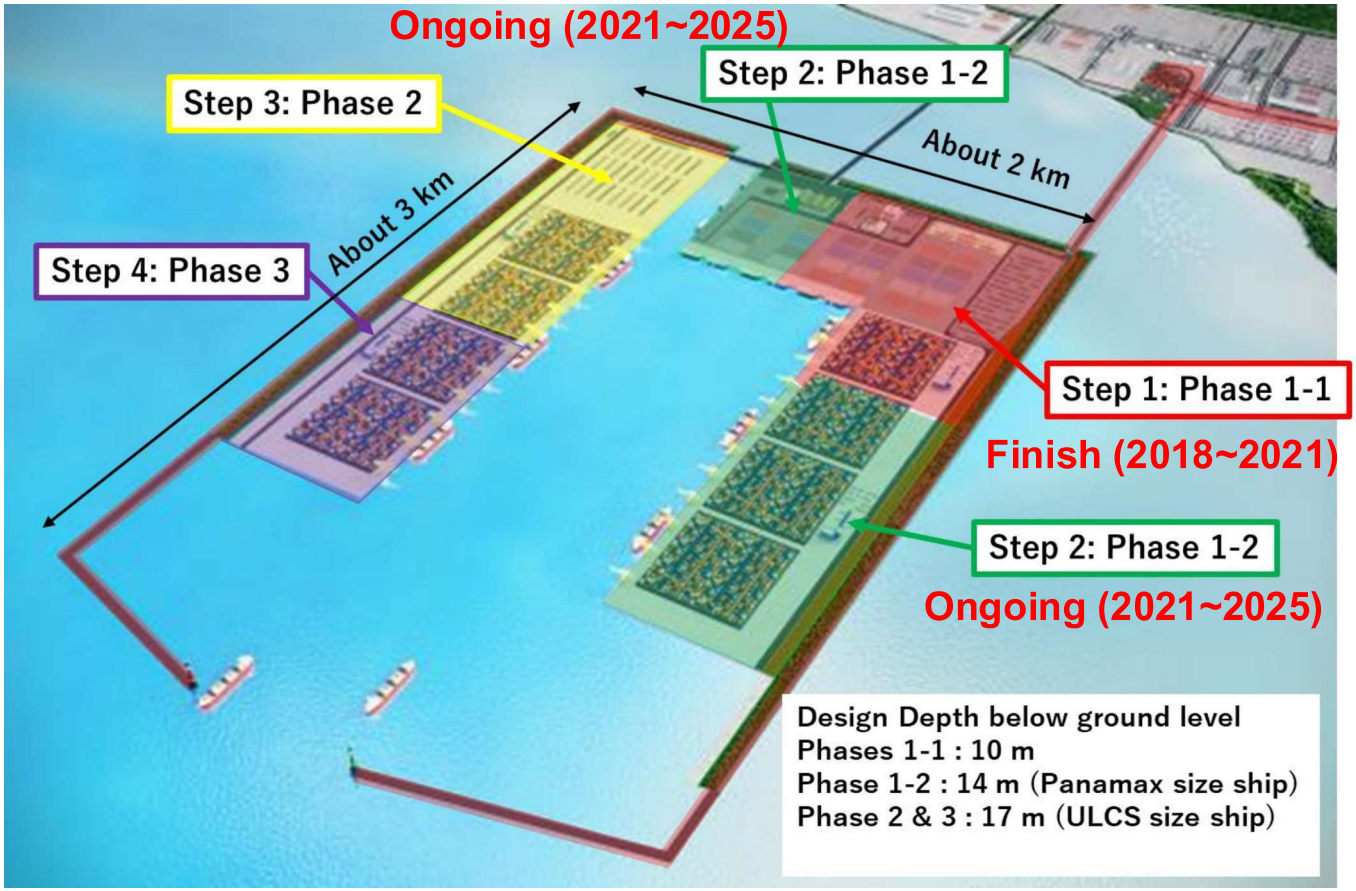
Reclamation



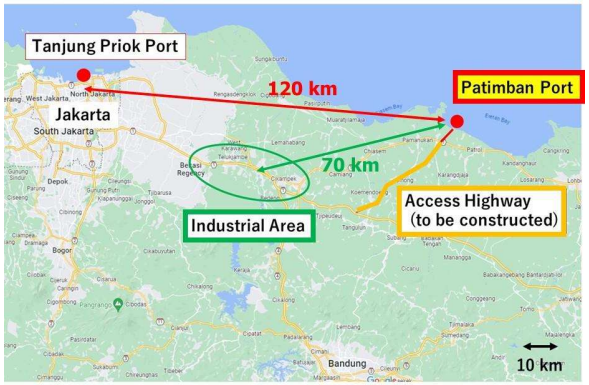
Studies on accuracy

Author	Target	Purposes	Root Mean Square Error
Mandar K et al (2020)	・Road Surface ・Non Road Surface	Acquire terrain information	Road Surface: 5.4 cm Non Road Surface: 11.3cm
Joonghee L et al (2023)	・Reclaimed Land	Evaluate Long term consolidation settlement	Reclaimed Area : 13cm

