Annex 1. Proposed Specifications of CORS equipment

Name of Equipment	Specification
GNSS receiver Reference Model of GSI (Geospatial Information Authority of Japan): Trimble NetR9 TOPCON NET-G3; NET-G5 JAVAD DELTA-G3T	The structure shall enable separation from the GNSS antenna.
	It shall be possible to conduct continuous observation without interruption at a sampling rate of 1Hz.
	Satellite tracking: GPS, GLONASS, QZSS, Galileo
	It shall be possible to receive, record, and output signals simultaneously from the positioning satellites below. [GPS(15)] L1C/A、L1C、L2C、L2P、L5 [GLONASS(15)] L1C/A、L1P、L2C/A、L2P [QZSS(7)] L1C/A、L1C、L2C、L5 [Galileo] E1、E5a、E5b、E5-AltBOC
	The number of received channels shall be at least 400 in consideration of the increase in the number of satellites and signals that will be launched in the future.
	At least the following performance shall be achieved for the positioning performance. In accordance with the high accuracy static method, Horizontal accuracy: 3 mm + 0.1 ppm X (distance) RMSE (root mean square error) Height accuracy: 3.5 mm + 0.4 ppm X (distance) RMSE (root mean square error)
	The dustproof and waterproof protection grade shall be at least IP67.
	For the capacity of internal memory, it shall be possible to store at least 60 days of the 1-second sampling observation data from the GPS satellite, GLONASS satellite, QZSS satellite, and Galileo satellite.
	It shall be possible to record and output the data indicated below from the signals received. [GPS] L1, L2, L5 carrier phase L1C/A, L1C, L2P, L2C, L5 code pseudo-range Navigation message Observation station coordinates by point positioning L1, L2, L5 carrier wave signal strength and Doppler shift [GLONASS] L1, L2 carrier phase L1C/A, L1P, L2C/A, L2P code pseudo-range Navigation message Observation station coordinates by point positioning L1, L2 carrier wave signal strength and Doppler shift [QZSS] L1, L2, L5 carrier phase L1C/A, L1C, L2C, L5 code pseudo-range Navigation message L1, L2, L5 carrier wave signal strength and Doppler shift [Galileo] E1, E5a, E5b, E5-AltBOC carrier phase E1, E5a, E5b, E5-AltBOC code pseudo-range Navigation message E1, E5a, E5b, E5-AltBOC carrier wave signal strength and Doppler shift
	It shall be possible to save the observation data that is saved to the internal memory of the receiver in one-hour intervals. In addition, it shall be possible to freely change the time intervals of the saved data.

Name of Equipment	Specification
	Internal memory shall have a function that makes it possible to save observation data that has already been stored without deletion even if the power supply for the receiver is interrupted.
	The output formats shall be RINEX2.x and 3.x, RTCM2.x and 3.x, and NMEA-0183.
	For the real-time data format and data format in the internal memory in the GNSS receiver, resolution shall be at least 10mm at a pseudo-range and at least 0.2 mm at a carrier phase.
	An uninterruptible power supply UPS shall be used as the power source supply for the GNSS receiver.
	There shall be an internal battery capable of at least 12 hours of continuous operation.
	It shall be possible to confirm the operational status of the GNSS receiver and update firmware through remote operation of the web browser.
	Even if the power source supply to the GNSS receiver is interrupted, it shall be possible to reboot the receiver with the same settings as before the power outage automatically when the power source is recovered.
	The language used shall be English. An English manual shall be included.
GNSS antenna Reference Model of GSI (Geospatial Information Authority of Japan): Trimble TRM29659.00; TRM57970.00; TRM59800.80 Topcon TPSCR.G5	The GNSS antenna shall have a choke ring structure and performance that is at least equivalent to the reference models to the left. In addition, the size shall fit the antenna radome.
	The antenna phase characteristics including the combination with the radome shall be disclosed.
	The connecting coaxial cable shall have a structure that includes a coaxial lightning arrester as a lightning countermeasure.
	A model that reduces the impact of interference from radio waves (radio waves from mobile phone base stations and radio waves from air control stations) other than GNSS satellites shall be used.
Radome Reference Model: Scign radome	It shall be installed on top of the antenna pillar to protect the GNSS antenna.
	The material shall have good radio frequency permeability, the shape shall be hemispherical, and the size shall be as GNSS antenna.

Annex2. Report on Social Experiment

[1] AKTIO Corporation

(1) Title

UAV Photogrammetry and reference point surveys using GNSS Markers for Aerial Photogrammetry

(2) Abstract

Use GNSS markers as airphoto signals in UAV photogrammetry. Examine whether the markers can be used as surveying equipment. *GCP -ground control point-surveys

(3) Background

In the future, productivity improvement in the construction industry in Thailand will be an issue. Japan is working on i-Construction positively,so we wond like tospread it in Thailand and help the construction industry. We focus on surveying and condust the experiment in the area. Surveying is well-versed in various fields and is a very important process but highly specialized. Therefore, we have been experimenting with the possibility of using technology that can make surveying work highly accurate for anyone in Thailand.

(4) Objectives

Perform high-precision aerial photogrammetry using GNSS markers and contribute to the efficiency and accuracy of surveying. Reference point surveying will be simplified and the efficiency of surveying operations will be improved. Simplify surveying work and contribute to improving productivity in the construction industry in Thailand.

(5) Contents of the social experiment

(a) Target area

Fig. 1 Target area

(b) Period

27th -29th August 2019

(c) Equipment used

・DJI Co Ltd,. Phantom4 x1 *Borrowed from GISTDA

・Aerosense Inc. GNSS Marker x 6 cars

Fig. 2 Equipment

(d) CORS system used

TOPCON (T-NET)

(e) Methods

Fig. 3　Experiment field

【1－a】Method of obtaining coordinates from reference point in the field *SKP

Fig. 4　GNSS marker

i) Preparation

Install aero marker (1) at reference point A and aero marker (2) at reference point B, and check accuracy. Place the aerobo marker on the reference point and place it for 30 minutes to get the positioning information.

ii) Measurement

Extract the obtained position information data from the aero marker placed on the reference point for 30 minutes and check the reference point coordinate data of SKP.

【1－b】Method of obtaining coordinates from electronic reference point correcting date near the site *SKP

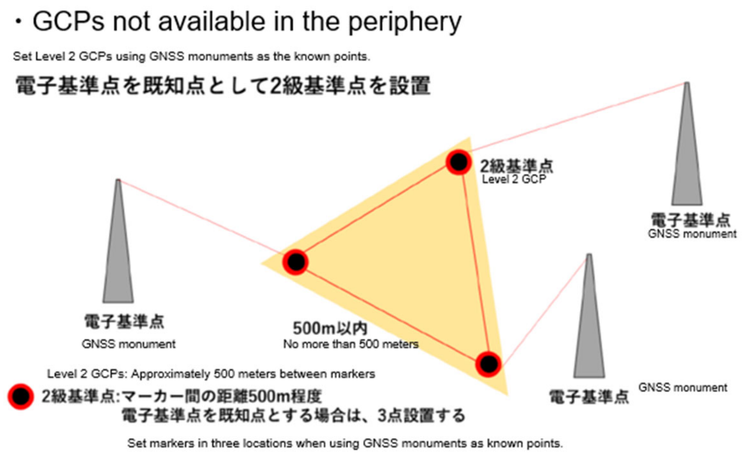


Fig. 5 Method of measurement【1-b】

i) Preparation

Install aero marker (1) at reference point A and aero marker (2) at reference point B, and check accuracy. Place the aerobo marker on the reference point and place it for 30 minutes to get the position information.

ii) Measurement

Extract the obtained position information data from the aero marker placed on the reference point for 30 minutes and check the reference point coordinate data of SKP.

【2】Method of obtaining coordinates from reference points around the site *SKP

Fig. 6 Method of measurement【2】

i) Preparation

Install aero markers at 6 locations, and place them for 30mins to get the location information. Perform aerial photogrammetry so that the aerobo marker is visible.

ii) Measurement

Phantom4 is automatically flying and aerial photogrammetry is performed.
UAV flight altitude: 60 meters, image wrap rate: 90% / 80%

(6) Results

【1－a】Accuracy result: X +2.0 cm / Y +87.0 cm / Z +23.0 cm ⇒ Large error between Y and Z
【1－b】Accuracy result: X +5.9 cm / Y +2.5 cm / Z +44.5 cm ⇒ Large error between Y and Z
【2】 Accuracy results: X 1.1 centimeter / Y 2.0 centimeter / Z 1.2 centimeter
UAV Flight Distance: 596m / Flight Altitude: 60m (2.6cm / pixel) /
Image wrap rate: 90% / 80% / 65 photos taken: 65

(7) Discussion

【1－a】

The accuracy was checked by placing an aero marker on the reference point *GCP. However this material is made of metal and may interfere with the aero marker. Also, the accuracy of the reference point coordinates provided by GISTDA is in sufficiency. Since it was confirmed that the aerobo marker can be used as an electronic reference point, an experimental result was obtained that it could be used immediately in Thailand.

【1－b】

The lack of accuracy in the experiment can be thought that the height was not corrected using the geoid model.
*If there is a geoid model, the accuracy will be within ± 2.0 centimeters.

【2】

The experiment was conducted with high accuracy. If there is a Thailand geoid here, the analysis processing by the cloud can be completed quickly.

(8) Issues/Challenges for the future

【Regarding experimental results】

We tried to download TGM2017 on the homepage of Thai Royal Research Department, Thai Military Headquarters. However, it could not be used because there was no link. From this case,The geoid model will be maintained and widely shared, so that the results will be accurate.

【About import and export】

The aerobo marker is harmless because it only receives location information and does not transmit.

(9) Future developments

Once the geoid model is in place and results come out with high accuracy, we will enable the "make world possible where anyone can easily achieve high accuracy surveying". We think that this technology in Thailand is very effective, and are going to actively conduct demonstrations.

[2] HII

(1) Title

Mobile Mapping System (MMS) and Continuously Operating Reference Stations (CORS) Combination for 3D Dyke Model Generation

(2) Abstract

Hydro-informatics Institute (HII) has a mission to develop and conduct research in Hydro-informatics technology and database, and publish and disseminate the works for the benefit of all in water management fields. Thailand has cooperated with Japan International Cooperation Agency (JICA) on "Request for selection of participant for technical visit to Japan, under JICA technical support for Knowledge and cooperation on the GNSS system development". Under this cooperation, HII has implemented Mobile Mapping System (MMS) technology onto Social Experiment to promote Global Navigation Satellite System (GNSS) Continuously Operating Reference Stations (CORS) 's utilization and its application in Thailand. The roads are used as a flood barrier in Bangkok and its outskirt was selected to measure the elevation, create a visualization 3D model and compare accuracy with RTK in the experiment. The results of this experiment represent that MMS can obtain the ground elevation in the larger area and the different between RTK and MMS show on 0.386 Root-Mean-Square Error (RMSE).

(3) Background

In order to handle water disaster, it is necessary to have specific tools and technologies which could collect data quickly, accurately, precisely, and could be met with the users' need. The tools and technologies must generate outcomes that support disaster preparedness and decision-making process. Steps in preparing for water disaster risk reduction must begin with the measurement of ground elevation. Presently, HII uses Static and Real-Time Kinematic (RTK) methods to survey which is highly accurate and useful, but in a larger scale surveying, these methods are time-consuming and labor-intensive. Therefore, MMS has been developed for improving ground-level observation which is significantly faster than the present methods. Application of MMS on water resource management is one of the main objectives of this project. This project aims to find the suitability and limitation of MMS method for effective outcomes that could represent the overall condition of particular area.

(4) Objectives

(a) To find suitable methods in observing water ridge elevation by using MMS and CORS data.

(b) To compare the differences set of water ridge elevation data that derived from MMS and RTK.

(c) To create three-dimension water ridge model around Bangkok and outskirt area.

(5) Contents of the social experiment

(a) Target area

The target area is Bangkok and its outskirt, which can be separated into two parts. Firstly, the highway along the Western Raphiphat canal was selected as a study area to compare ground elevation observation derived from MMS and RTK, which is the total 14 kilometers survey distance. Another, the western-eastern ring road of Bangkok and Paholyothin road (Zeer to Bang Pa-in) was selected to observe ground elevation by MMS because of these roads as a flood barrier of central Bangkok, which the total survey distance is approx. 100 kilometers. (See the observed map in Fig. 7)

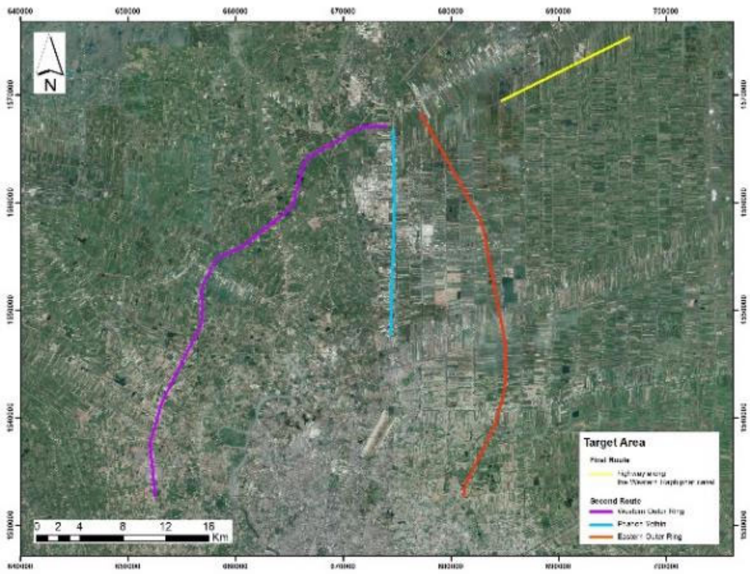


Fig. 7 Target area: Highway along the Western Raphiphat canal (Yellow) and the western-eastern ring road of Bangkok and Paholyothin road (Violet, Orange, and Blue respectively)

(b) Period of the social experiment.

1st May 2019 -31st July 2019

(c) Equipment used

i) Mobile Mapping System (MMS)

Including multi-sensors; (1) Ladybug 360° spherical camera (2) Laser Scanner, (3) GNSS+INS receiver and Dual Antenne is shown in Fig. 8.

Fig. 8 HII MMS

ii) GNSS Receiver for RTK

Leica GS10 as a multi-frequency receiver is used to survey RTK method.

(d) Precise Positioning Data used

(a) GNSS receiver of MMS is multi-frequency and GPS+GLONASS receiver.

(b) GPS+GLONASS Rinex observation data from THAI HII CORS for post-processing with MMS data. The coverage area of HII GNSS CORS Network is shown in Fig. 9.

(c) HII GNSS CORS Network server transmits RTCM correction stream for the virtual reference station (VRS) as correction data to Leica GS10 rover via 4G network for RTK surveying.

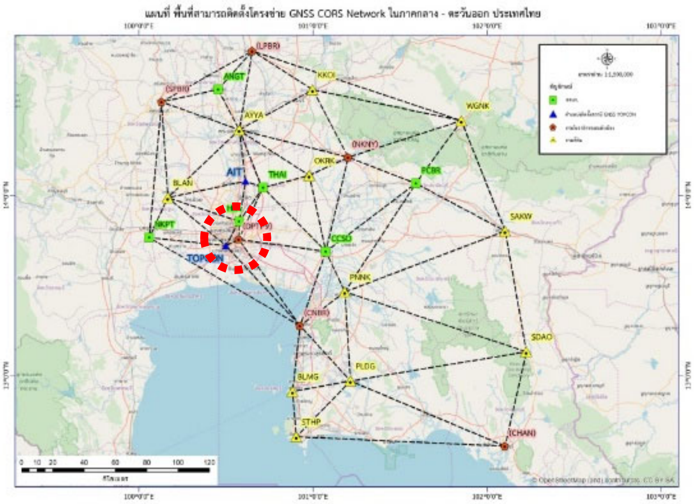


Fig. 9 HII GNSS CORS Network

(e) Methods

i) Ground elevation survey and data collection

- The target area is selected for this ground elevation observation, and it is separated into 2 sections for supporting 2 objectives as mention in Target area part. Then, the survey plan is set up.

- RTK observing method which positioned every 200 meters of the highway along the Western Raphiphat canal, that VRS concept is used to access correction services from HII GNSS CORS Network via 4G network.
- After that, MMS drove approx. 60 kilometers/hour to scan all target areas.

ii) Data processing

- Because of having multi-sensors on MMS, it creates different types of data. Step of post-processing starts at combination all of the data from MMS including positioning data, Point Cloud data and also observation data from THAI HII CORS.
- Then, the processed MMS data of the highway along the Western Raphiphat canal are selected to compare elevation with RTK. Before that, Thailand Precise Geoid Model 2017 (TGM2017) was adjusted to the RTK and MMS data in order to convert ellipsoid height to orthometric height (above Mean sea level: MSL height).
- Finally, the processed MMS data of the western-eastern ring road of Bangkok and Paholyothin road are used to create 3D visualization and profile leveling map.

(6) Results

The results would be summarized based on the objectives. The three key results of this project are:

i) Suitable water ridge elevation methods that align with MMS

- One of the main goals of the project is applying MMS to collect the data and adjusting with observation data from HII GNSS CORS. MMS obtained the multi-data including lidar data from Velodyne, the trajectory from IMU and GNSS, and high resolution image from Ladybug. Finally, MMS achieved the total 120 kilometers. survey distance within 6 hours, and MMS observing method scanned all the points past by vehicle at speed of 60 kilometers/hour.

ii) Comparative of water ridge elevation between MMS and RTK methods

- In this part, the height above MSL of parallel Raphiphat canal road derived from the two methods for comparison. The RTK method provides more accurate data thus RTK data as the reference. The results of ground elevation of MMS are almost equal, and the trend of both shows in the same way. Moreover, Root-Mean-Square Error (RMSE) between two data sets was 0.386.

Fig. 10 Comparative ground elevation results by RTK (Green) and MMS (Red)

iii) Three-dimension results of water ridge elevation along Bangkok's highway

- The process of data collection is done by MMS along the routes (The western-eastern ring road of Bangkok and Paholyothin road). The results are represented in Point Cloud in LAS file format by combining data from multi-sensors, then it was post-processing by observation data from THAI HII CORS to increase the position's accuracy. Moreover, the visualization 3D results are generated in this project as Fig. 11 (Left). The profile of water ridge elevation is created on MSL, and this result can describe the degree of elevation from the three different roads are varied. In the Fig. 11 (Right), as Phahon Yothin road (mark in light blue) is at the lowest elevation points as compare to Western Outer Ring and Eastern Outer Ring. Phahon Yothin road is considered as a hazard area.

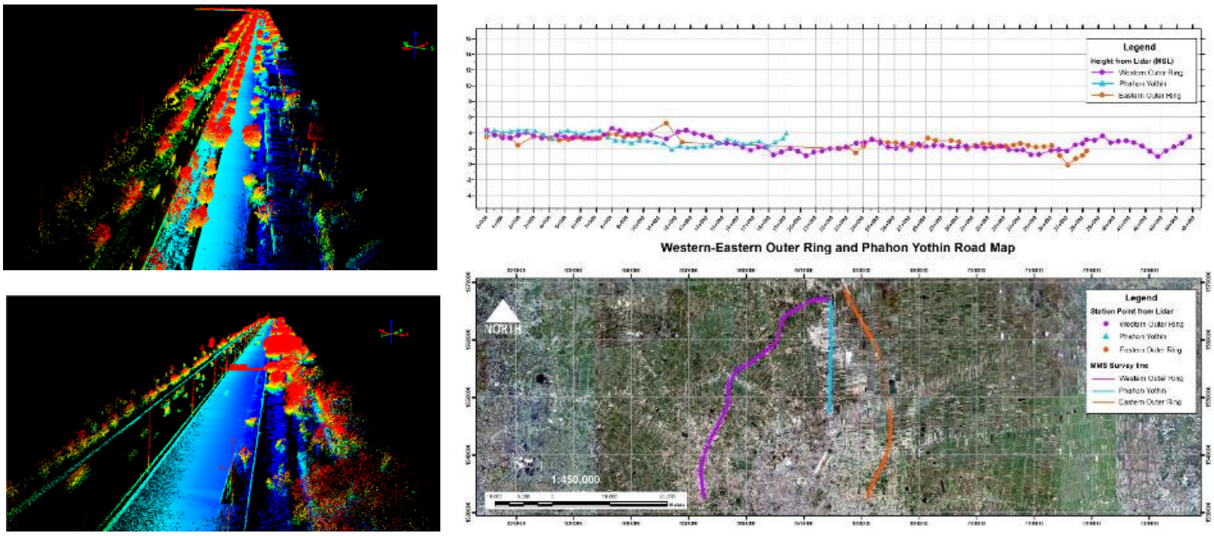


Fig. 11 Left: Example of visualization 3D model, Right: the Western – Eastern Outer Ring Road and Phahon Yothin Road Profile leveling map

(7) Discussion

While not all of the results were significant, the overall direction of results indicated that MMS could be helpful to collect the data because of the efficiency of MMS. It supported a large scale area survey faster than other methods, which was 120 kilometers survey distance within 6 hr. while RTK method requires a longer surveying period. Time-consuming from MMS measurement is shorter than RTK 12 times. Depending on the condition of each work. In addition, the result of comparison of height from MMS and RTK method, it was found that the result from both systems showed the trend in the same direction and 0.386 RMSE. Since the MMS will visualize the outcome in 3D data such as watergates, width, and height of canals and obstacles, it helps to illustrate the overall image of the area for better management and immediate response.

MMS is more preferable for disaster preparedness. MMS could interpret the changes in ground elevation and easier to detect and determine the water overflow and the direction for draining water. In the future, the data from MMS will be an effect of different ways of water management.

(8) Issues for the future

- Bangkok and outskirt areas will be considered to collect the data for further analysis.

(9) Future developments

- Performance of processing system to deal with huge data of MMS
- Automated filtering data system will be developed to support faster a result generation.

[3] Iwane Laboratories, Ltd. & Iwane Laboratories, Thailand

(1) Title

Accuracy Assessment of Mobile Mapping System (MMS) using CORS network

(2) Abstract

In the SKP (Space Krenovation Park: Science and Technology Center) site in Thailand, we put a GNSS on our mobile mapping system (IMS3) and captured a few kilometers of road imagery within the area. We used the electronic reference point CORS network in this test and found that we can make much use of this network to generate our CV imagery with 3D coordinates.

(3) Background

We have our own product of image-based mobile mapping system that can collect digital content in the required area at the required time. Once the collected omnidirectional video is uploaded to the cloud, the video and the related data can be shared easily with personal computers or tablets via our web application. Since the video is very compatible with Artificial Intelligence, new algorithm that can not only recognize each objec in the video automatically but also calculate its positional coordinate is currently under development. In addition, these techniques can be used to generate and update 3D maps that are indispensable for autonomous driving. In order to make our technology and services more popular and expansive in Thailand, the use of CORS network must be very helpful and beneficial.

In fact, our group has a track record in the following governmental sectors in Thailand, and its coverage is more than 60,000 km.

- DOH:Department of Highway, Ministry of Transport, Thailand
- DRR:Department of Rural Road, Ministry of Transport, Thailand
- Department of Public Works and Town & Country Planning of Thailand
- Traffic and Transportation Department of BMA, Thailand

Since the use of the CORS network is expected to be extremely effective in the implementation of such projects in the future, we would like to regard the participation in this experiment as a good opportunity to improve our mobile mapping system to a more suitable form for the CORS network.

(4) Objectives

Verify the accuracy of CV imagery in both urban and rural areas using CORS network.

(5) Contents of the social experiment

(a) Target area

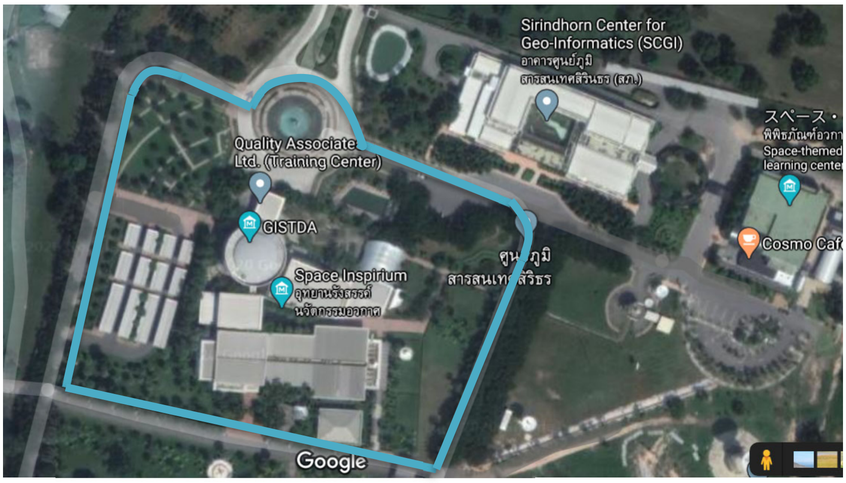


Fig. 12 Target area（inside SK, 2.3 liner km）

(b) Period

- Travel photography and data collection: 14th August 2019 (12: 00-14: 00)
- Obtaining a RINEX format file from the CORS network: 26th August
- Data processing work: 27th -28th August 2019

(c) Equipment used

- Our mobile mapping system (IMS3) Refer to photo on next page

Fig. 13 Outlook of Iwane Mobile Mapping System（IMS3）

Fig. 14 GNSS: Novatel PwrPak7-E1

（d）Data used

Post-processing work was performed using RINEX format files from the CORS network

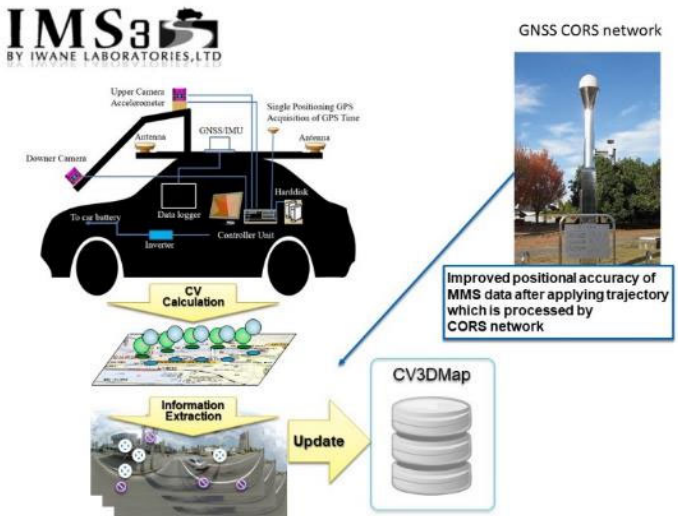


Fig. 15 Overview

(e) Methods

i) Preparation

- Setup and calibration adjustment of equipment to vehicles
- Selection of data collection area
- Data collection by running shooting
- Download format file from CORS network
- Implementation of data processing
- Check accuracy results

ii) Measurement

- Data collection
- Data processing was performed using RINEX format files obtained from the CORS network
- Data processing was performed using only GNSS data
- Comparison of accuracy when using CORS network and using GNSS data

(6) Results

We found the use of the RINEX format file collected from the CORS network so much reduced the amount of our work that its efficiency was improved compared with the conventional survey method (implemented in SKP in 2014) where base stations should be set up within the area of operation. During this experiment, a series of task were quite comfortable. The processing procedure for the RINEX format file was also easier than we had expected and the accuracy was also high. We can expect that this high accuracy can be secured when we generate CV imagery with 3D coordinates by our mobile mapping system.

Table 1 Trajectry collected by Inertial Explorer （Ver.8.70.6404）

Number of Epochs	Total in GPB file	14,489
	No processed position	9,574
	Missing Fwd or Rev	798
	With bad C/A cod	0
	With bad L1 Phase	0
Measurement RMS Values	L1 Phase	0.0213 (m)
	C/A Code	0.93 (m)
	L1 Doppler	0.081 (m/s)
Fwd/Rev Separation RMS Values:	East	0.068 (m)
	North	0.077 (m)
	Height	0.400 (m)
wd/Rev Sep. RMS for dual FWD/REV fixes (2337 occurances)	East	0.017 (m)
	North	0.019 (m)
	Height	0.050 (m)
Quality Number Percentages	Q1	55.7%
	Q2	34.3%
	Q3	9.9%
	Q4	0.0%
	Q5	0.0%
	Q6	0.0%
Position Standard Deviation Percentages	0.00 - 0.10 m	88.1%
	0.10 - 0.30 m	11.9%
	0.30 - 1.00 m	0.0%
	1.00 - 5.00 m	0.0%
	5.00 m + over	0.0%
Percentages of epochs with DD_DOP over 10.00:	DOP over Tol	3.00%
Baseline Distances:	Maximum	41.944 (km)
	Minimum	0.059 (km)
	Average	11.973 (km)
	First Epoch	41.944 (km)
	Last Epoch	0.059 (km)

(7) Discussion

The CORS network in Thailand has proved more useful in many fields than we had expected. Above all, it seems to be quite useful and effective in the field of surveying.

.

(8) Issues for the future

In order to make our shooting and data processing easier and faster, we will improve the equipment configuration and work on updating related software while collecting the latest information of equipments and devices. In addition, it is necessary to establish an organization that can handle maintenance and support as well as field shooting and data processing.

(9) Future developments

Since the effectiveness of the CORS network was confirmed after this experiment, we would like to use this network actively and develop 3D maps throughout Thailand by taking advantage of the opportunities of both public projects and our company's voluntary business, while conducting continuous experiments by ourselves in both the urban and rural fields in Thailand.

[4] Kaiteki-Kukan – FC Co., Ltd. & PASCO (Thailand) Co.,Ltd.

(1) Title

Accuracy Evaluation of Basic Data for Determination of Disaster Situation Based on UAV-Borne Laser Survey

(2) Abstract

This demonstration experiment was conducted on two sites at the SKP (SpaceKrenovationPark) site and in Sri Racha city (see Fig. 16). 3D data was acquired using a mobile mapping system, and the resulting position accuracy and 3D data acquisition status were evaluated, confirming whether the data would be useful in the field of disaster prevention and management.

(3) Background

In Thailand, there are various low-lying areas that suffers from flash-flood of about 1m deep everytime in heavy rain even in just short time. It is believed that the data that can be used for the extraction, investigation, and design of the area where there is a risk of flooding can be reduced and mitigated by acquiring high-accuracy planar 3D data.

(4) Objectives

The purpose of this experiment was to verify whether the construction period could be shortened from the survey stage to the design stage and the project be improved by applying the disaster prevention plan and public works in Thailand.

(5) Contents of the social experiment

(a) Target area

Fig. 16 shows the location map of the demonstration experiment. The left figure is MMS measurement in Sri Racha city. The figure on the right shows the scope of UAV laser measurement in SKP.

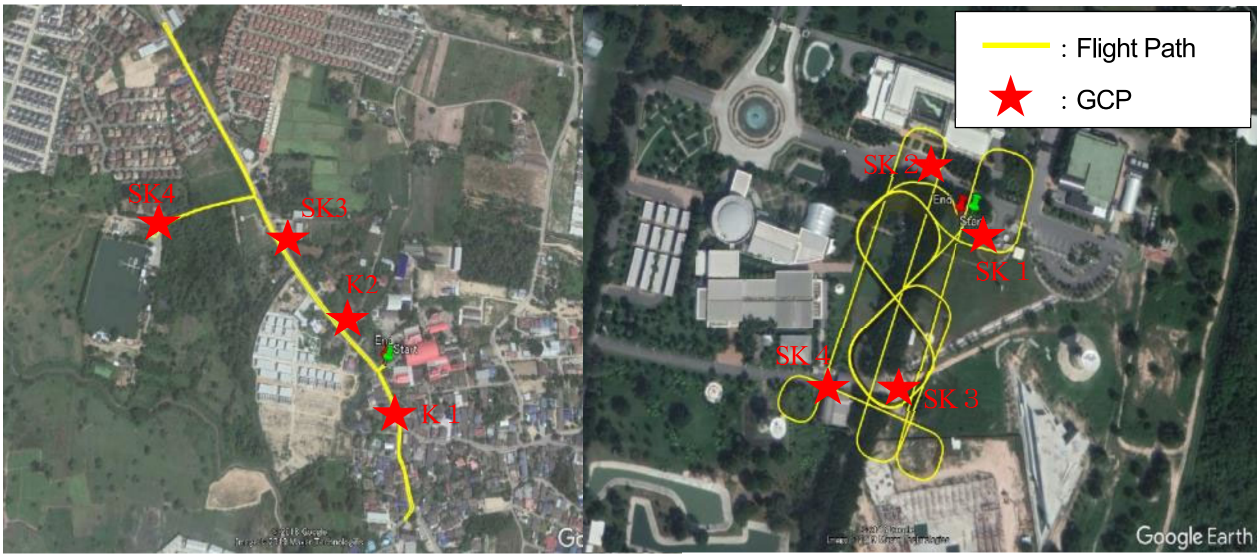


Fig. 16 Target area (Left: Sri Racha MMS, Right: SKP UAV laser)

(b) Period

- Site Survey: 3rd – 5th July 2019
- Data acquisition: MMS (27th August), UAV laser (28th August), SKP Reference Station Data and Sri Racha city VRS data acquisition (27th – 29th August), Static Point Data (27th – 29th August)
- Data Analysis and Evaluation : (27th August – 27th Sepetember)

Fig. 17 Equipment used

(c) Equipment used

- PHOENIX LIDAR SYSTEMS Laser Scanner (Velodyne VLP-32 with KVH-1750 IMU with GNSS Receiver)
- GNSS Receiver, etc.

(d) CORS system used

For accuracy validation, VRS data was streamed from TOPCON (T-NET), HII and DOL respectively.

(e) Methods

i) Planning & Preparation

- Carrying Out Field Survey

The field survey was conducted on July 4th and 5th, identifying UAV takeoff and landing locations, checking for flight obstacles, and checking the local topographic conditions.

Fig. 18 Site verification

- Flight Permit Application, etc.

To fly unmanned UAV in Thailand, a flight permit from The Civil Aviation Authority of Thailand (CAAT) is required. Therefore we have applied as such, however we did not the approval on-time for the planned work period. Hence the data acquisition in Sri Racha City was amended into MMS data acquisition.

ii) Data acquisition

For data acquisition, 3D measurement data was taken with MMS and UAV lasers using the equipment shown in Fig. 17. Note that data acquisition in the range shown in Fig. 19 was about 10 minutes.

iii) Static data observation

The static data observation was conducted using GNSS receivers to obtain local location information (hereinafter referred to as “GCP”) to verify the accuracy of the 3D data, and compared with the 3D data.

iv) Data analysis

Data obtained with MMS and UAV lasers were subjected to post-processing analysis using VRS data distributed from each institution to create point cloud data. Fig. 19 shows the 3D data point cloud in the created SKP site.

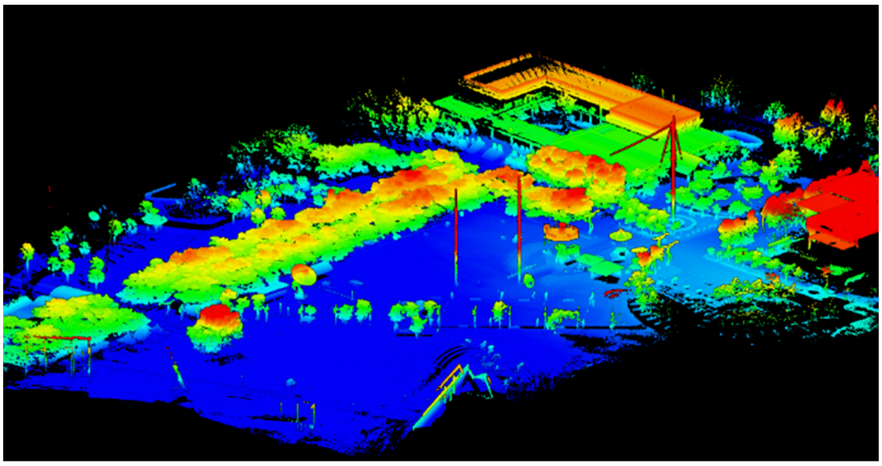


Fig. 19 3D data points acquired with UAV laser

v) Experiment Verification

- UAV Laser Data Verification by Height

  3D laser data (LP) acquired by mobile laser units and data (GCP) acquired locally were subjected to post-processing analysis using VRS data of each institute, and the position accuracy was compared.

- Verification of GCP Static Observation Data

  GCP data observed by the static method was organized and checked.

- Validation and Verification of VRS Data from Each Institute.

  Since the position accuracy varies depending on the the base data used, the status of VRS data streamed from each organization was checked.

- Verification on the Apllicability of MADOCA Method

  During the actual work period, the correction data could not be received in real-time. Therefore data was obtained after returning to Japan and it was applied to post processing analysis.

- Effectiveness of the Acquired 3D Data

  We examined whether the data can be used as a part of a disaster prevention plan or survey design data..

(6) Validation results

(a) Result of UAV Laser Data Verification by Height

The point cloud data obtained by mobile laser system and the height data obtained at the site were compared and summarized in Table 2 and Table 3. For post-processing analysis, SKP reference stations, TOPCON-VRS, HII-VRS, and DOL-VRS data were used, and the VRS virtual reference point was set at the center of the MMS measurement area.

Table 2 27 August, MMS (Sri Racha city) Accuracy Verification Results

	SKP基準局		較差	TOPNET－VRS		較差	HII－VRS		較差	DOL－VRS		較差
	LP	GCP		LP	GCP		LP	GCP		LP	GCP	
K1	-4.497	-4.476	-0.021	-4.488	-5.295	0.807	-4.063	-4.648	0.585	28.629	-5.398	34.027
K2	-5.927	-5.918	-0.008	-5.932	-5.536	-0.396	-6.039	-6.013	-0.027	-41.804	-6.860	-34.944
K3	-5.484	-5.479	-0.005	-5.486	-5.539	0.053	-5.620	-5.608	-0.012	-14.681	-6.544	-8.137
K4	-5.225	-5.209	-0.016	-5.245	-4.607	-0.638	-4.812	-5.350	0.539	2.673	-6.250	8.923

Table 3 28 August, UAV Laser (Within SKP Area) Accuracy Verification Results

	SKP基準局		較差	TOPCON-VRS		較差	HII-VRS		較差	DOL-VRS		較差
	LP	GCP		LP	GCP		LP	GCP		LP	GCP	
SK1	23.489	23.509	-0.020	23.481	23.460	0.020					20.177	
SK2	21.190	21.231	-0.041	21.183	21.387	-0.204	No data provided			VRS data had problems		
SK3	19.335	19.419	-0.084	19.320	19.336	-0.016						
SK4	18.781	18.813	-0.031	18.775	18.770	0.005					17.692	

In the MMS accuracy check, it can be observed that the accuracy of the data analyzed using the SKP reference station is good. On the other hand, DOL-VRS is considered inaccurate and has problems with VRS distribution data. TOPNET-VRS and HII-VRS must be evaluated considering the FIX rate during GCP observation.

In the UAV lasers accuracy check, the data have shown that both SKP reference stations and TOPCON-VRS have obtained good accuracy. For GCP with a large difference, the effect of the aerial view above the GCP installation location may be a cause. HII-VRS was unable to receive VRS data during GCP observation time, so post-processing analysis could not be performed. DOL-VRS was unable to perform post-processing analysis due to a defect in VRS data. We will explain in detail about the problem of the distribution data later.

(b) Validation check for static GCP data

The checking of GCP observation data was carried out using observation data obtained for four points in each area. GCP observations were performed for 1 second based on 20 minutes in Sri Racha area and 30 minutes in SKP site. The results are shown in Table 4 and Table 5. The standard deviation value was calculated using only the FIX solution.