Patimban Port Development Project (Indonesia)



Logistics Plan



Development Plan

Construction Scale	Plan
Terminal Area	320 ha
Berth Length	4,000 m

Handling plan

Terminal	Plan
Container Terminal	7.5 million TEUs
Car Terminal	0.6 million CBUs

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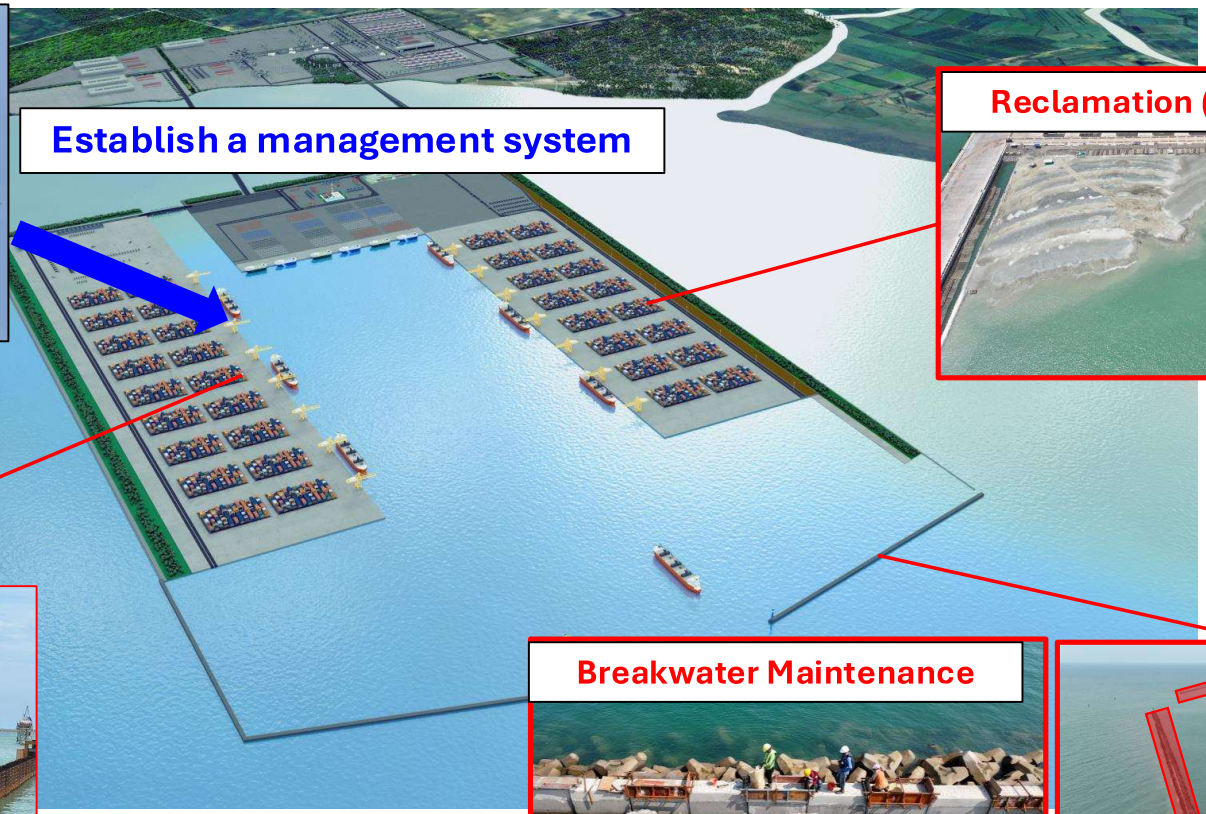
Implementation Target and View

LiDAR UAV



Reclamation (CPM)