Table 4 Sri Racha Area GCP Observation Result

		SKP基準局						TOPNET - VRS					
		FIX %	全エポックス数	STDEV	Max	Min	Average	FIX %	全エポックス数	STDEV	Max	Min	Average
K1	X	77.4%	1212	0.008	713632.452	713632.398	713632.423	48.8%	1212	0.794	713633.820	713632.045	713632.569
	Y			0.006	1452120.186	1452120.159	1452120.172			0.006	1452119.535	1452119.511	1452119.522
	Z			0.027	-4.369	-4.531	-4.476			0.126	-5.023	-5.457	-5.295
K2	X	99.8%	1222	0.007	713544.422	713544.390	713544.407	58%	1222	0.231	713544.422	713543.542	713543.980
	Y			0.003	1452278.519	1452278.498	1452278.504			0.144	1452278.797	1452278.258	1452278.580
	Z			0.017	-5.867	-5.961	-5.918			0.587	-5.198	-7.280	-5.536
K3	X	100%	1208	0.012	713408.647	713408.592	713408.619	69.1%	1208	0.016	713408.657	713408.592	713408.629
	Y			0.003	1452446.224	1452446.211	1452446.217			0.003	1452446.226	1452446.211	1452446.218
	Z			0.037	-5.392	-5.576	-5.479			0.050	-5.435	-5.646	-5.539
K4	X	100%	1208	0.005	713144.166	713144.144	713144.156	76.2%	1208	0.315	713145.349	713144.155	713145.254
	Y			0.003	1452483.280	1452483.264	1452483.273			0.029	1452483.280	1452483.208	1452483.235
	Z			0.013	-5.153	-5.255	-5.209			0.187	-4.509	-5.286	-4.607
		HII - VRS						DOL - VRS					
		FIX %		STDEV	Max	Min	Average	FIX %		STDEV	Max	Min	Average
K1	X	84.4%	1212	0.008	713632.496	713632.430	713632.463	10.8%	1212	0.008	713632.278	713632.224	713632.235
	Y			0.003	1452120.142	1452120.123	1452120.132			0.006	1452120.216	1452120.187	1452120.208
	Z			0.038	-4.500	-4.734	-4.648			0.037	-5.274	-5.453	-5.398
K2	X	99.8%	1222	0.005	713544.477	713544.444	713544.460	59.7%	1222	0.156	713544.470	713543.636	713544.155
	Y			0.002	1452278.479	1452278.459	1452278.465			0.007	1452278.570	1452278.537	1452278.552
	Z			0.013	-5.968	-6.050	-6.013			0.017	-6.812	-6.892	-6.860
K3	X	100%	1208	0.008	713408.690	713408.636	713408.658	17.5%	1208	0.011	713408.494	713408.429	713408.465
	Y			0.002	1452446.193	1452446.182	1452446.187			0.006	1452446.281	1452446.243	1452446.254
	Z			0.029	-5.517	-5.682	-5.608			0.037	-6.408	-6.646	-6.544
K4	X	100%	1208	0.008	713144.209	713144.166	713144.195	3%	1208	0.003	713144.003	713143.992	713144.002
	Y			0.003	1452483.268	1452483.253	1452483.261			0.002	1452483.322	1452483.315	1452483.319
	Z			0.018	-5.281	-5.394	-5.350			0.009	-6.231	-6.269	-6.250

Table 5 SKP Area GCP Observation

		SKP基準局						TOPNET - VRS					
		FIX %	全エポックス数	STDEV	Max	Min	Average	FIX %	全エポックス数	STDEV	Max	Min	Average
SK1	X	100%	1859	0.003	709197.574	709197.552	709197.564	99.5%	1859	0.005	709197.585	709197.563	709197.571
	Y			0.002	1449240.382	1449240.370	1449240.375			0.004	1449240.386	1449240.366	1449240.374
	Z			0.009	23.554	23.461	23.509			0.013	23.520	23.404	23.460
SK2	X	90.1%	1834	0.007	709160.827	709160.794	709160.810	59%	1834	0.290	709162.001	709160.783	709160.908
	Y			0.003	1449284.611	1449284.590	1449284.599			0.004	1449284.609	1449284.588	1449284.599
	Z			0.026	21.308	21.164	21.231			0.523	23.049	21.127	21.387
SK3	X	85.5	1805	0.007	709123.062	709123.018	709123.042	27.4%	1805	0.491	709124.307	709121.726	709123.213
	Y			0.005	1449149.643	1449149.606	1449149.622			0.051	1449149.881	1449149.595	1449149.629
	Z			0.029	19.511	19.349	19.419			0.357	21.314	18.668	19.336
SK4	X	97.7%	1808	0.005	709079.805	709079.783	709079.792	99.9%	1808	0.007	709079.816	709079.772	709079.792
	Y			0.007	1449150.090	1449150.059	1449150.076			0.005	1449150.099	1449150.071	1449150.084
	Z			0.014	18.864	18.774	18.813			0.018	18.832	18.722	18.770
		HII - VRS						DOL - VRS					
		FIX %	全エポックス数	STDEV	Max	Min	Average	FIX %	全エポックス数	STDEV	Max	Min	Average
SK1	X							64.1%	1859	0.057	709195.906	709195.710	709195.801
	Y									0.023	1449240.146	1449240.075	1449240.099
	Z									0.157	20.459	19.863	20.177
SK2	X	No data provided						81%	1834	0.018	709160.707	709160.577	709160.633
	Y									0.009	1449284.668	1449284.630	1449284.646
	Z									0.045	20.293	19.987	20.178
SK3	X							74.4%	1805	0.013	709122.877	709122.801	709122.839
	Y									0.008	1449149.696	1449149.654	1449149.680
	Z									0.050	18.523	18.227	18.359
SK4	X							11.2%	1808	0.010	709079.609	709079.566	709079.589
	Y									0.004	1449150.166	1449150.138	1449150.152
	Z									0.018	17.739	17.650	17.692

From the observation results, it was confirmed that each institution had different FIX rates and variations in the observed values. Differences in accuracy are confirmed at the same point as in Sri Racha area “K4”. These results suggest that the distance from the electronic reference point used by each institution and the satellite at the time of GCP observation affect the position and reception conditions.

(c) Verification results of VRS data of each organization (TOPCON, HII, DOL)

As mentioned above, since the difference in accuracy was confirmed by the base data used for the post-processing analysis, the data of 27th August were used for post-processing analysis and verification of the VRS data of the SKP base station and each organization. The verification results are organized by standard deviation every hour, and the results are shown in Fig. 21, Fig. 22 and Fig. 23 in DOL-VRS data, it was confirmed that the reference station coordinate data in the distribution data was distributed differently, so the data was deleted and verified (Fig. 20).

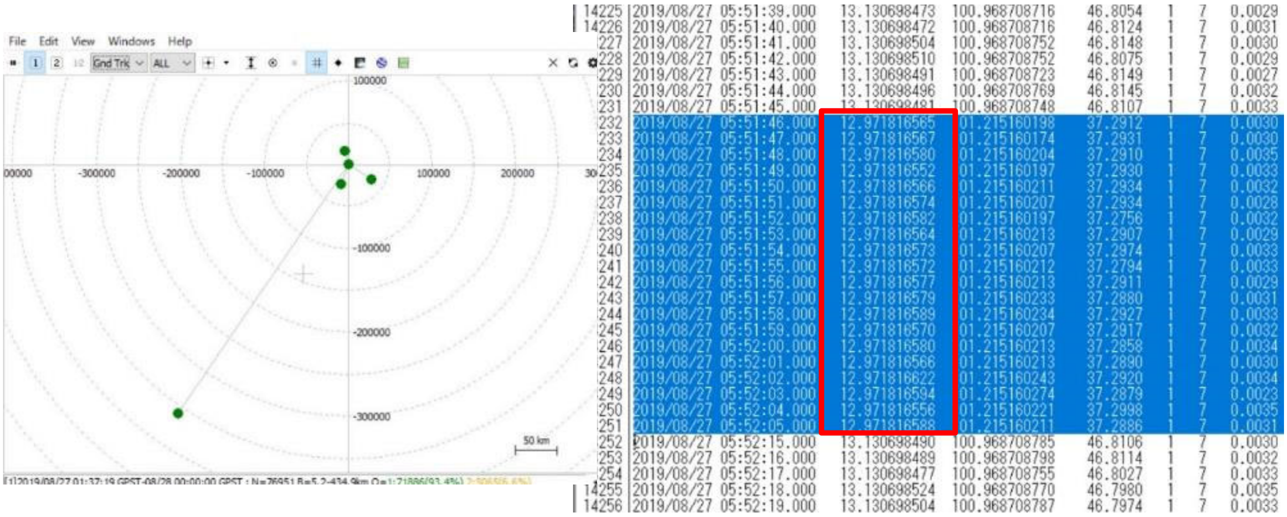


Fig. 20 Data With Fluctuating Reference Station Coordinates

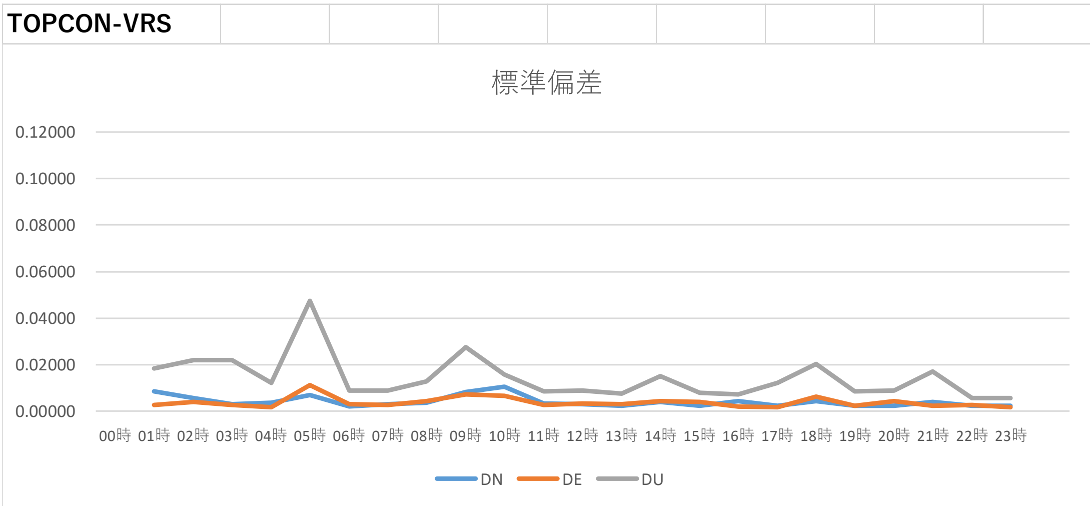


Fig. 21 TOPCON-VRS Hourly Analysis Results (Standard Deviation)

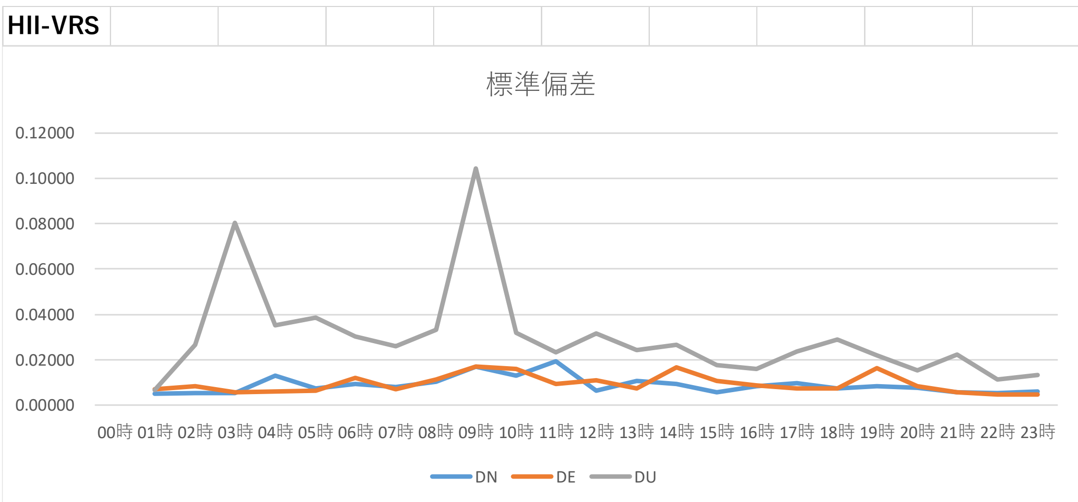


Fig. 22 HII-VRS Hourly Analysis Results (Standard Deviation)

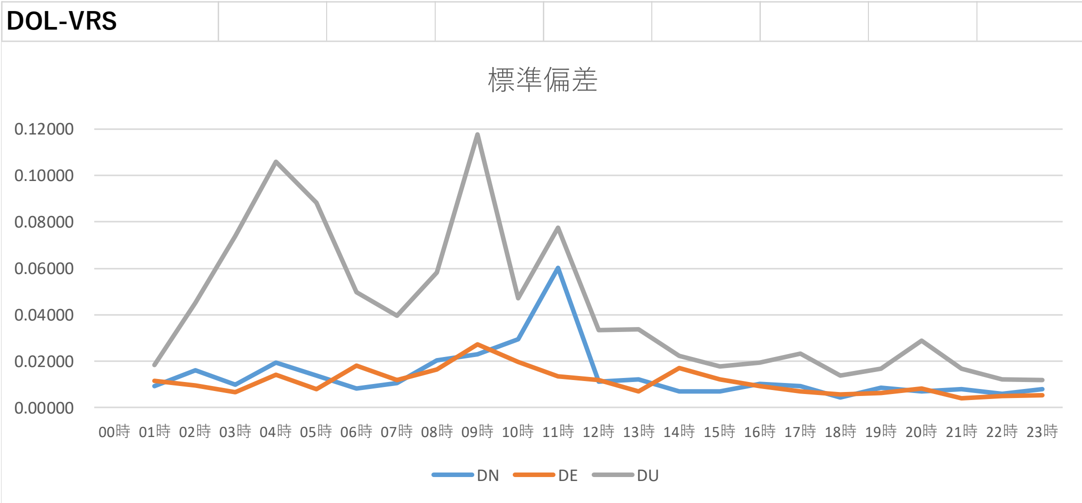


Fig. 23 DOL-VRS Hourly Analysis Results (Standard Deviation)

From the VRS data for one day, it was confirmed that the accuracy of each institute varied, and TOPCON-VRS confirmed that there was little variation in the analysis results. DOL-VRS was analyzed as described above, with the phenomenon that the coordinate values of the reference station that were sent were fluctuated, and the shifted data was deleted. By time zone, variation was confirmed in the daytime time in Thailand (In graph 05:00 is 12:00 in Thailand). These are thought to be influenced by the state of the ionosphere due to solar activity.

(d) Effectiveness of utilizing 3D data as disaster prevention plans and survey design materials

Verified 3D data acquired by UAV can be used to determine whether the data contributes to disaster prevention plan and survey design data. The data acquired in the SKP site can be confirmed from the three-dimensional data of the area, and the level difference of the area and the fine topography of the area can be confirmed firmly (see Fig. 24).

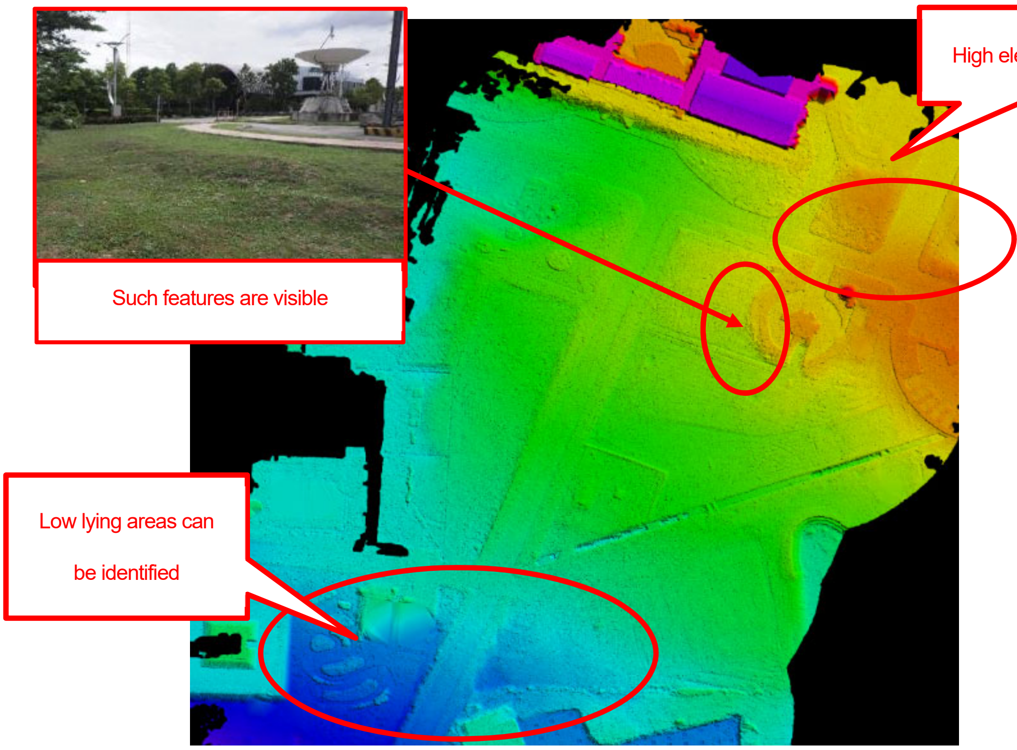


Fig. 24 Elevation Map Created From Ground Data

The ground (road) data under vegetation, which is the best strenght of the laser method, can be seen clearly (Fig. 25). By using these three-dimensional data, a wide-area survey can be completed in a short time in the survey stage, and it is possible to survey safely even in places where it is difficult for workers to enter. Since plane 3D data is acquired at the design stage, multiple examinations such as cross-sectional views and height confirmation at any location are possible, and no additional work such as on-site re-investigation is required. Can contribute to shortening the construction period.

Fig. 25 Laser Data Sample (Left side: Actual Photograph, Right side: Laser Data)

(7) Evaluation of positioning accuracy analyzed by MADOCA

We evaluated positioning accuracy analyzed by MADOCA by using the results of GNSS data observed at GCPs and those acquired during UAV laser measurements in SKP. RTKLIBver2.4.33b33 was used for this analysis.

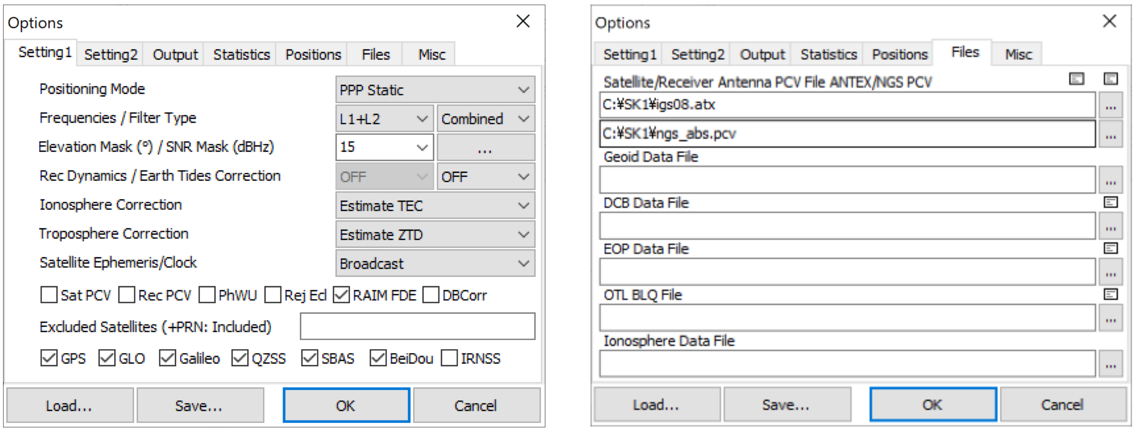


Fig. 26 Analysis conditions for RTKLIB

(a) Evaluation by observation at GCPs

We carried out static observation for approx. 30 minutes at each GCP. The results were that the standard deviation (STD) of horizontal component was approx.10cm and that of vertical was approx. 20cm.