Piling Monitoring

Breakwater Maintenance

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UAV : MATRICE 300 RTK

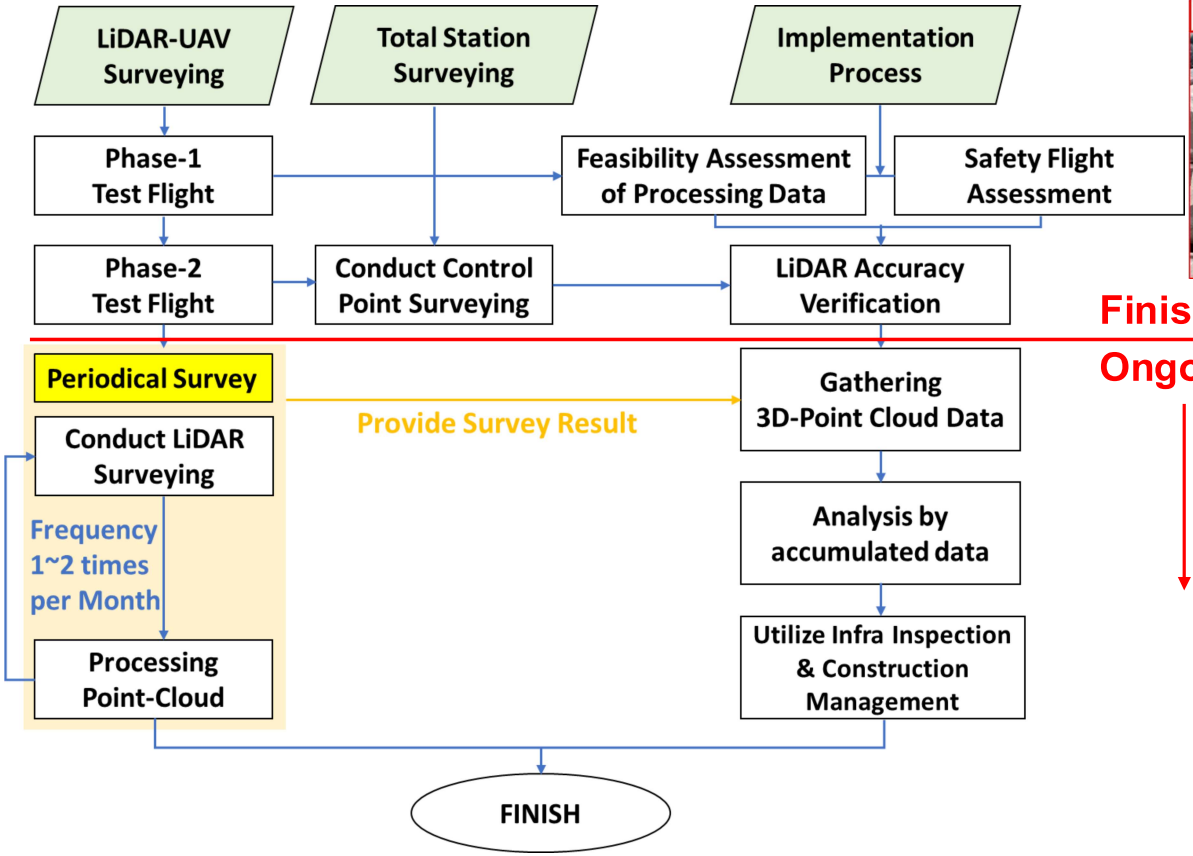
CAMERA : ZENMUSE L1

Mobile Station : D-RTK2

☐ Specs and Features

MATRICE 300 RTK	ZENMUSE L1	D-RTK2
・55min **Max Flight Time** ・7m/s **Max Descend Speed** ・7000m **Service Ceiling** ・15m/s **Wind Resistance** ・23m/s **Max Speed**	・**Point Rate /**Single return: max. 240,000 pts/s **/**Multiple return: max. 480,000 pts/s ・**System Accuracy /** Horizontal: 10 cm @ 50 m **/** Vertical: 5 cm @ 50 m ・**RGB Camera Resolution /** 20MP	・**Positioning System** / RTK ・**Accuracy** Horizontal / 1 cm+ 1 ppm Vertical / 2 cm+ 1 ppm (RMS)

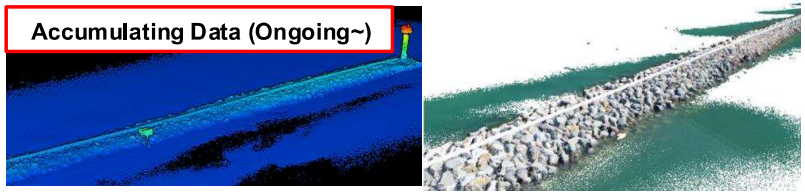
Implementation Plan Flow Chart

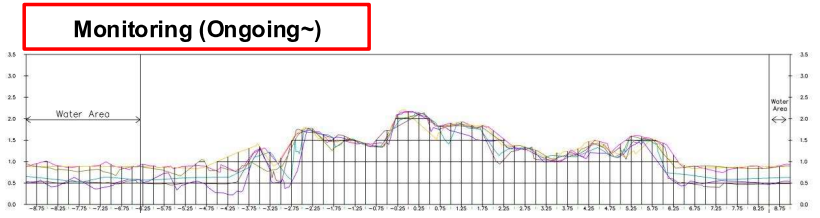


LiDAR Implementation Study Progress

Finished

Ongoing





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【Accuracy Verification Test of LiDAR Survey】