Table 6 Observation results at GCPs in SKP (MADOCA)

GCP	Epochs		STD	Maxmum	Minimum	Max-Min
SKP1	1859	X	0.027	709197.717	709197.607	0.110
		Y	0.051	1449240.334	1449240.135	0.199
		Z	0.268	26.295	25.345	0.950
SKP2	1834	X	0.077	709161.697	709161.426	0.271
		Y	0.051	1449284.420	1449284.234	0.186
		Z	0.246	23.061	22.142	0.919
SKP3	1805	X	0.086	709122.684	709122.379	0.305
		Y	0.057	1449149.575	1449149.347	0.228
		Z	0.275	22.551	21.508	1.043
SKP4	1808	X	0.120	709079.523	709079.147	0.376
		Y	0.149	1449150.039	1449149.559	0.480
		Z	0.222	21.625	20.859	0.766

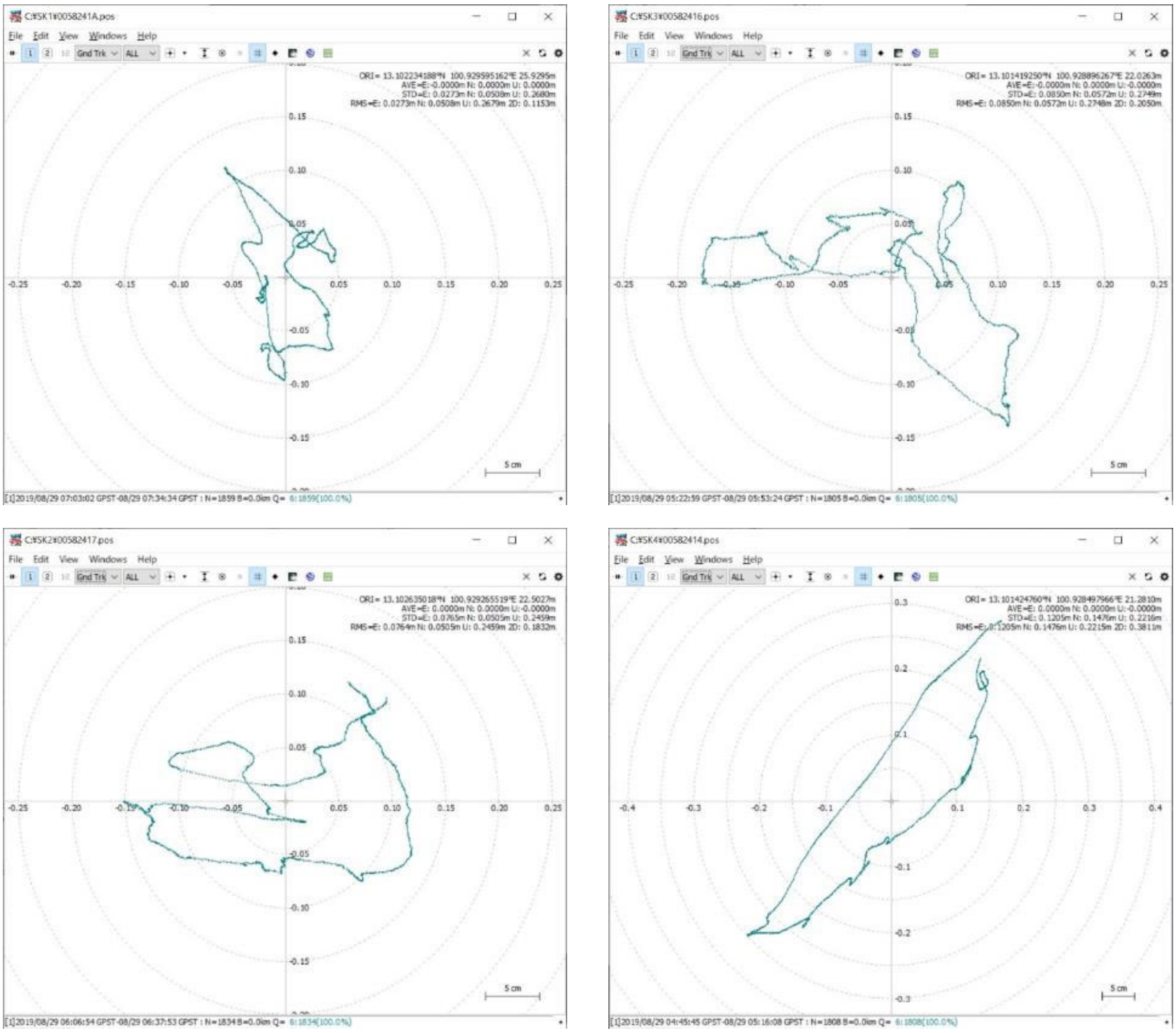


Fig. 27　Behavior of horizontal components of GCP observations using MADOCA

（Top left: SKP1, top right: SKP2, down left: SKP3, down right: SKP4）

（b）Evaluation by observation of a moving body

We analyzed and evaluated positioning accuracy by using GNSS observation data which was acquired during UAV laser measurements.

Fig. 28 shows horizontal differences, and Fig. 29 shows vertical differences between a) results of kinematic analysis using SKP-TOPCON as a base station and b) results of analysis by MADOCA-PPP. It was confirmed that differences during straight flight are stable with horizontal shift error of 1.00m and vertical shift error of -1.88m. However, differences during figure-eight flight and at takeoff and landing tend to be larger.

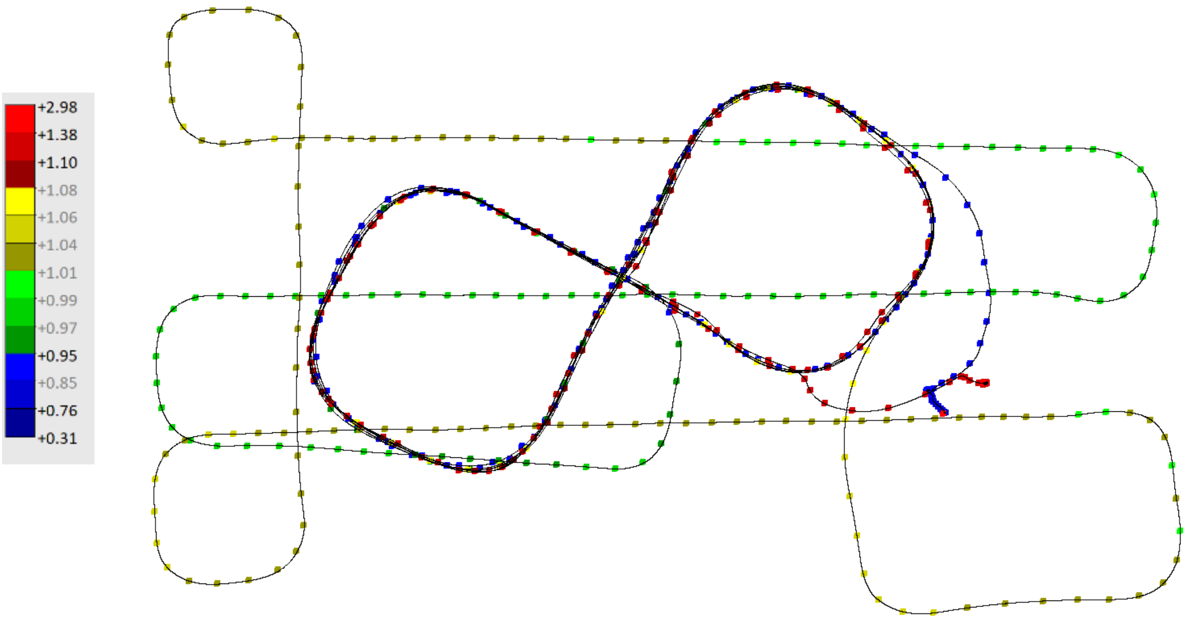


Fig. 28 Result of analysis of observation using MADOCA (Horizontal differences)

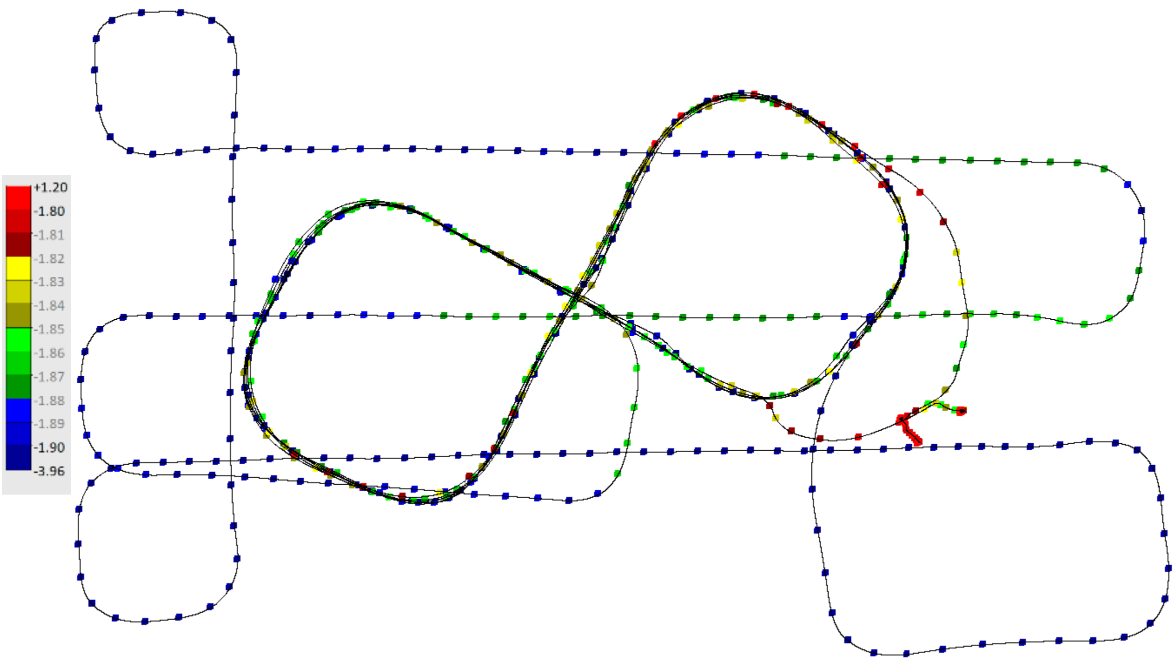


Fig. 29 Result of analysis of observation using MADOCA (Vertical differences)

(8) Discussion

The results of this experiment in Thailand can be applied to disaster prevention plans and public works. On the other hand, the accuracy of 3D data for moving object measurement is affected by GNSS positioning. Caution must be taken at this time because the accuracy of the three-dimensional data obtained from the results of this experiment may vary greatly depending on the institute data used.

(9) Issues for the future

- There were times when HII-VRS data could not be received and connection was cut off.
- The DOL-VRS data had a phenomenon where the coordinate value of the reference station flew off to another location.
- The distance between the reference points is an issue to the accuracy.

Fig. 30 Work Site Location in Relation to Reference Stations

In UAV surveys, it is necessary to apply for flight permit to the authorities, and it takes about two months to approve the application.

(10) Future developments

As mentioned above, since it is possible to acquire topography with a high degree of accuracy, it can be applied to disaster prevention plans and public works in relatively small areas such as flood-prone areas in Sri Racha city.

Therefore, it is necessary to meet the needs from local governments that need such disaster prevention plans, etc., and consider whether it can be realized as a business including costs.

On the other hand, since the survey using UAV takes about two months or more to obtain permission to fly to the air station, it explains the social necessity of the survey using UAV. It is necessary to proceed early in order to shorten the application proceed and the related necessary steps.

[5] KOKUSAI KOGYO CO., LTD.

(1) Title

Behavior Grasp of a Local Base Point and Correction for GNSS-based Displacement Monitoring by Using its Neighboring CORS

(2) Abstract

When monitoring ground and structures using GNSS surveying technology based on static positioning, a local base point is usually installed near the monitored area.

However, although it is not usually implemented, an electronic control point CORS analysis may be used in combination with local control points that may not be secured. Thereby, while grasping the behavior of a local reference point, the fluctuation value of a measurement point can be corrected.

(3) Background

KOKUSAI KOGYO has been providing the monitoring service shamen-net with the system configuration shown in Fig. 31 for over 20 years. At present, there are more than 800 GNSS sensors in operation that constitute local reference points or measurement points.

- In the course of such business, the company has experienced many cases where the immobility of the local reference point is not guaranteed. In such cases, the company used GEONET (GNSS Earth Observation Network System: Japanese CORS) managed by the Geographical Survey Institute and has recognized its usefulness.
- Therefore, the company decided to confirm the usefulness of CORS through social experiments even in Thailand,where the ground displacement monitoring is highly needed as in Japan.

Fig. 31 shamen-net service system configuration

(4) Objectives

The purpose was to create an environment where immobility is not guaranteed by applying forced displacement to the local reference point, and to confirm the usefulness of CORS as described above.

(5) Contents of the social experiment

(a) Target area

- With the support of the secretariat, the area with the slope in SKP was selected as the target demo site.
- As shown in Fig. 32, measurement point G-1 was set up on the slope in the target area, and local base point K-1 was set up in a flat area near G-1 in the same target area. K010 was used as CORS.

Fig. 32 Target area

(b) Period

23rd – 30th August 2019

(c) Equipment used

- GNSS antenna and receivers: 2 sets of AS-10's and GR-10's (Leica Geosystems), respectively
- Tripods and fixing materials: 2 sets
- Dedicated storage boxes (receiver, power supply, etc.) : 2 sets
- Forced displacement jig: 1 set

(d) CORS system used

TOPCON (T-NET)

(e) Methods

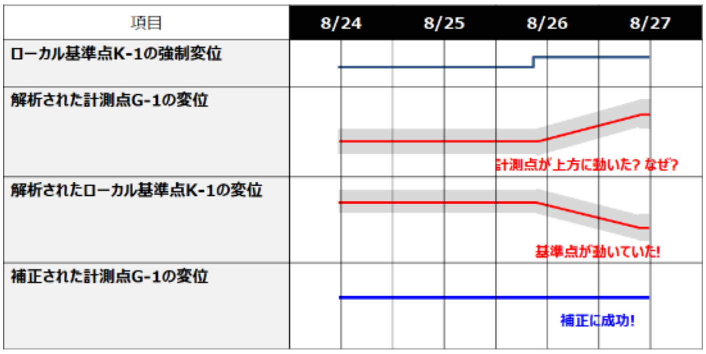
i) Preparation

- The above equipment was set as shown in Fig. 33 and Fig. 34. The forced displacement jig was inserted between the K-1 antenna and the tripod so that the antenna could move. The dedicated storage box was placed close to each point, and the tripod was fixed with metal piles. In addition, a photograph of the appearance of CORS K010 is also shown.

Fig. 33 Setup for social experiment equipment

Fig. 34 Left: Field work, Right: CORS K010 at SKP

- The equipment setup was completed by 24th August am.
- The experimental scenario assumed before measurement under the above setup is shown in Fig. 35 including the displacement vector. In other words, it was suspected that K-1 was immovable when G-1 was analyzed as if it was displaced in the direction of climbing the slope by the baseline analysis from K-1. Therefore, when the baseline analysis from K010 to G-1 was performed, it was found that it was displaced. As a result, K-1 was corrected based on G-1 displacement.



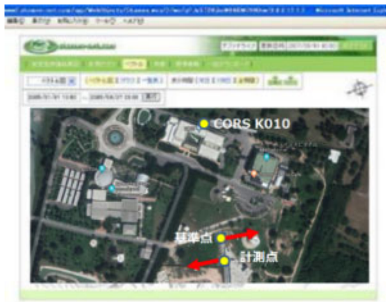


Fig. 35 Experiment scenario

ii) Measurement

- Data acquisition started around 12:00 on 24th August, and K-1 was forcibly displaced by 10 mm in the west direction around 10:00 on 26th August. Around 14:00 on the following day, 27th August, all data was collected and sent to the company's shamen-net monitoring center in Fuchu, Tokyo over the Internet.
- On the other hand, K010 data from Topcon was also obtained, and all the analyses were completed by 28th August.

(6) Results

- The actual analysis results are shown in Fig. 36 and Fig. 37. The green vertical line shows the timing (26th August 10:00) when the forced displacement was applied. Based on the baseline analysis from K-1, G-1 was displaced 10 mm in the east direction (the direction of climbing the slope). Therefore, when the baseline analysis of G-1 from K010 was tried, it was calculated that it was displaced 10 mm in the west direction as forced displacement. Based on these results, the G-1 data was corrected. A displacement vector diagram was also created.
- Fig. 38 also shows the Web display created for the distribution of measurement results.

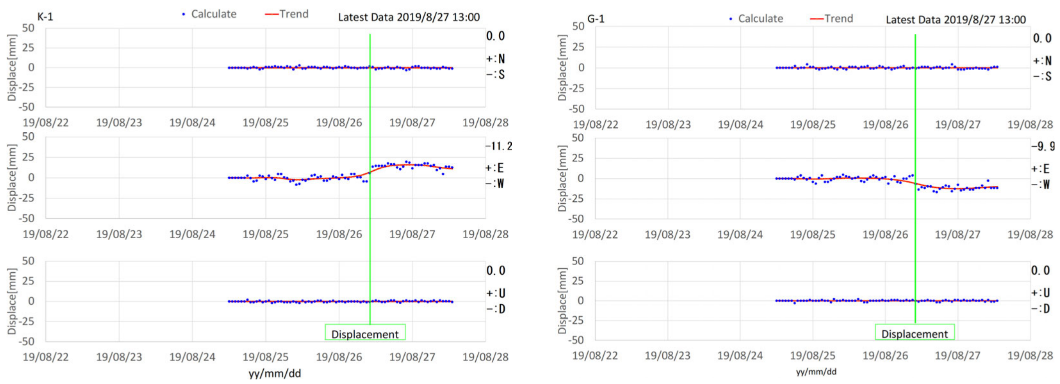


Fig. 36 Displacement graph (G-1 on the left, K-1 on the right)

Fig. 37 Left: G-1 displacement corrected for the base point movement, Right:displacement vector

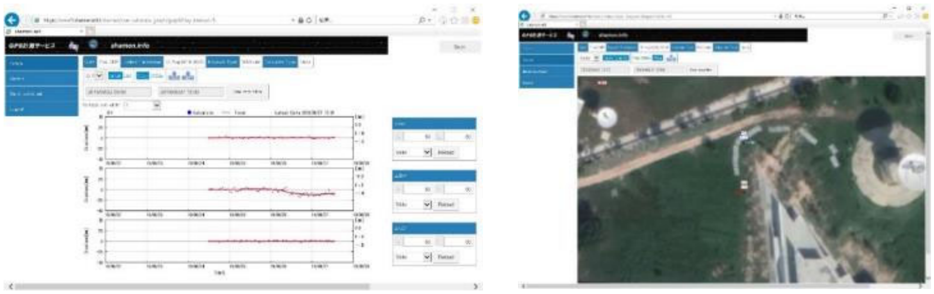


Fig. 38 Experiment result distribution screen

On 30th August DEMO DAY, as shown in Fig. 39, the company were able to introduce the contents and results of the experiment to many participants, having received a number of questions that showed participants' interest.

Fig. 39 Explanation of the experiment at the demonstration booth

(7) Discussion

Expected results were obtained in the experiment. CORS is not necessary for normal shamen-net service implementation, but when the measurement points showed abnormal behavior, we were able to appeal that CORS has an important role to correct the behavior.

(8) Issues for the future

At the stage of future full-scale deployment, it is necessary to confirm the relevant authorities regarding the export of data outside Thailand (for the experiment, data was sent to Japan via the Internet with prior permission).

To solve the problems above, it is desirable to build the analysis service in Thailand.

ATA carnet was required to bring in and take out the equipment from/to Japan, and it took a lot of time to prepare. However, the actual customs clearance process were carried out smoothly.

(9) Future developments

Since Thailand is suffering from disasters similar to those in Japan, the company will continue to explain the usefulness of shamen-net and the importance of CORS development.

The use of CORS associated with local base point installation is particularly important for large-scale landslides, wide-area land subsidence, large-scale social infrastructure like dams and bridges. Furthermore, disasters associated due to global warming are expected to intensify, and demand is expected around the world.

[6] KUBOTA Corporation

(1) Title

Pilot test of autonomous agricultural machine utilizing GNSS-base station

(2) Abstract

We conducted autonomous driving in a test filed based on high-precision positioning (RTK) using correction information from CORS located in Thailand. And we evaluated the straight-work accuracy of the plowed area. (Verification of the straight-line driving performance.)

(3) Background

Kubota has released agricultural machines naming "Farm Pilot Series" equipped GNSS device to resolve some agricultural problems in Japan prior to other companies. We've participated this social experiment to evaluate the performance of our "Farm Pilot Series" many times in Thailand and to enhance our business opportunity in Thailand and ASEAN area.

(4) Objectives

The purpose of the experiment is the verification of the accuracy of autonomous driving work relative to tilling work by skilled workers in order to improve the work-efficiency and achieve labor-saving.