【Target Survey Area】 South Seawall in Patimban Port (Figure→)

【Target accuracy】 within 10 cm error for both horizontal & vertical

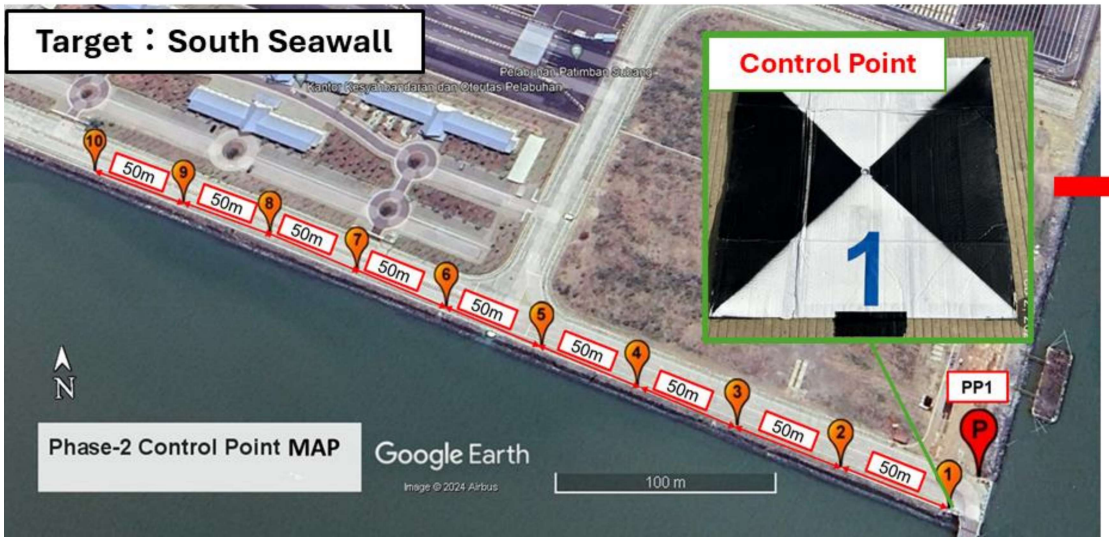
(Referring to Public Surveying – working rules and regulations of Japan ,MLIT ,2023)

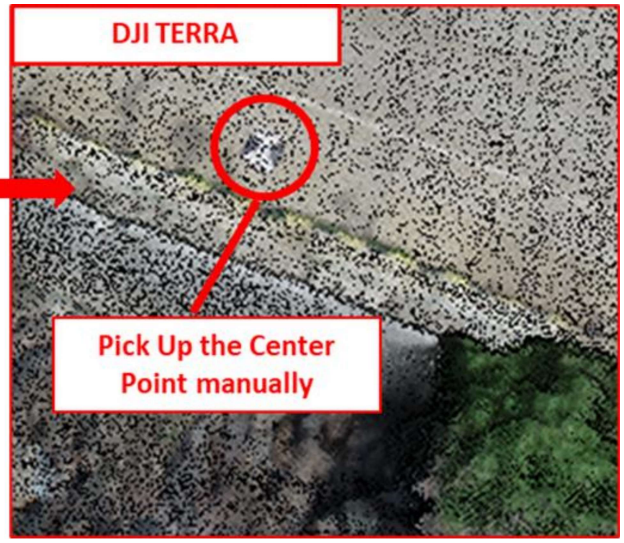
【General Methods】

①Control points: 10 Control Points were installed on 50m interval

②Comparison between LiDAR surveying and Total Stations Surveying.

③Verified the accuracy of LiDAR surveying by comparing the horizontal & vertical error.





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To find Optimum flight condition, Verification was carried out in two altitudes (50m and 80m).

☐ Flight Condition

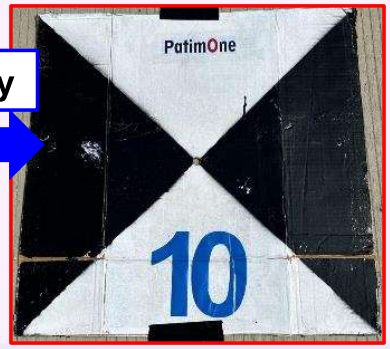
	Option 1	Option 2
Flying Height (m)	50	80
Flying Speed (m/s)	2.5	2.5
Overlap Ratio(%)	80	80

*Flight Speed and Overlap Ratio was decided by trial flight and existing case study

☐ Flight Route

Survey

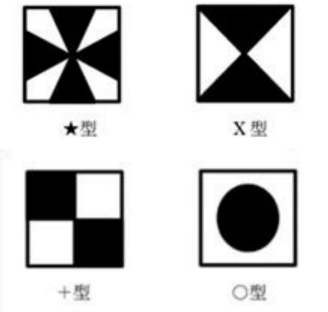
Control Point



【Features】

Number：10 pieces
Size：62cm × 62cm
Design：Referring to the Standards of “Geospatial Information Authority of Japan”