(5) Contents of the social experiment

(a) Target area

①Test field in Chon Buri prefecture

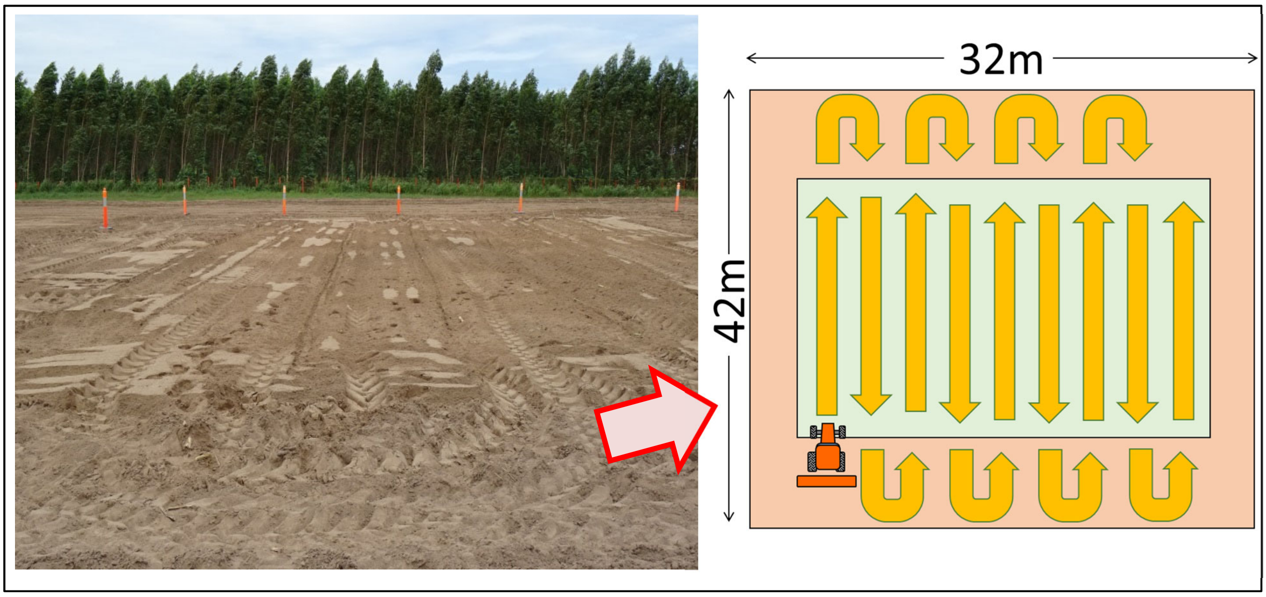


Fig. 40 Test field in Chon Buri prefecture

②Experimental filed in SKP

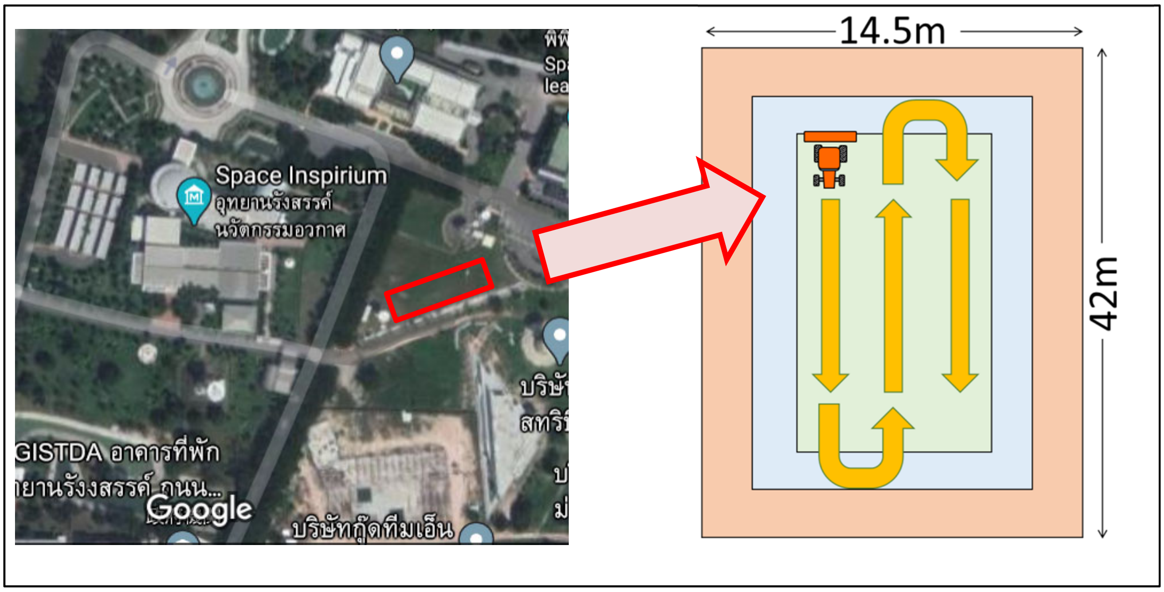


Fig. 41 Experimental field in SKP

(b) Period

①Test field in Chon Buri prefecture: 5th August 2019

②Experimental field in SKP: 26th and 27th August 2019

(c) Equipment used

Agri-Robo tractor SL60A

(d) RTK base-stations used

- RTK base-station manufactured KUBOTA
- RTK base-station manufactured TOPCON
- T-NET, CORS located in Thailand (located at GISTDA)

(e) Methods

i) Conditions for experiment

The measurement is executed with 4 conditions as the followings.

①Autonomous work using KUBOTA base-station

②Autonomous work using TOPCON base-station

③Autonomous work using CORS in Thailand

④Manual work by skillful operator (for comparison)

ii) Measurement items

①GNSS Positioning Result (Straightness, Error of work width (Average/Standard Deviation))

②Measurement Result of Actual work width by tape measure(Error of work width (Average/Standard Deviation))

Experimental field in SKP

Test field in Chon Buri prefecture

Fig. 42 Photos of social experiment

(6) Results

(a) Measurement result in Chon-Buri test filed

	GNSS Positioning Result			Measurement Result (Actual line width)	
	Straightness	Error of work width		Error of work width	
	SD[cm]	Ave[cm]	SD[cm]	Ave[cm]	SD[cm]
①Kubuta base-station	0.8	0.6	1.4	1.1	4.4
②Topcon base-station	0.8	0.8	1.4	0.0	5.8

(b) Measurement result in SKP experimental field

	GNSS Positioning Result			Measurement Result (Actual line width)	
	Straightness	Error of work width		Error of work width	
	SD[cm]	Ave[cm]	SD[cm]	Ave[cm]	SD[cm]
③CORS in Thailand	0.7	0.4	1.3	2.2	2.3
④Skilled operator	4.6	8.9	7.4	7.6	5.3

(7) Discussion

- In this experiment, the following results of work accuracy was confirmed.
  - Work straightness : < 1cm
  - Accuracy of Work width: <1cm

  These results showed that high accuracy works by autonomous agricultural machine could be executed in Thailand.
- Also in case of using CORS located in Thailand, these results showed that high accuracy agricultural work could be executed as well as using KUBOTA base-station.
- The work result by autonomous agricultural machine showed that the straightness and the work width have higher accuracy and stability than work result by a skillful operator.

(8) Issues for the future

- Although the establishment of CORS network has been in progress, the autonomous agricultural work can be executed in only a part of area in Thailand. Therefore we expect the acceleration of the establishment of CORS network.

- Development of legislation related to autonomous driving of agricultural machines will be also necessary in each district from now on.
- We'd like to request the support for the development of legislation so that we can use Japanese technologies(many kinds of wireless devices and safety sensor systems) as well in Thailand.
- If the next social experiment will be planned in near future, we’d like to request the import/export supports about the equipment(Wireless devices etc.), which are the smoother communication and the speedup of the processing to the related organizations in Thailand.
- Actually, when we executed the experiment, the correction data distribution stopped temporarily. It's important for CORS to continue the stable service.

(9) Future developments

We'd like also to continue the evaluation of GNSS for the overseas development (MADOCA is included) and put it into effect from now on.

[7] Nikon-Trimble Co.,Ltd.,

(1) Title

Comparison of positioning availability by GNSS only and GNSS with IMU in Thailand

By: Nikon-Trimble Co.,Ltd., and Asia Technology Industry

(2) Abstract

We compared and grasped the areas that can be measured only by GNSS and the areas that can be measured with combining GNSS and inertial measurement Unit (IMU), by actually driving at around Bangkok city area. Specifically, Applanix POS LVX, which is a relatively inexpensive GNSS+IMU unit is installed in the vehicle, and it drove on the routes with different environments, and also positioning by GNSS alone with u-Blox F9P for compare. We measured the ratio and time of positioning and compare the positioning availability.

(3) Background

With the aim of gathering geographic information using mobile mapping system (MMS) in Thailand in the future, it aims to grasp the availability of satellite positioning system in advance. A wide variety of MMSs are currently on sale. In high-end systems, multiple LiDARs (lasers) and omnidirectional cameras are installed, and a high-precision IMU is used, so the total amount is about 1 million USD. In order to acquire a wide range of information using high-end MMS, the budget is large and the number of units is limited, so it is desirable to increase the efficiency of information acquisition in combination with entry-level MMS. For this entry-level MMS, it is common to reduce the number of LiDARs and cameras, or make GNSS+IMU an inexpensive system.

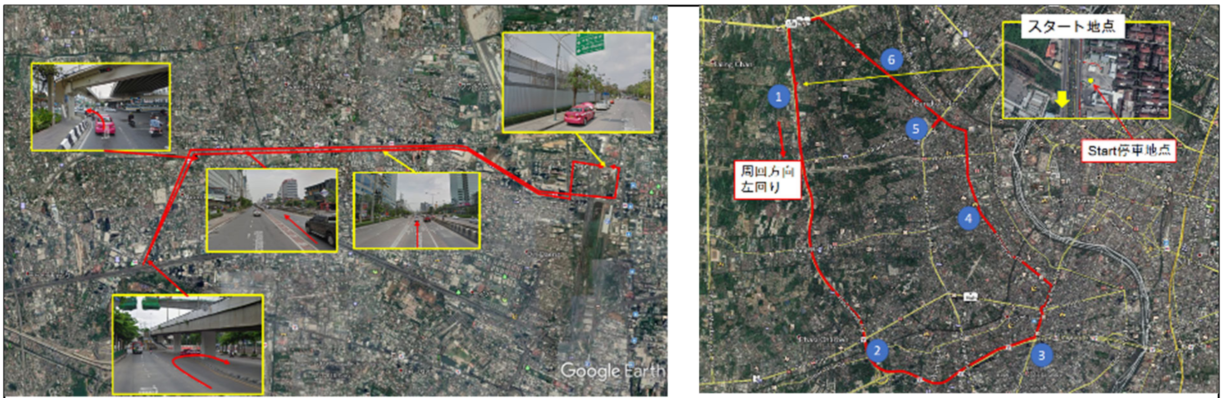
(4) Objectives

This experiment is to grasp the dependence of IMU on positioning. Positioning availability is key factor of using MMS, cost of MMS is related in whether the high-performance inertial navigation system Fiber Optic Gyro or Laser Ring Gyro is required , or inexpensive Micro Electro Mechanical Systems (MEMS) be used. we used entry level GNSS + IMU to chech the availability to positioning urban environments in Thailand.

(5) Contents of the social experiment

(a) Target area

We drove the following 2 courses in Bangkok.



Urban course: Ratchadaphisek Rd　　Sub urban course: Bangkok Suburb

Fig. 43　Target area

(b) Period

22nd August - 30th September 2019

(c) Equipment used

Equipments	Specification	Remarks
Applanix POS LVX	GPS L1/L2/L2C/L5 and GLONASS L1/L2, QZSS, Beidou, IRNSS, and Galileo, and supporting SBAS, RTK,	Dual Antenna (GAMS) GNSS-RTK+IMU MEMS type
u-Blox EVK-F9P	GPS L1C/A L2C, GLO L1OF L2OF, GAL E1B/C E5b, BDS B1I B2I, QZSS L1C/A L2C	GNSS-RTK

(d) RTK network used

Using original Base station on the Chulalongkorn University roof, the specifications are as follows.

Chulalongkorn University (Trimble NetR9) Base station	Latitude	13.735982
	Longitude	100.533933
	El. Height	74.387000
GPS	L1, L2, L5	
GLONASS	L1, L2, L3	
Galileo	E1, E5a, E5b	
BaiDo	B1, B2, (B3)	
QZSS	L1, L2, L5	

(e) Methods

i) Preparation

For the measurement vehicle, Applanix POS LVX and u-Blox EVK-F9P were installed in the same environment, and Regular RTK positioning was performed.

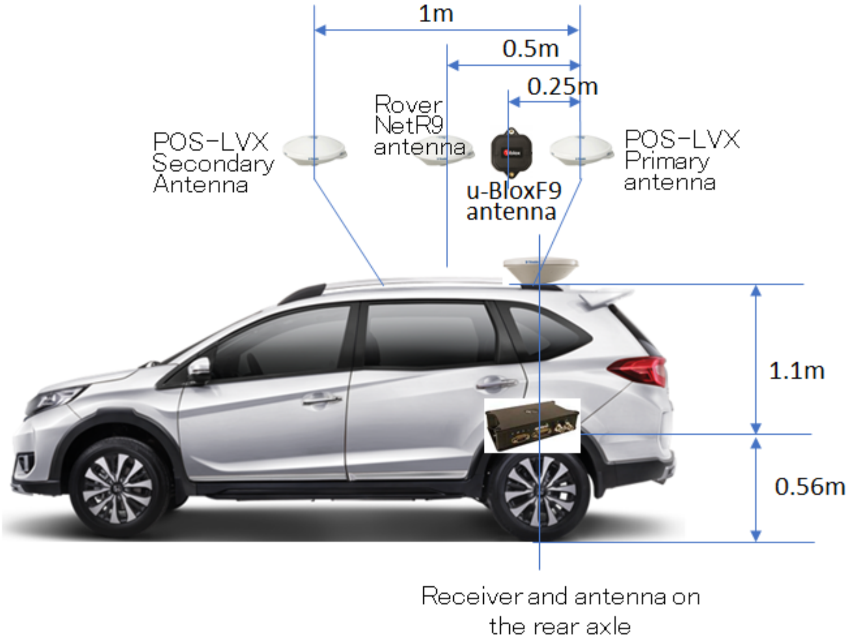


Fig. 44 Preparation

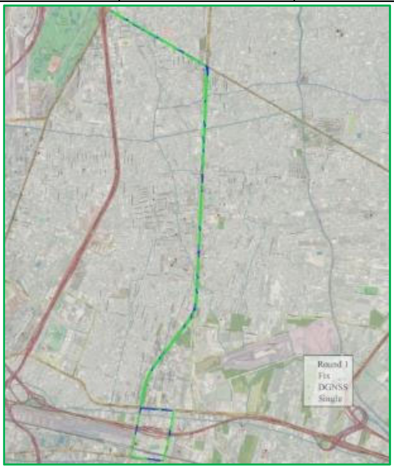
ii) Measurement

In the measurement test with the vehicle running, both the Ratchadaphisek Rd course and the Bangkok Suburb course were run three times, and by traveling at different times, the bias in results due to differences in satellite arrangement and road conditions was eliminated as much as possible.

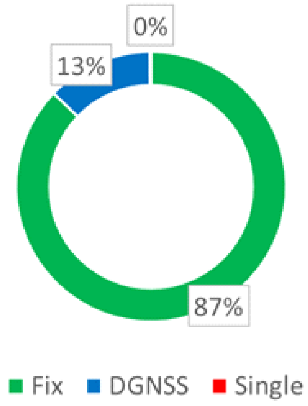
Each measurement result was summarized as a graph. How to read the graph is as follows.

- Positioning mode on the map (Fix: RTK, DGNSS: Submeter, Single: Single positioning)
- Satellite systems (GPS, GLONASS, BeiDou, BeiDou, Galileo, QZSS)
- Fix rate and maximum timeof not fixed
- Number of satellites during driving (maximum, minimum, average)
- Maximum interval time graph that did not fix (Fix other than this time)

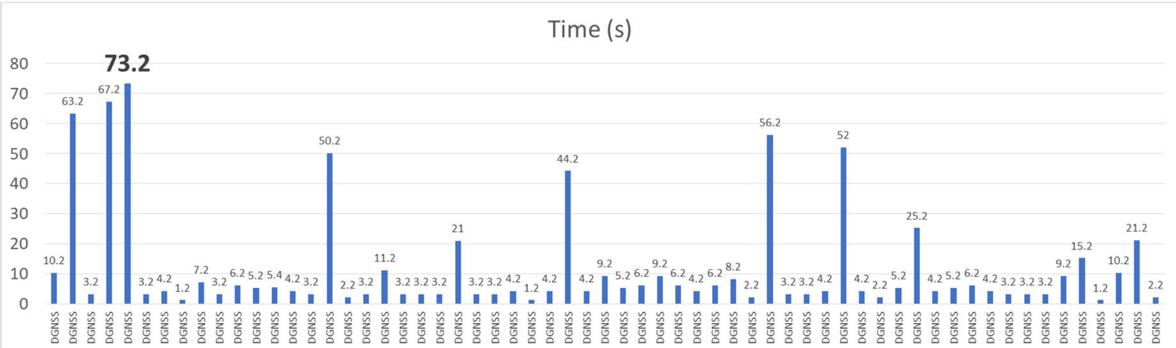
Urban area	Round 1	Ratchadaphisek Rd course



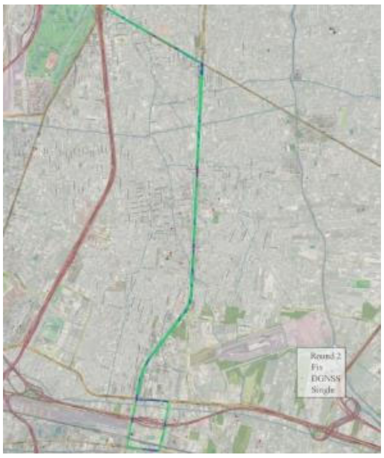
Used Satellites	GPS GLONASS BeiDou Galileo QZSS



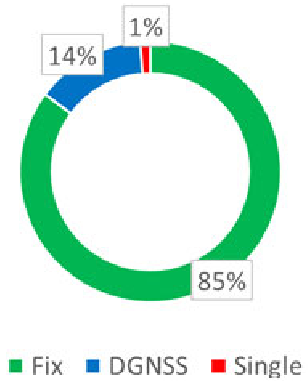
Number of Satellites	
Maximum #	34
Minimum #	2
Avarage #	20
Positioning Mode	
FIX rate	87%
Max NotFIX	73.2 sec



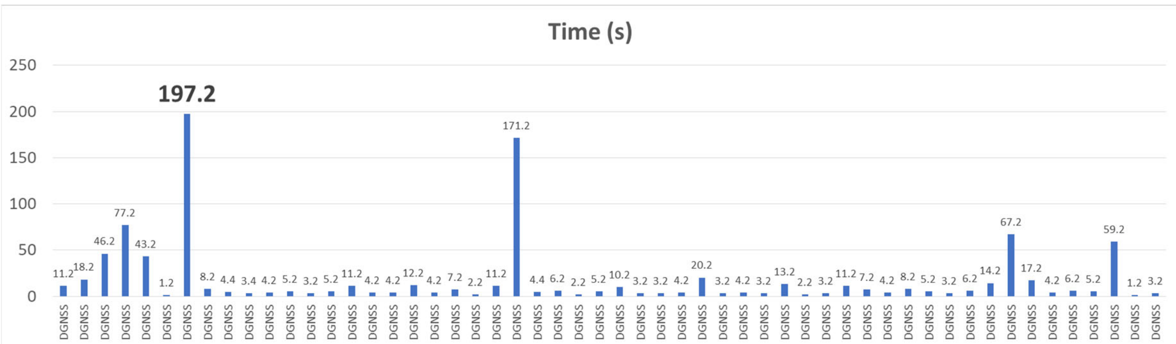
Urban area	Round 2	Ratchadaphisek Rd course



Used Satellites	GPS GLONASS BeiDou Galileo QZSS

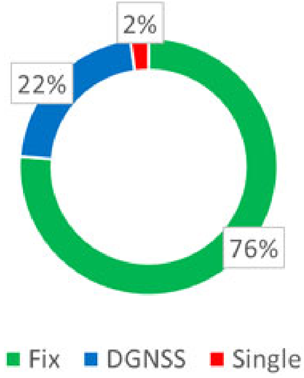


Number of Satellites	
Maximum #	33
Minimum #	2
Avarage #	22
Positioning Mode	
FIX rate	85%
Max NotFIX	197.2 sec

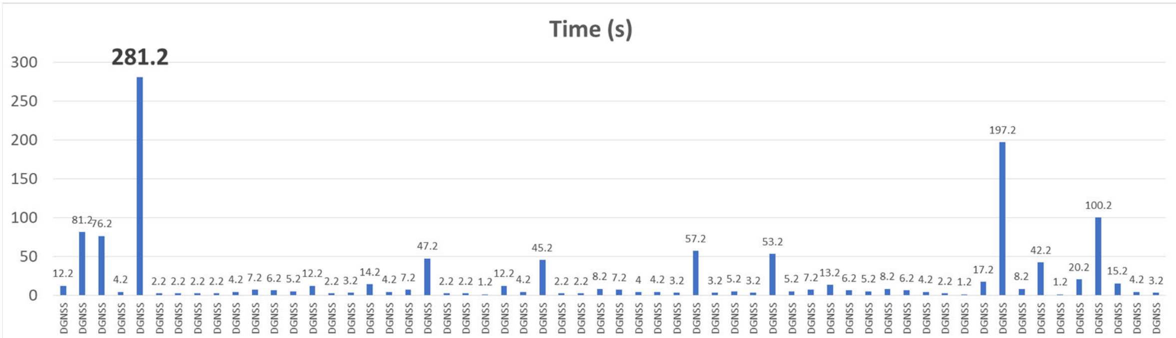


Urban area	Round 3	Ratchadaphisek Rd course

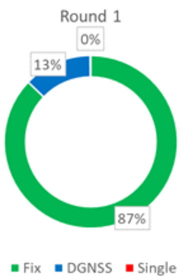
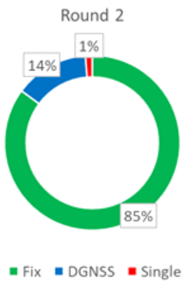
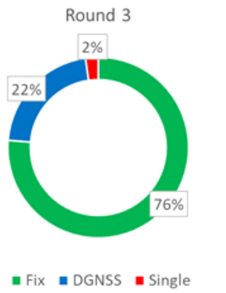
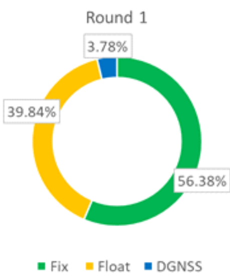
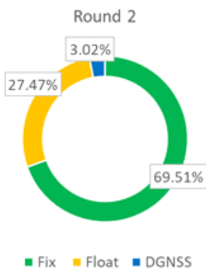
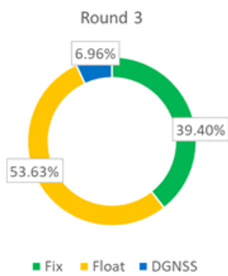
Used Satellites	GPS GLONASS BeiDou Galileo QZSS