【Reference】 Safety Standards for the Use of UAVs in Public Surveying (GIAJ)



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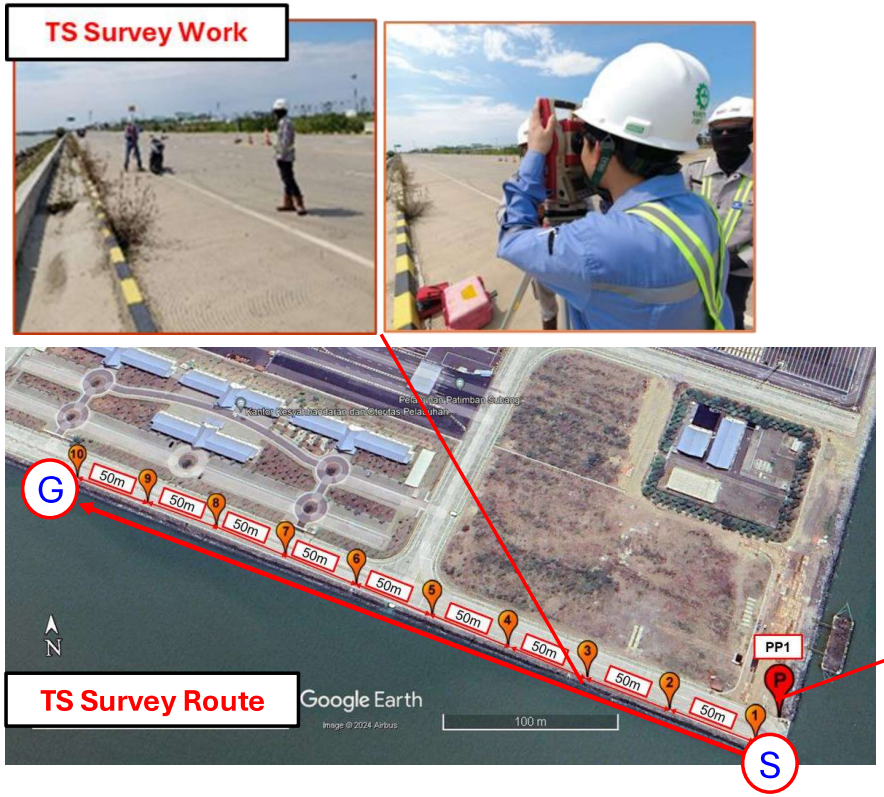
Method : Single-Point Surveying



Coordinates Transformation

LiDAR Surveying : **GNSS Coordinates**
Total Station Surveying : **Localized Coordinates**
⇒**Need For Unification**

Convert Horizontal Coordinates : Localized ⇒ GNSS

$$\begin{bmatrix} x_G \\ y_G \end{bmatrix} = s \begin{bmatrix} (x_L - x_{PP0}) \\ (y_L - y_{PP0}) \end{bmatrix} + \begin{bmatrix} x_{PP0} \\ y_{PP0} \end{bmatrix}$$

$GNSS\ Coordinate: (x_G, y_G)$, $Localized\ Coordinate: (x_L, y_L)$,
PP.00 Coordinate: (x_{PP0}, y_{PP0}) s: scale factor $(= 1.00088)$

Reference Point			PP.00
UTM (48S) ZONE			
Easting=X(m)	Northing=Y(m)	Z(m)	
821420.669	9308882.035	2.185	

【Accuracy Assessment : RMSE (Root Mean Square Error)】

$$RMSE(x,y,z) = \sqrt{\frac{1}{N}\sum_{i=1}^{N}\left\{\left(x_{t(i)},y_{t(i)},z_{t(i)}\right)-\left(x_{l(i)},y_{l(i)},z_{l(i)}\right)\right\}^2}$$

$Total\ Station\ Survey : \left(x_{t(i)},y_{t(i)},z_{t(i)}\right)$ $LiDAR\ Survey : \left(x_{l(i)},y_{l(i)},z_{l(i)}\right)$

【Assessment Result 】

- Target errors (mean error and RMSE within 10 cm) achieved in both horizontal and vertical directions.
- In particular, the vertical accuracy , RMSE are being around 1 ~ 3cm.
- Altitude 50 m is optimal for construction site scale surveys when higher accuracy is required.

☐ TS vs LiDAR UAV (50m) >>Accurate>>

	ERROR = Total Station - LiDAR		
Point	ERROR X (m)	ERROR Y (m)	ERROR Z (m)
P1	0.021	0.062	0.012
P2	0.043	0.024	0.012
P3	-0.027	0.041	0.018
P4	-0.038	-0.009	0.030
P5	-0.087	0.004	0.011
P6	-0.059	0.045	0.019
P7	-0.034	0.013	0.012
P8	-0.019	0.011	0.010
P9	-0.064	0.041	-0.026
P10	-0.053	0.085	-0.022
	X	Y	Z
Mean Error (m)	0.044	0.034	0.017
Root Mean Square Error (m)	0.049	0.042	0.018

OK!

☐ TS vs LiDAR UAV (80m)

	ERROR = Total Station - LiDAR		
Point	ERROR X (m)	ERROR Y (m)	ERROR Z (m)
P1	-0.060	0.059	-0.003
P2	0.057	0.034	-0.047
P3	-0.012	0.061	-0.025
P4	-0.069	0.065	-0.022
P5	-0.048	0.051	-0.022
P6	0.046	0.060	-0.009
P7	-0.036	0.079	-0.007
P8	0.005	0.096	-0.023
P9	0.046	0.077	-0.043
P10	-0.022	-0.011	-0.034
	X	Y	Z
Mean Error (m)	0.040	0.059	0.023
Root Mean Square Error (m)	0.045	0.063	0.027

OK!

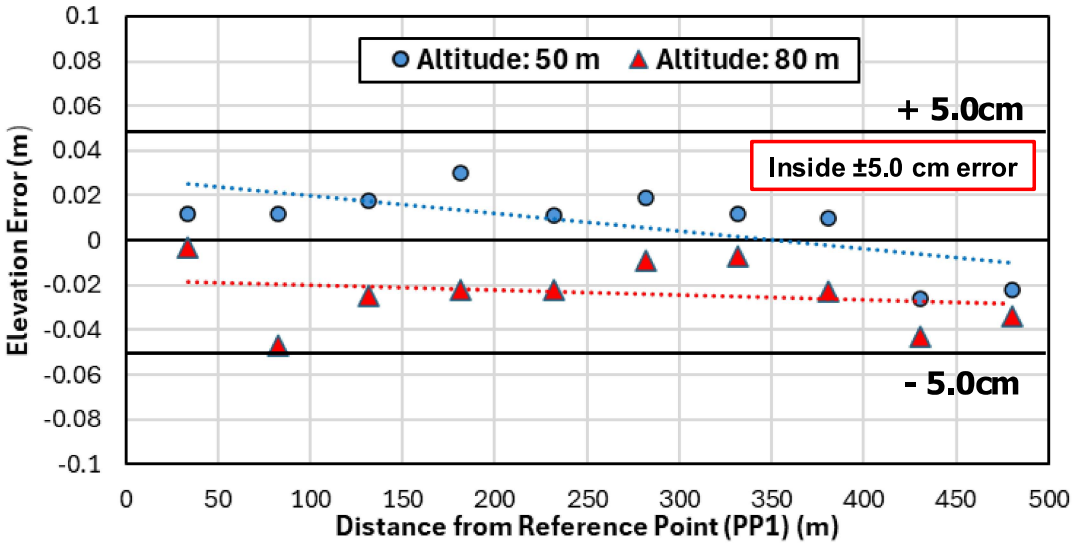
【Relation between distance from reference point and error value】

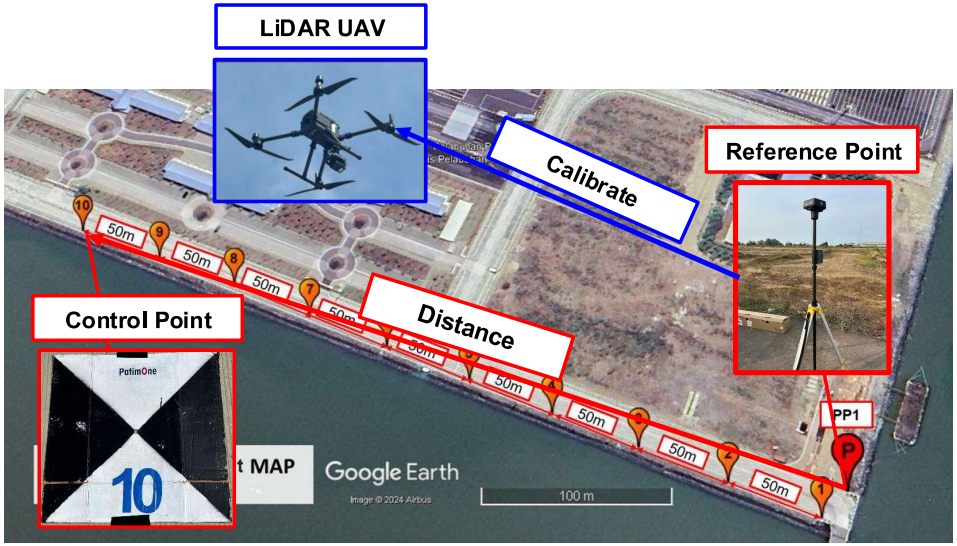
The elevation (z) errors for all points are within 5 cm absolute value, regardless of the distance.