Number of Satellites	
Maximum #	33
Minimum #	2
Avarage #	19
Positioning Mode	
FIX rate	76%
Max NotFIX	281.2 sec

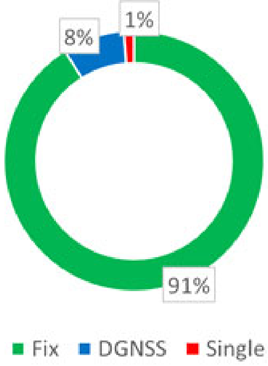


Fix rate comparison with GNSS receiver u-Blox F9P, which is positioned simultaneously with POS LVX

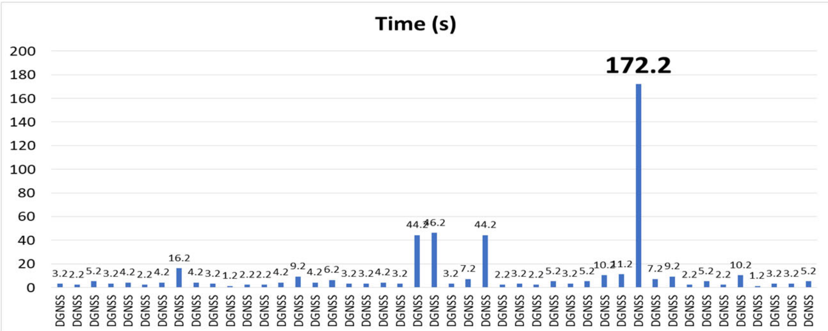
	Round1	Round2	Round3
POS -LVX	 FIX rate = 87%	 FIX rate = 85%	 FIX rate = 76%
u-Blox F9P	 FIX rate = 56%	 FIX rate = 69%	 FIX rate = 56%

Sub Urban	Round 1	Bangkok Suburb course

Used Satellites	GPS GLONASS BeiDou Galileo QZSS

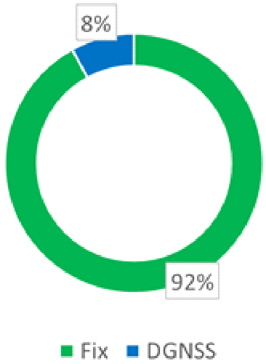


Number of Satellites	
Maximum #	37
Minimum #	5
Avarage #	26
Positioning Mode	
FIX rate	91%
Max NotFIX	172.2 sec

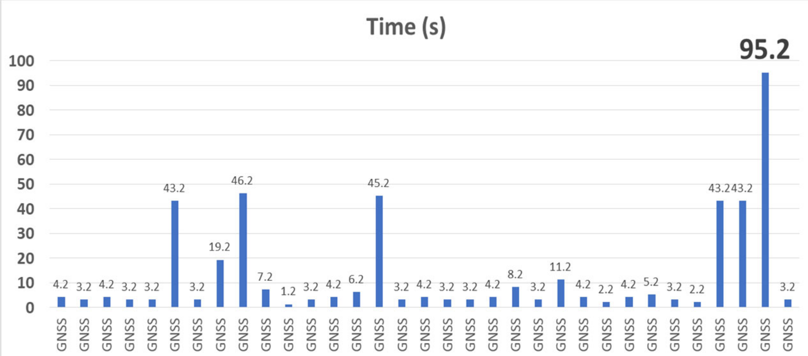


Sub Urban	Round 2	Bangkok Suburb course

Used Satellites	GPS GLONASS BeiDou Galileo QZSS

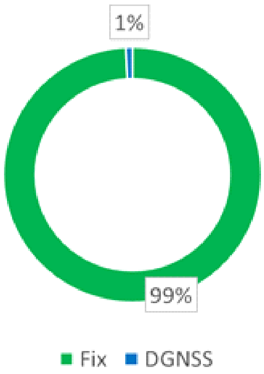


Number of Satellites	
Maximum #	35
Minimum #	5
Avarage #	21
Positioning Mode	
FIX rate	92%
Max NotFIX	95.2 sec

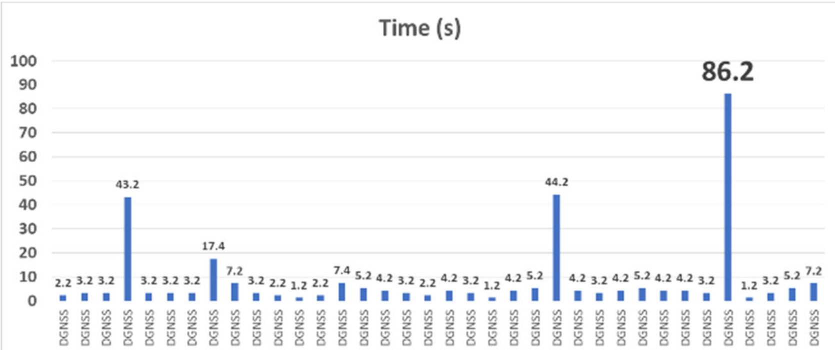


Sub Urban	Round 3	Bangkok Suburb course

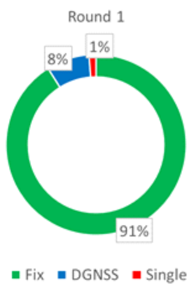
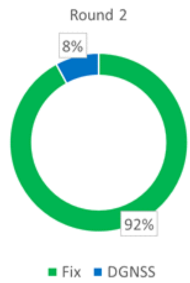
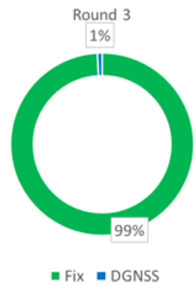
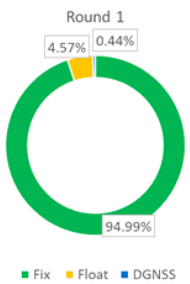
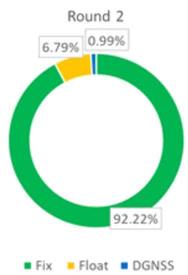
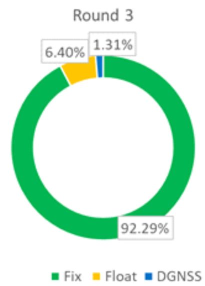
Used Satellites	GPS GLONASS BeiDou Galileo QZSS



Number of Satellites	
Maximum #	34
Minimum #	5
Avarage #	21
Positioning Mode	
FIX rate	99%
Max NotFIX	86.2 sec



Fix rate comparison with GNSS receiver u-Blox F9P, which is positioned simultaneously with POS LVX

	Round1	Round2	Round3
POS -LVX	 FIX rate = 91%	 FIX rate = 92%	 FIX rate = 99%
u-Blox F9P	 FIX rate = 94%	 FIX rate = 92%	 FIX rate = 92%

(6) Results

In this experiment, the urban Ratchadaphisek Rd course has a 20% FIX rate higher in the GNSS + IMU device POS-LVX than the GNSS device u-Blox F9P, and POS-LVX and u-Blox F9P have almost the same FIX rate in the suburban Bangkok Suburb course. Possible causes are that the POS-LVX antenna is a surveying accuracy class and the u-Blox F9P is a broadband antenna for vehicles. This is because the Ratchadaphisek Road course has many high-rise buildings, so there is a difference in GNSS signal processing and multipath mitigation feature to avoid the errors by reflections.

In an environment where the FIX state cannot be maintained, high-precision positioning is continued by inertial navigation using the IMU until a positioning result in the FIX state is obtained in the case of the GNSS + IMU unit. On the other hand, in the case of a GNSS device, the position change becomes remarkable because it is DGNSS or single positioning, and positioning cannot be measured by applications such as MMS.

From this result, the FIX rate exceeds 90% in the suburbs, and the number of times of Not FIX is not frequent, and the result is less than 3 minutes at most, so entry level GNSS + IMU equipment is sufficient for MMS. On the other hand, in urban areas, the FIX rate drops to 75-87% and the maximum time when Not FIX exceed 1 minute frequently occurs as 3-5 times. Since it is difficult to obtain high-precision positioning results, it is considered necessary to introduce a high-end GNSS + IMU device.

Table 7 FIX rate of GNSS-RTK

	Receiver	1st(%)	2nd(%)	3rd(%)
Ratchadaphisek Rd Course	POS LVX	87	85	76
	uBlox-F9P	56	69	56
Bangkok Suburb course	POS LVX	91	92	99
	uBlox-F9P	94	92	92

Table 8 Maximum time without FIX by POS LVX (impossible for GNSS-RTK) and times exceeding 60 seconds

	1st		2nd		3rd	
Ratchadaphisek Rd Course	73.2 sec	3 times	197.2 sec	4 times	281.2 sec	5 times
Bangkok Suburb course	172.2 sec	1 time	95.2 sec	1 time	82.2 sec	1 time

(7) Discussions

From this test result, there was a maximum of 281.2 seconds when POS-LVX was not fixed due to environmental influences or traffic jams. The degradation in positioning accuracy in about 5 minutes depends on the type of IMU used, and the higher the performance of IMU, the smaller the degradation. For reference, the supplementary performance after moving 1 km or 60 seconds after GNSS-RTK becomes unusable in POS LV 620, which is the high-end of Applanix, and POS LVX, which is the entry level used this time, is described. “Position” is m notation, and “Roll & Pitch” and “Heading” are Deg notation.

Table 9 Supplementary performance of POS LV 620 and POS LVX

Model	Position X-Y	Position Z	Roll & Pitch	True Heading
POS LV 620	0.035	0.050	0.005	0.020
POS LVX	1.000	2.000	0.090	0.300

(8) Issues for the future

In this experiment, because a problem in the export procedure was assumed, we used MEMS type POS LVX that does not use gyro type of inertial measurement unit. It is better to use POS LV 620 grade GNSS+IMU unit as a reference at the time when GNSS-RTK positioning is not possible as True Position.

(9) Future developments

We evaluated the availability of GNSS and GNSS + IMU positioning in this time. we would like to bring actual MMS to capture the geospatial information (buildings and structures) to compare the accuracy of the coordinates of object measured by high-end and entry-level MMS in the future.

[8] Nishio Rent All Co., Ltd. & Topcon Corporation

(1) Title

i-Construction Trial in Thailand

(2) Abstract

In Japan, i-Construction is being used to improve productivity in the field of civil engineering and construction in order to respond to social problems such as declining labor force.

We evaluated the suitability of i-Construction in Thailand because it is expected that the labor force will decrease in Thailand in the future.

Evaluation method was as follows: using the same construction yard and design data, we compared the construction time and operation surface of conventional work method in Thailand against i-Construction method. For construction time, with respect to the conventional construction time of 190 minutes, i-Construction was only 30 minutes, and it was confirmed that the construction time can by reduced by about 80%. For the operation surface, it was confirmed that it does not change substantially from conventional construction method.

We hope that i-Construction will be implemented in Thailand in the future, and improve productivity and accelerate infrastructure development.

(3) Background

In Japan, i-Construction was introduced in fiscal year 2016 with the aim of improving productivity in the civil engineering and construction sector.

This i-Construction requires high-precision location information and consistent 3D data utilization.

In Japan, more than 1,300 CORS (Continuously Operating Reference Stations) have been deployed by the Ministry of Land, Infrastructure, Transport and Tourism, and the data is shared to the public and is used effectively in i-Construction.

In Thailand, several government organizations operate CORS independently, but they only use it for their own respective purposes.

Therefore, by participating in the "Social Experiment using High-Precision Positioning Data in Thailand", a research project initiated by the Japan International Cooperation Agency (JICA), and in evaluating the suitability of i-Construction in Thailand, we aim to demonstrate the effective use of CORS.

(4) Objectives

i-Construction consists of a series of construction processes (survey → design → construction →

inspection) but in this experiment we will focus on construction.

By measuring the construction time for conventional work flow and i-Construction respectively, we will demonstrate the effectiveness of productivity improvement by i-Construction.

(5) Contents of the social experiment

(a) Target area

Fig. 45 Target area

(b) Period

19th – 30th August 2019

(c) Equipment used

- Motor Grader VOLVO G930
- 3DMC Motor Grader System

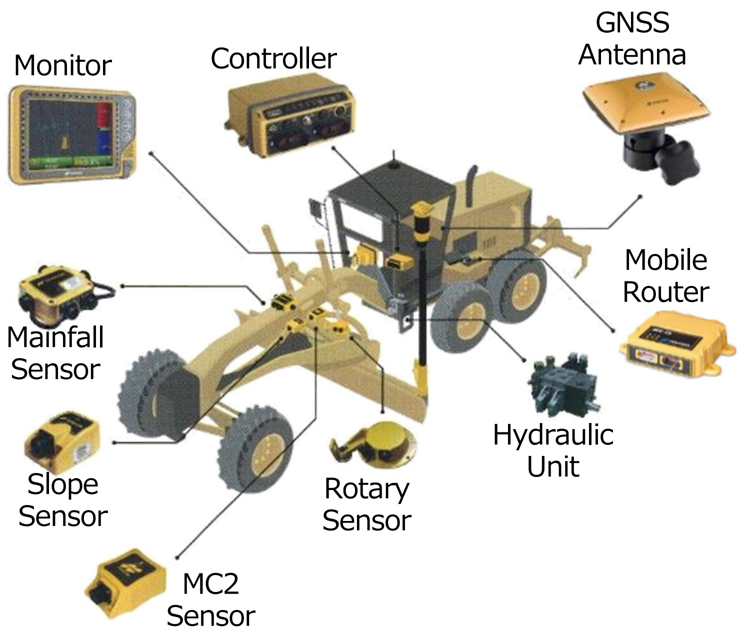


Fig. 46 Equipment used

(d) CORS system used

TOPCON (T-NET)

(e) Methods

i) Preparation

In a 30m x 60m yard on the SKP site, we created road design data of 9m width 70m extension (Fig. 47 Left). (However, since the vicinity of the start and end points is the waiting area of the motor grader, the evaluation section was 50m in the center part.)

Design data comprised of a horizontal alignment of straight portions (about 35m) and curved portions (about 35m), the profile slope was constant at 1.2%. For the cross section slope, the straight portion was 0%, and the curved portion was to change from 0% to 3%.

It is simple design data, but because of the profile and cross section slope, the height of the design surface was constantly changing.

In order to perform the grading work with the grader using this design data, a test yard was made with about 5cm of soil added to the top (Fig. 47 Right).

Fig. 47　Left: Road Design Data Plan, Right: Experiment Yard

ii）Measurement

(A) Conventional Thai Method

Step1: Horizontal positioning of reference piles

In the conventional construction method, in order to show the design data (construction area and construction height) to the grader operator, reference piles are installed. In doing construction of this design data, five reference piles were required on one cross section (two width piles and three height piles). There were nine sections (straight portion had 10m intervals, curved portion 5m intervals), so there was a need to install a total of 45 reference piles (Fig. 48 Left). Positioning work was done using a total station, by 4 workers (total station operation 1 person, prism 1 person, 2 piling persons) (Fig. 48 Right). The operation time for this positioning work was measured.

Fig. 48　Left: Position of Reference Pile, Right: Stakeout of Horizontal Position

Step2: Adjustment of Reference Pile Height

The height of the height piles are adjusted so that the height of the pile is the same as the design height. There were 3 height piles on one cross section, and since there were 9 cross-sections in all, there was need to adjust the height of 27 height piles in total (Fig. 49 Left). Height adjustment work was done using the auto level, with 5 workers (1 auto level operation, 1 to hold the leveling rod, 2 piling people, 1 person with a landmark ribbon) (Fig. 49 Right). The operation time for this adjusting work was measured.

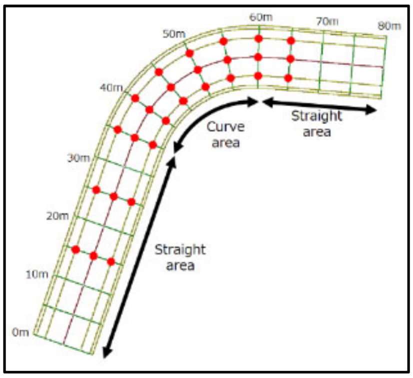


Fig. 49 Left: Position of Height Piles, Right: Height Adjustment Work

Step3: Grading Operation

Using a motor grader, grading of construction surface is performed. Construction area was 450m^2 (width 9m, extension 50m: evaluation target was the entire construction section). Control of the grader blade is done manually by the opearator, while visually checking the height piles (Fig. 50).

Additionally, height piles need to be maintained in their position until the operation in finished, so assistants are there to resurrect the pile when damaged or misplaced. 6 workers are necessary (1 grader operator, 1 auto level operator, 1 to hold leveling rod, 3 assistants). The operation time for this manual work was measured.

Fig. 50 Manual Operation

Step4: Measurement of Operation Surface

In conventional construction, measurement of the operation surface is done by a total station, but this time in order to perform the comparison with i-Construction, a three-dimensional measurement of the construction surface was done using a laser scanner (Fig. 51).

Therefore, the time applied to the operation surface measurement work was not measured.

Fig. 51 Scanner Measurement

(B) i-Construction Operation

Step1: Grading Operation

Using a motor grader, grading of surface is performed. Construction area was the same 450m^2 as the Thai conventional construction method (width 9m, extension 50m: the evaluation target was the entire construction section). Control of the blade was done using a 3D machine control system, to automatically adjust the height (Fig. 52).

Furthermore, during i-construction it is not necessary to have assistants maintaining the height piles, but workers were placed to measure and inspect the height. The operation time for this i-Construction operation was measured.

Fig. 52 i-Construction Operation

Step2: Measurement of Operation Surface

3D measurement of operation surface was done by a laser scanner（Fig. 51）.

(6) Results

Operation Time

Working time for each step and total working time of the Thai conventional construction and i-Construction construction, was as follows (Table 10). In i-Construction operation, the working time for grading operation was shortened by approximately 60% (72 minutes to 30 minutes), and because the installation reference piles is not required, the total work time was shortened by approximately 80% (190 minutes to 30 minutes).

Table 10 Operation Time

Type of Operation	Conventional method	i-Construction method
Horizontal positioning of reference piles	65 min.／4 workers	Unnecessary
Height adjustment of reference piles	53 min.／5workers	Unnecessary
Grading Operation	72 min.／6workers	30 min.／2 workers
Total Operation Time	190 min.／15 workers	30 min.／2 workers

Operation Surface

Upon comparing the 3D measurement results of each operation surface of the conventional and i-Construction method against the design along the center line, both had design deviation within 2cm, resulting in almost exactly the design.

(7) Discussion

Through this demonstration experiment, it was confirmed that the construction time can be greatly reduced by implementing i-Construction construction in Thailand. In addition, the construction area of this time was only 450 m^2, but when applied to the construction area of the actual motorway, even more significant construction time is expected to be shortened.

In the actual construction work, the same result may not be obtained due to the effects of material procurement, loading, and bad weather, but shortening the working time can be certainly expected.

(8) Issues for the future

In order to perform i-Construction operation, it is necessary to have high-precision position information and 3D design data. Establishment of a the CORS system available throughout Thailand is needed for high-precision location information. It is also important to have consistency with the national reference point currently used.

For 3D design data, standardization of handling the data and training of operators will be an issue.

Presently in Thailand, if only the cost is taken into account, it is difficult to prove that ICT construction has merits despite the additional cost to conventional methods. Therefore, it is important to consider approaches of "Quality assurance regardless of human resources" and "Less need to get on and off the machines/ Less workers in the site leading to improved safety assurance".

(9) Future developments

We will continue to promote i-Construction to the construction industry in order to improve productivity and shorten construction periods by utilizing i-Construction in infrastructure development and motorway construction in the ECC area, following the promotion of Thailand 4.0.

It is important to advocate for the creation of opportunities to conduct a large number of pilot projects in Thailand, such as large-scale construction, and to inform the convenience of ICT construction in business to a broad layer, and in turn, to persuade people of the need for CORS.