Vertical accuracy is maintained even when surveying at remote locations.

⇒LiDAR UAV is validated for remote surveying of offshore structures

☐ Distance – Elevation Error Values





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Breakwater Features

Terms after construction Breakwater : 2.5 Years (From November 2021)

The breakwater Location : approximately 2 km offshore from land.

Excessive settlement is observed at several locations, demand regular monitoring for maintenance purpose

Current Monitoring Method

- **Field Inspection (1 time/ month) : Recording Damage & Settlement**
- **Carrying out Repair works based on Field Inspection Result**

Monthly Field Investigation

Wave-dissipating blocks Settlement

Coping Concrete Side Slide

Problem Found in Field Investigation

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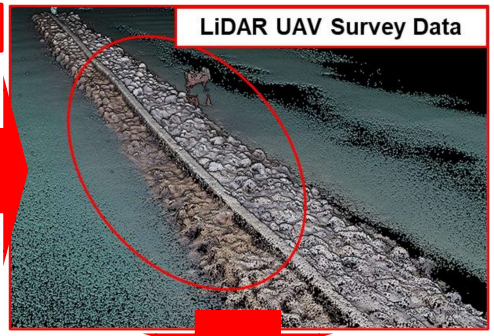
☐ Utilization for Breakwater Repairing Work

Conduct Periodic surveying by LiDAR UAV

Contributing to save time in Inspection

【Previous】 **0.5～2 day / 1 time**

【After LiDAR introduction】 **25 minutes / 1 time**



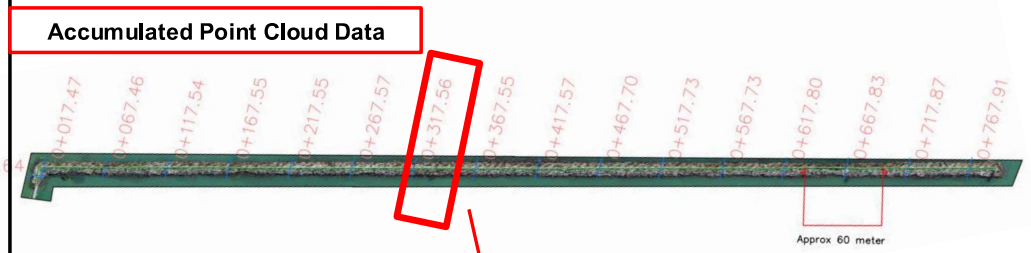
【By LiDAR UAV Data】
① Measuring the Settlement Range and Elevation Change
② Estimating the Number of blocks required.
⇒Improvement Efficiency of Repairing Work

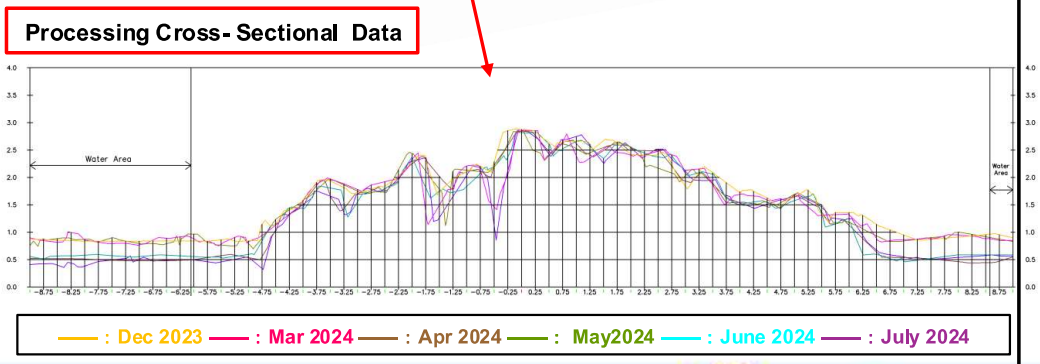
☐ Utilization for Breakwater Long term Monitoring

Accumulate survey data by LiDAR UAV (Dec 2023～)

Long-term sliding and settlement considered

⇒Acquiring Settlement data that be used for future construction.





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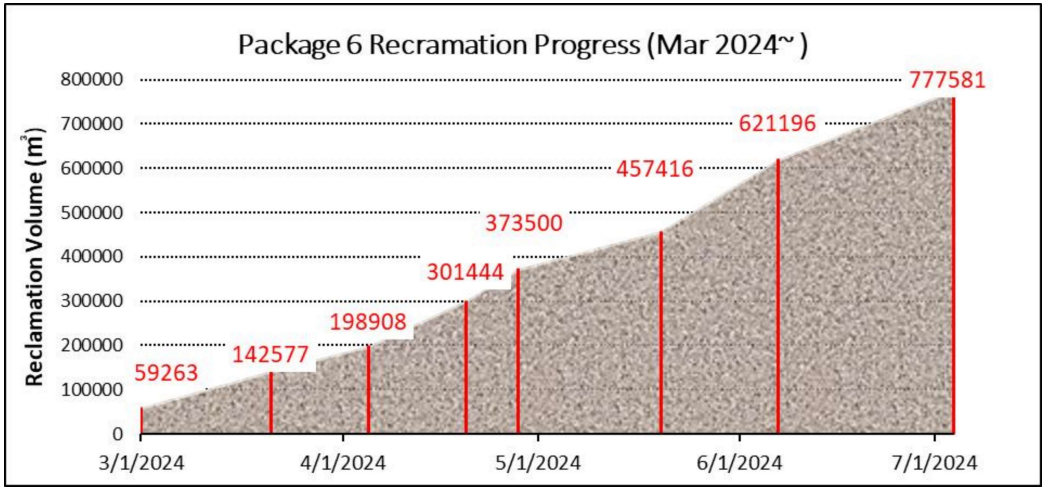
Utilization for Reclamation Work Monitoring

Application of LiDAR UAV for monitoring the progress of reclamation works.
Expected to improve operational efficiency and obtain the data needed for analysis.

Pilot Implementation Case Study

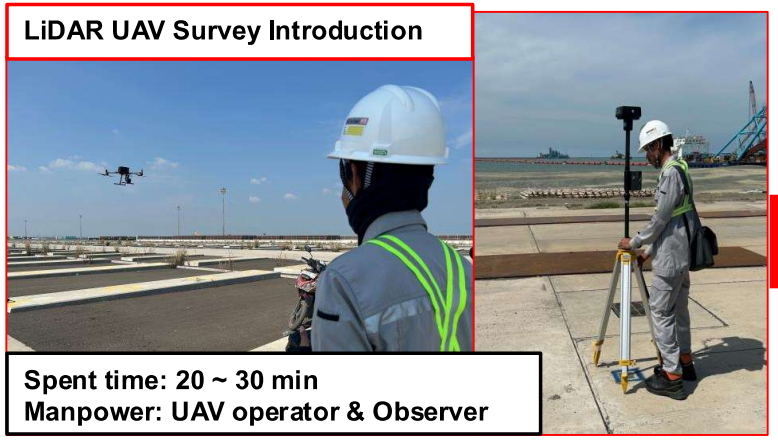
- **Volume calculations of reclaimed soil (Ongoing)**
- **Observation of reclaimed area settlement (Ongoing)**



Current Topographic Survey (RTK-GNSS)

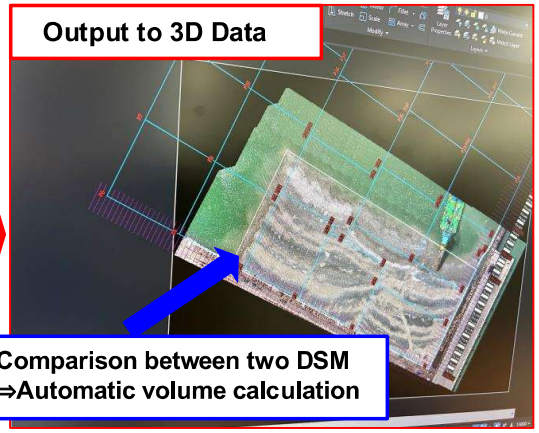
Spent time: 2 day
Manpower: 5 people ~

LiDAR UAV Survey Introduction



Spent time: 20 ~ 30 min
Manpower: UAV operator & Observer

Output to 3D Data



Comparison between two DSM
⇒Automatic volume calculation

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Summary and Next Purpose

【Study Summary】

- ✓ A Preliminary Implementation flowchart was planned and Accuracy check was conducted before the actual monitoring of port construction management.
- ✓ According to our Accuracy Check Result, Target errors (mean error and RMSE within 10 cm) achieved in both horizontal and vertical directions by 50m and 80m Altitude. And It was suggested that accuracy was maintained in remote surveying areas.
- ✓ We are now conducting pilot implementation study at Break water and Reclamation area monitoring. And each showed usefulness like time savings and application to analysis.

【Next Purpose】

- ✓ Continue current implementation study following the monitoring schedules and validate the effectiveness of LiDAR UAV in Port Construction Management.
- ✓ Conduct Detailed Analysis of settlement observations of Marine construction by accumulated 3D Point Cloud data.

LiDAR Survey proves to be a reliable and timesaving alternative for Survey Works!


THANK YOU
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