[9] Tokai Clarion, Ltd. & Asia Technology Industry Co.,Ltd

(1) Title

Intelligent Transport System

By: Asia Technology Industry Co.,Ltd , Chulalongkorn University, Tokai Clarion, Nicon Trimble, AIT

(2) Abstract

The low cost micro-EV is a joint research between Asia Technology Industry (ATI) and Chulalongkorn University (CU). The autonomous vehicle is embedded with RTK multi-GNSS receiver compatible with electron reference point CORS network for positioning. The Tokai Clarion communication camera is installed for operational management of the vehicle. The integration results in low-cost, high-performance vehicle and positioning control, without using of expensive sensors. However, issues endure such as, in importing low cost, high accuracy sensors (Gyro, IMU), and support to new BeiDou signals (B3) in GNSS receiver, which can be addresses in business development plans. The continuous demonstration will help to realize the necessity of autonomous vehicle for smart cities in Thailand.

(3) Background

In recent years, the traffic accidents by elderly drivers are often occurring. Automobiles are indispensable for elderly people. Although, public transportation such as buses, trains and taxis functions as candidates, but due to migration of younger generation into newly developed residential areas away from city center, developed during the bubble economy in 1990's. These areas have become depopulated resulting in increased number of withdrawal cases from buses and taxi companies. For this reason, the autonomous driving technology is attracting attention as a solution to this situation. It is impossible to let go the private cars for access to lifestyle infrastructure such as retail stores, supermarkets, and railway stations. To overcome the problem, there is urgent need to supply an ultra-low-cost self-driving vehicle service that can be used even by pensioners who realize door to door operations. In southeast Asia, Thailand, in addition to the aging of population, the disorderly real estate development in the suburbs of Bangkok and other areas is rapidly progressing, which will result into the same situation as in Japan after 10 years.

(4) Objectives

In SKP demonstration experiment, it will be confirmed that high-performance with high positional control are possible even in harsh environments where the satellite interruption occurs frequently, with the aid of multi-GNSS using network and trajectory estimation travel algorithms.

(5) Contents of the social experiment

(a) Target area

Space Krenovation Park, Sri Racha, Chonburi.

See attached document 1

(b) Period

Vehicle production: June – July 2019 1 month

Vehicle test: July – August 2019 2 months

(c) Equipment used

Using Chulalongkorn University TOYOTA COMS autonomous driving vehicle

POS-LVX, u-BloxF9, NetR9 as GNSS receiver

(d) CORS system used

TOPCON (T-NET), station located in SKP (GPS, GLONASS, BeiDou, Galileo, QZSS)

(e) Methods

1-1 Experimental vehicle system. See attached document 2

1-2 Vehicle monitoring communication system. See attached document 3

(6) Results

See attached document 4

(7) Discussion

Conventional automatic driving method uses LiDAR and a camera to localize with a high-precision 3D map. These sensors are expensive and is difficult to put into practical use. However, in the demonstration, a low-cost high-performance vehicle control and position-driven control using a route prediction map with a multi-GNSS receiver is used. It is proved that without using expensive sensors the autonomous driving is possible.

(8) Issues for the future

When importing a GNSS receiver from Japan, if the receiver specification has a function such as transmitter (Bluetooth, WiFi) etc., NBTC certification is needed otherwise the import will be abandoned. The same applies to the antennas as well. The multi-GNSS satellites (GPS, GLONASS, BeiDou, Galileo and QZSS) all these positioning satellites are must to achieve stable high-precision positioning in the suburbs. However, in this demonstration the reference station has some problem in sending the correction data for BeiDou, which need to be analyzed in the future.

(9) Future developments

In the business development of micro EVs (ultra-small electric vehicles), we plan to develop modules for GNSS receivers, obstacle sensors, and control ECUs for smart cities in Thailand. Also, we are developing a receiver that supports MADOCA broadcast from QZSS, which the Japanese government has been developing.

Contents of the Social Experiment （a）Target area

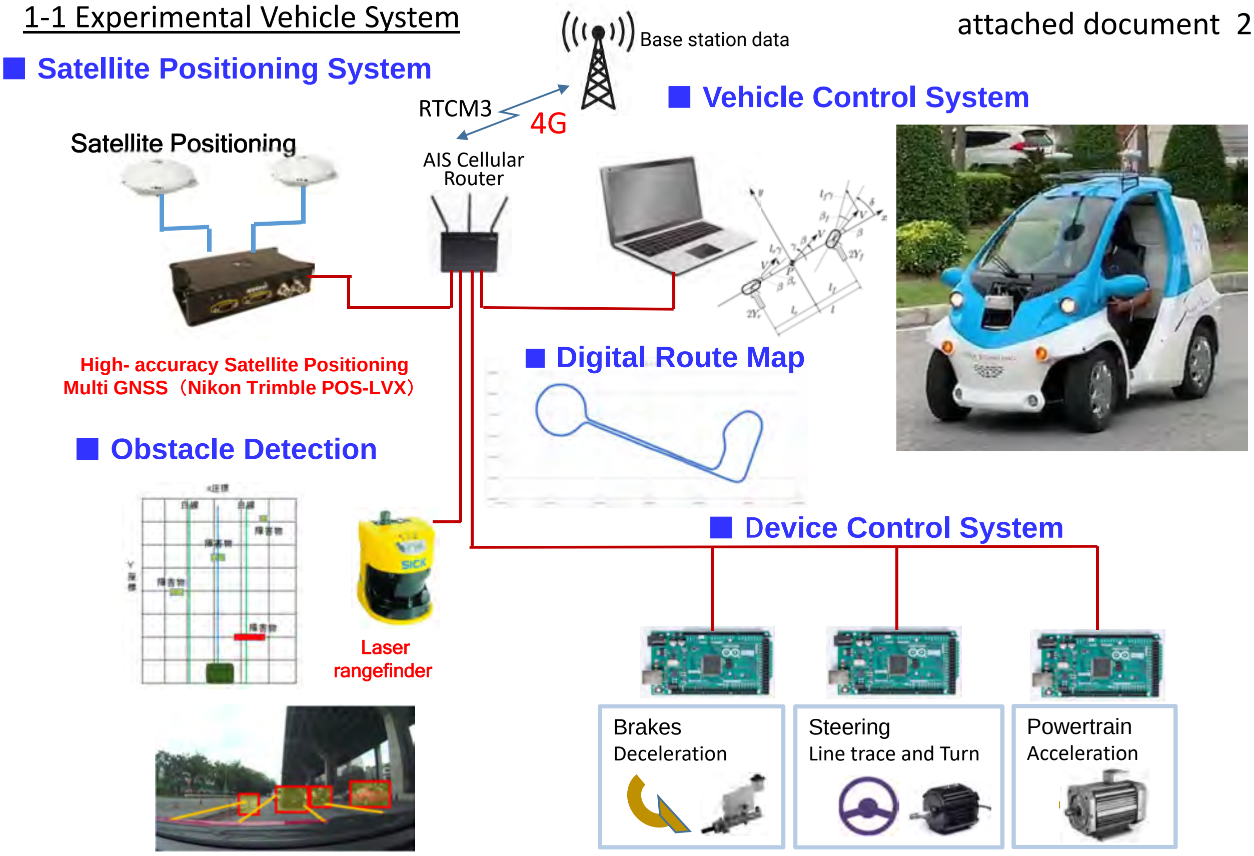
attached document 1

Space Krenovation Park, Si Racha, Chonburi

1）Preparation （e）Methodology – Social Experiment

1-1 Experimental Vehicle System

attached document 2



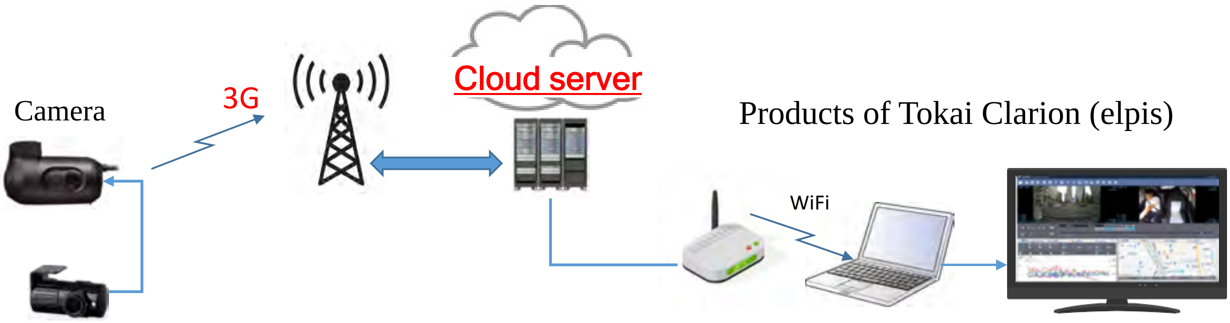
1）Preparation （e）Methodology – Social Experiment

1-2 Vehicle Monitor Communication System

attached document 3

Autonomous vehicle real−time monitor

- Check real-time images of the front and driver's seat
- Vehicle position monitor
- Detects vehicle behavior



Record camera images on a server and monitor in real time using a cellular line System. The vehicle can be controlled in real time by using 5G in the future.

Test Results

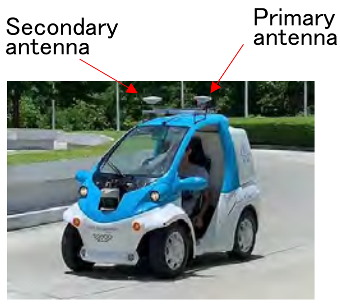
attached document 4

Base station receiver (CORS Network)

SKP (TOPCON GRS-80) Base station	Latitude	13 06 11.42282094
	Longitude	100 55 46.14373043
	El. Height	33.537(m)
GPS	L1,12,15	
GRONASS	L1,L2	
BeiDou	B1,B2	
Galileo	E1,E5a,E5b	
QZSS	L1,12,15	
SBAS	L1,L5	

Rover receiver

Trimble POS-LVX Rover(Spec)	Position (m)	0.02H
	Roll & Pitch (deg)	0.03
	True Heading5(deg)	0.09
GPS	L1,12,15	
GRONASS	L1,L2	
BeiDou	B1,B2	
Galileo	E1,E5a,E5b	
QZSS	L1,12,15	
SBAS	L1,L5	



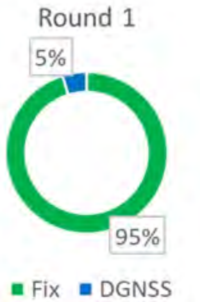
テストデータは後記参照

SKP POS-LVX Test Results

Used satellite
GPS.GLONASS, BeiDou, Galileo, QZSS

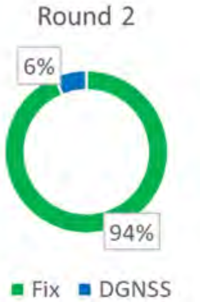
Number of Satellites Received

FIX rate



FIX rate = 95%

Min number of Satellites 5, Max is 35 and Average is 23



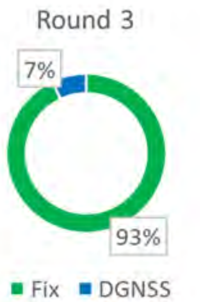
FIX rate = 94%

Min number of Satellites 10, Max is 33 and Average is 23

SKP POS-LVX Test Results

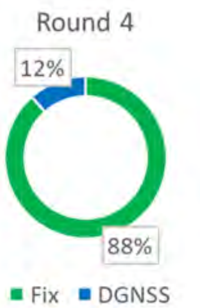
Number of Satellites Received

FIX rate



FIX rate = 93%

Min number of satellites 5, Max is 33 and Average is 23

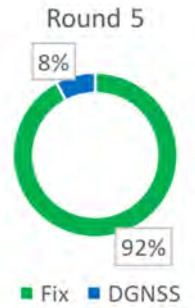


FIX rate = 88%

Min number of satellites 11 Max is 35 and average is 23

SKP POS-LVX Test Results

FIX rate



FIX rate = 92%

Number of Satellites Received

Min number of satellites 8, Max is 34 and Average is 22

Since the SKP course has a large number of positioning satellites, it can be seen that it can maintain the FIX without being affected by tree canopy and provide position information that enables stable autonomous driving.

[10] YANMAR AGRIBUSINESS CO., LTD.

(1) Title

Autonomous driving demonstration of agricultural machines

(2) Abstract

Yanmar's Robot Tractor successfully ran and worked in Thai field with correct signals from the Thai CORS.

(3) Background

The future agricultural population is expected to decrease in Thailand, and we believe that autonomous agricultural machines are necessary to improve agricultural productivity.

In this social experiment, we used the advanced positioning data, which was jointly developed by the Thai government and the Japanese government.

This experiment was conducted to confirm whether Yanmar's robot tractor, released in Japan in October 2018, can run and work in Thai fields.

(4) Objectives

This is to confirm that Yanmar's robot tractor can perform the same work as in Japan in a Thailand field.

The items to confirm are whether the robot tractor can autonomously travel (straight and turn) with tablet operation, and perform agricultural work using implement used in Thailand..

(5) Contents of the social experiment

Two experiments were performed.

i) Sugar cane planting work with a robot tractor in Thailand field

ii) Corn seeding work in SKP by cooperation of a robot tractor and manned tractor

(a) Equipment used

Robot tractor (YT5113 robot)

Fig. 53 YT5113 robot

(b) CORS system used

TOPCON (T-NET)

(c) Period and Target area

i) Sugar cane planting work with robot tractor in Thailand field

The implementation period is 23rd – 24th July 2019, and the target areas are shown below.

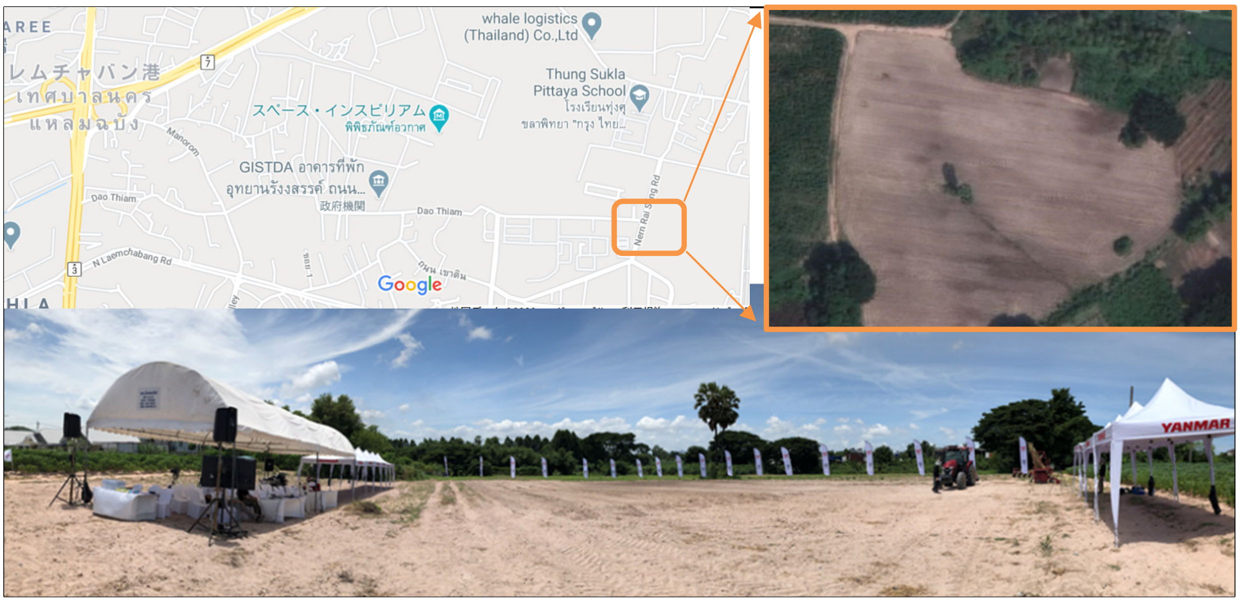


Fig. 54 Target area ① Thailand field

ii) Corn seeding work in SKP by cooperation of robot tractor and manned tractor

The implementation period is 30th August 2019 (Thai-Japan GNSS DEMO DAY), and the target areas are shown below.

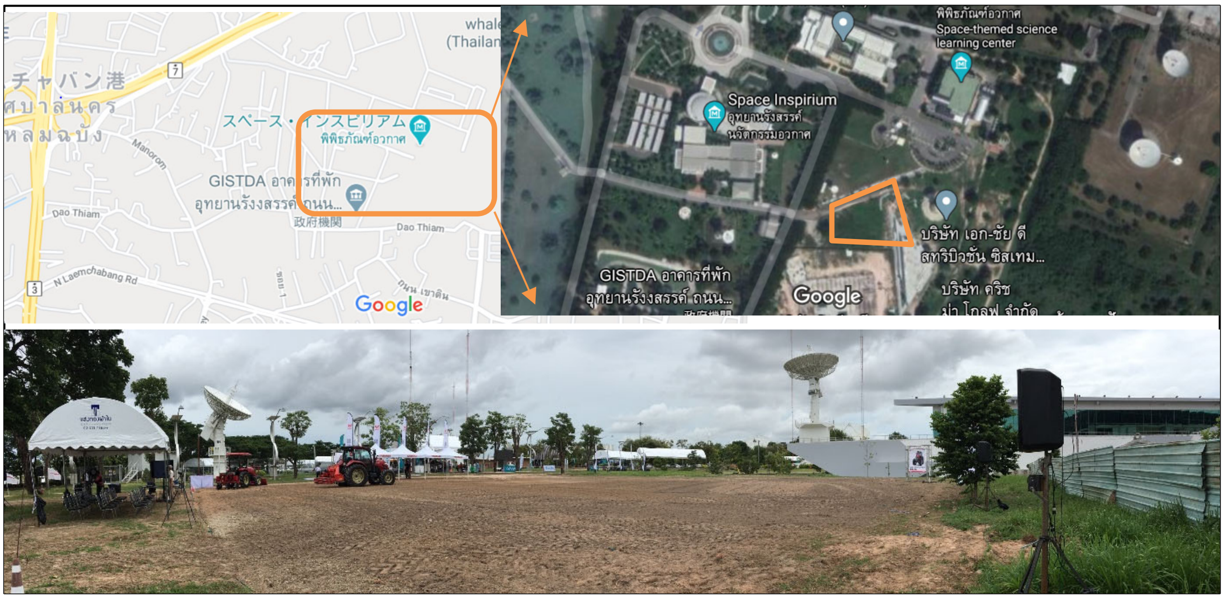


Fig.55　Target area ②SKP

（d）Methods

We confirmed that the robot tractor, which is already on sell in Japan, can autonomously run and work in Thailand, as in Japan.

In order to operate the robot tractor autonomously, positioning information of the tractor is necessary. This positioning method used RTK (Ntrip).

High-precision positioning in cm units was realized by GNSS receiver installed in the robot tractor and correction information through internet from the CORS in Thailand.

Fig.56　Positioning metho

(6) Results

Yanmar's robot tractor was confirmed that it has ability to work in the same way as Japan on a Thai farm.

In autonomous driving, the robot tractor automatically traveled on the registered Straight or turning path by operating the tablet, without getting on the tractor.

The state of each operation of the robot tractor is shown below.

i) Mini combine (subsoiler) and sugar cane planter

The robot tractor was equipped with a mini combine (subsoiler) and a sugar cane planter. After plowing the ground with a subsoiler attached to a robot tractor, the implement was replaced to a sugar cane planter and planted sugar cane.

Fig.57 Top left: Mini combine, Bottom left: After work, Top right: Sugar Cane Planter, Bottom right: After work

ii) Collaborative work using power harrow and corn seeder

One person operated two different tractors. This is an efficient collaborative work.

The preceding tractor was a robot tractor for plowing the ground with a power harrow, and the following tractor was equipped with a corn seeder to seed the corn.

The operator operated the following tractor on following tractor, and operated the preceding robot tractor with a tablet.

Fig.58 Collaborative work

(7) Discussion

In both experiments, the robot tractor's autonomous travel and work with Thai implement was successful. Because both fields were performed near the CORS, correct signals from the CORS could be received.

Therefore, it is considered that the robot tractor was able to travel without deteriorating positioning accuracy.

(8) Issues for the future

Maintenance and use of CORS

In recent years, the installation of CORSs is increasing in Thailand, but the distance between CORSs is longer than in Japan.

If a stable positioning environment is required, we think that a higher-density GEONET is necessary.

In addition, the CORS installed in Thailand have different managers. For this reason, it is necessary to request to different managers to use CORS. In addition, there are many inconveniences because there are restrictions on the use CORS by different managers.

Customs and radio certification

In this social experiment, equipment was brought from Japan to other countries. For this reason, procedures for "customs clearance for import / export" and "approval for radio wave authentication" are required with relevant Thai organizations. If it is a business, each company should apply these procedures, but in social experiment, if the governmental organizer can arrange in advance, the experiment will proceed smoothly.

(9) Future developments

Yanmar will pay attention to Thailand agricultural population, and will promote its business. We will continue to establish a system that can promote smart agriculture in Southeast Asian countries including Thailand. Yanmar participates in the Japan-Thailand G Space Promotion Cooperation Council and will continue its activities in accordance with its purpose.

Annex3. Presentation Material of Thailand Japan Special Session

Multi GNSS Asia Conference

Japan - Thailand Special Session

28 August 2019

Impact Arena Muong thong Thani Bangkok, Thailand

Japan - Thailand Special Session

9:00- **Opening Remarks**
By Dr. Damrongrit Niammuad, GISTDA
By Mr. Satoshi Kogure, National Space Policy Secretariat, Cabinet Office

9:05- **Keynote Speech**
By Mr. Hiroyuki Miyazaki, Ph.D., University of Tokyo & Asian Institute of Technology

9:15- **Keynote Speech**
By Professor Dr. Chalermchon Satirapod, Chulalongkorn University

9:25- **Introduction of Establishment of National CORS Data Center (NCDC) and JICA Technical Cooperation**
By Col. Attawoot Kiatiwat, Thai Japan Cooperation WG & Royal Thai Survey Dept.
By Mr. Masaki Murakami, JICA Team (PASCO CORPORATION)

9:35- **Introduction of Pilot Projects in Thailand**
By Representatives of the participating companies from Japan and Thailand

10:25- **Closing Remarks**
By Mr. Takahiro Otsuka, JICA Thailand Office

GNSS CORS as the National Positioning Infrastructure to support Thailand 4.0

Professor Dr. Chalermchon Satirapod
Department of Survey Engineering
Chulalongkorn University
Thailand

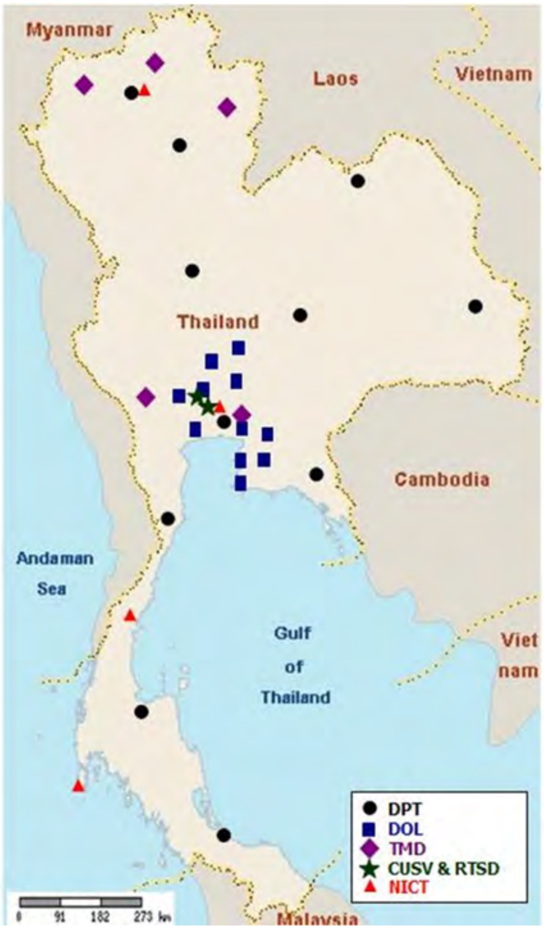
CHULA ENGINEERING
Foundation toward Innovation
100th Anniversary of Chula Engineering 2013

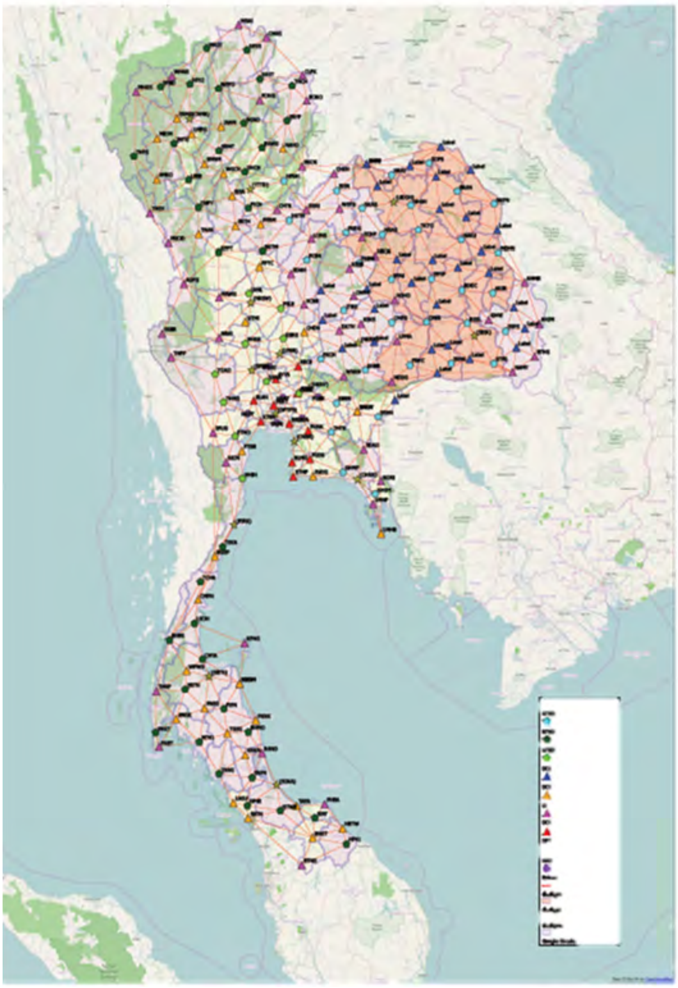
Outline

- Thailand Continuous Operating Reference Systems (CORS) : system and concept
- How GNSS CORS can support Thailand 4.0?
- Past collaboration between Thailand and Japan

Thailand CORS

- Many Thai organizations and University established CORS for their own purposes.
  - Department of Public Works and Town & Country Planning (DPT)
  - Royal Thai Survey Department (RTSD)
  - National Institute of Information and Communications Technology (NICT)
  - The Thai Meteorological Department (TMD)
  - Department of Lands (DOL)
  - Chulalongkorn University
  - Geo-informatics and space technology development agency (public organization)





Year 2019
CORS > 200 stations

GNSS CORS Installation Plan:

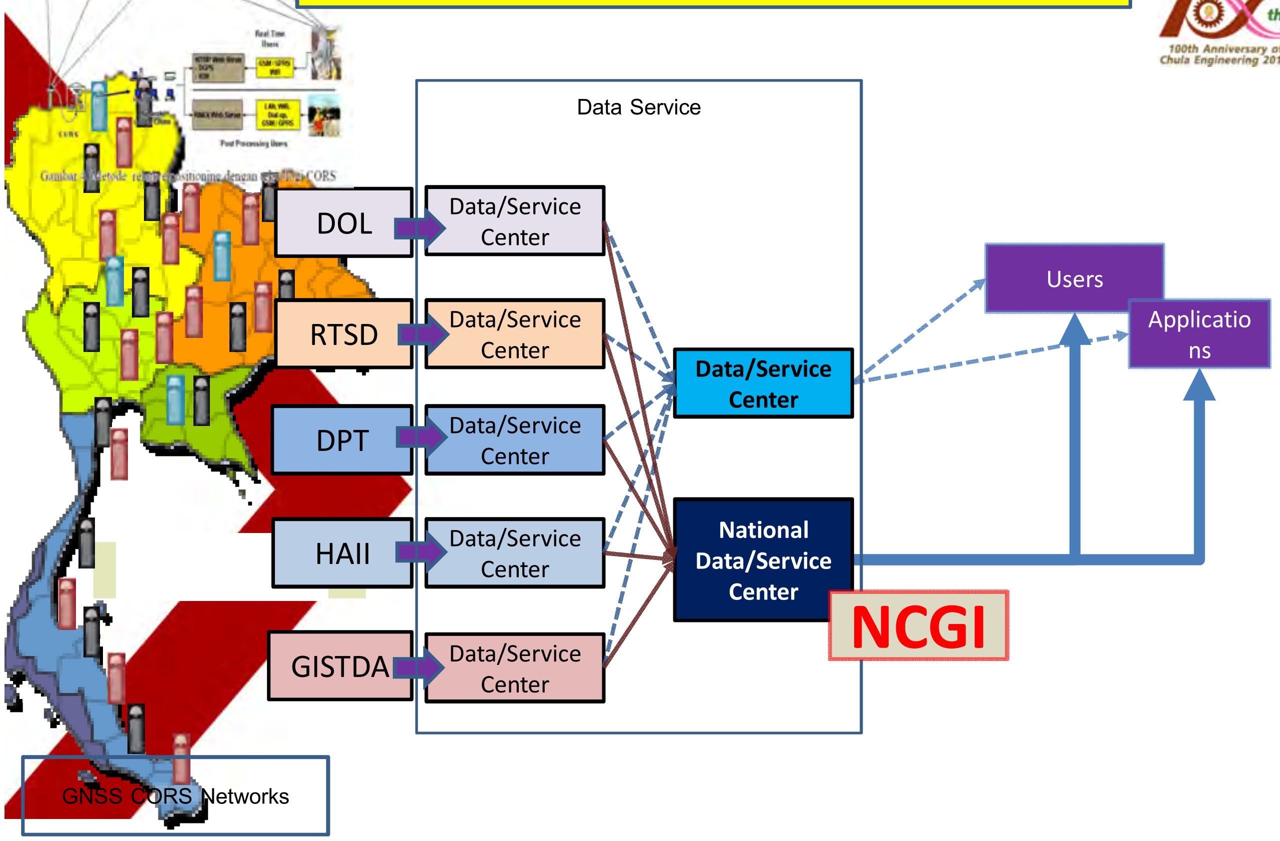
- RTSD: Survey (Backbone) 80 CORS
- DOL : Land Survey 134 CORS + 47 CORS (2020)
- DPT : Planning Town survey 15 CORS
- GISTDA: Research & App 5 CORS
- CU & KMILT : Research 4 CORS
- HII: 6 CORS

Baseline:
30-80 km.

Service:
Collection data of CORS, Correction data for precise positioning

Application:
Surveying, I-construction, Logistics, Precise farming, Autonomous driving, Scientific research

GNSS CORS Data Services Concept



http://www.tmd.go.th/mainmenu/images/thailand_map.gif

www.eng.chula.ac.th
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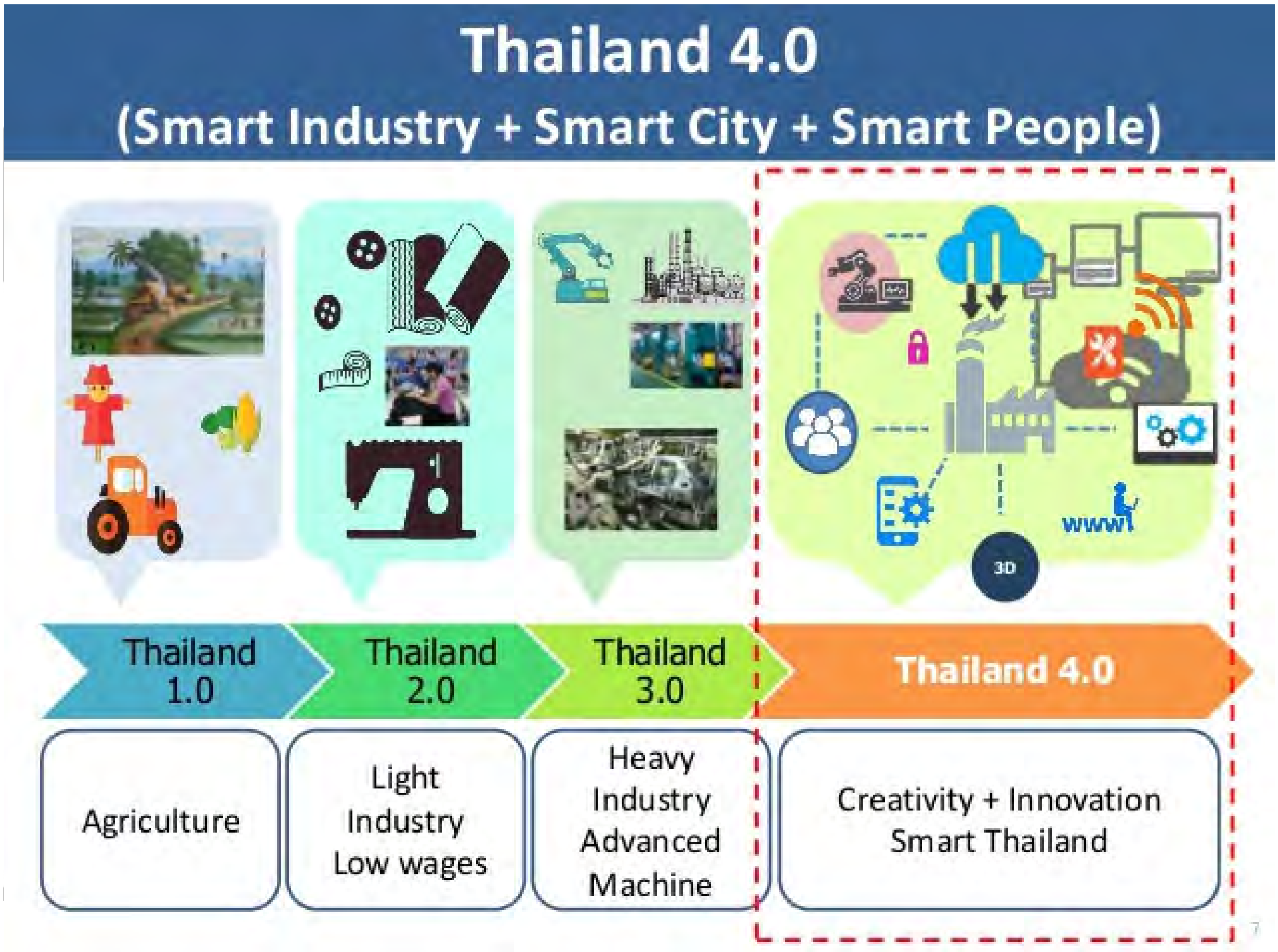
What is next?

- Integrate all available GNSS CORS to provide a real-time service to public
- Propose to all organizations to use the latest ITRF coordinate reference frame
- Decide on the nature of Thai datum (static, semi-dynamic, dynamic???)
- Promote the use of RTK service from National GNSS CORS to the targeted sectors (i.e. agriculture, aviation, construction)



FUTURE USE OF GNSS CORS IN THAILAND

THAILAND 4.0

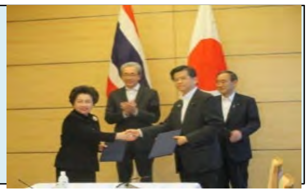
SMART CITY SMART INDUSTRY
SMART PEOPLE

- AGRICULTURE
- AVIATION
- SURVEYING AND MAPPING
- AUTONOMOUS DRIVING VEHICLE

Japan-Thailand Joint Press Statement (February 9, 2015)

MOU for development of CORS network（June 7, 2017）

- Establish an integrated data center
- Cooperate for integrated CORS network
- Establish GNSS Innovation Center



2016-2017 Cabinet Office cooperating with HII Social demonstration of GNSS utilization in Thailand

- NISHIO RENT ALL CO.,LTD.
- PASCO CORPORATION
- Jenoba Co., Ltd.
- KUBOTA Corporation
- MAZELLAN SYSTEMS JAPAN Inc.
- NIKON-TRIMBLE CO., LTD.
- YANMAR CO., LTD.
- TOPCON CORPORATION
- Mitsubishi Electric Corporation

Opening of GNSS Innovation Center（January 10, 2018） Japan pavilion（10 private companies, Cabinet Office, GSI, JAXA exhibition）established GISTDA-annexed to the Space Museum.

100th Anniversary of Chula Engineering 2013

1st Technical visit to Japan in 2017

2017-03-07: The Thai delegation from 4 agencies discussed CORS infrastructure with experts at GSI.

GISTDA, DOL, RTSD, Prof.Satirapod, HAII, Mr.Nakagawa

2nd Technical visit to Japan in 2019

2019-6-12: The Thai delegation from 7 agencies discussed CORS infrastructure with experts at GSI.

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Foundation toward Innovation

Without the support from Japan, we would not come this far. Thank you very much!

ありがとうございます

คณะกรรมการภูมิสารสนเทศแห่งชาติ
The National Geo-Informatics Board

Introduction of establishment of National CORS Data Center (NCDC) and JICA technical cooperation

Col. Attawoot Kiatiwat
Director of Map Information Center
Royal Thai Survey Department

28 August 2019

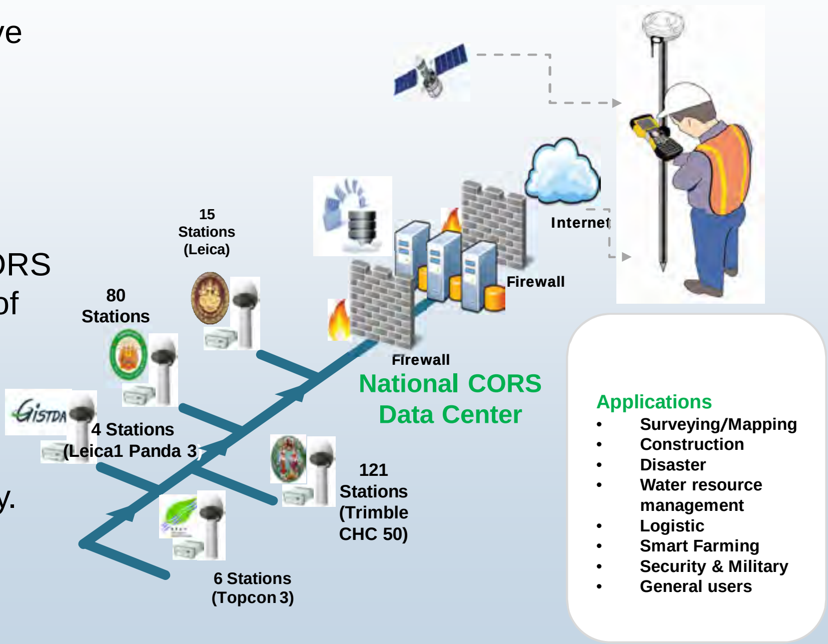
Japan - Thailand Special Session,
Multi GNSS Asia Conference

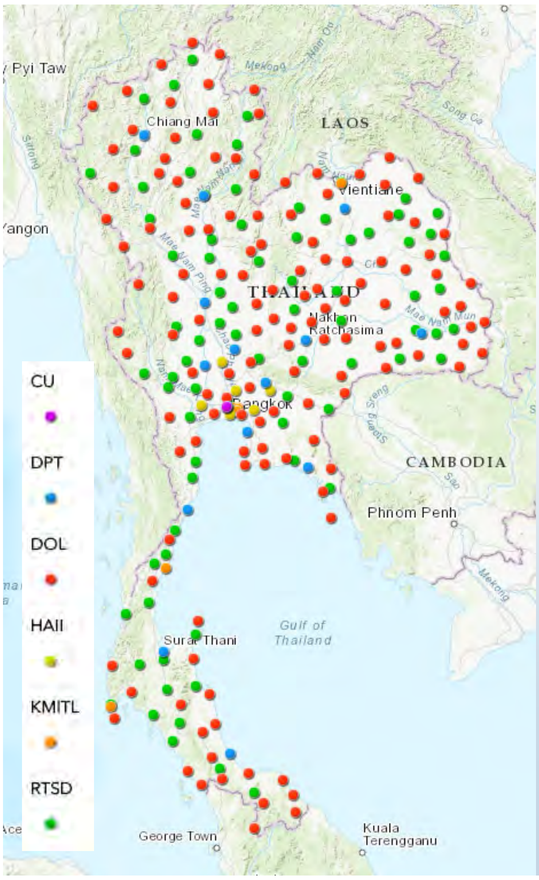
Outline

- The establishment of NCDC
- Organization and Management
- NCDC & JICA Technical cooperation
- NCDC: Today status & in the far future

The Establishment of NCDC

- In Thailand, governmental agencies have owned CORS stations but not yet integrated among agencies.
- National Geo-informatics Board (NGB) have approved establishment of the National CORS Data Center for co-ordination integration from all GNSS CORS stations and assigned RTSD in charge of this task.
- NCDC will be the essential national infrastructure beneficial for international competition and social economic development as well as national security.





Thai GNSS CORS Status

In the end of year 2019: 249 stations[1]

o RTSD: Survey (Backbone)	80	CORS
o DOL : Land Survey	134	CORS[2]
o DPT : Planning Town survey	15	CORS
o GISTDA: Research & App	5	CORS
o HII:	5	CORS
o KMILT : Research	8	CORS
o CU: Research	1	CORS
o NIMT:	1	CORS

Baseline: 30-80 km.

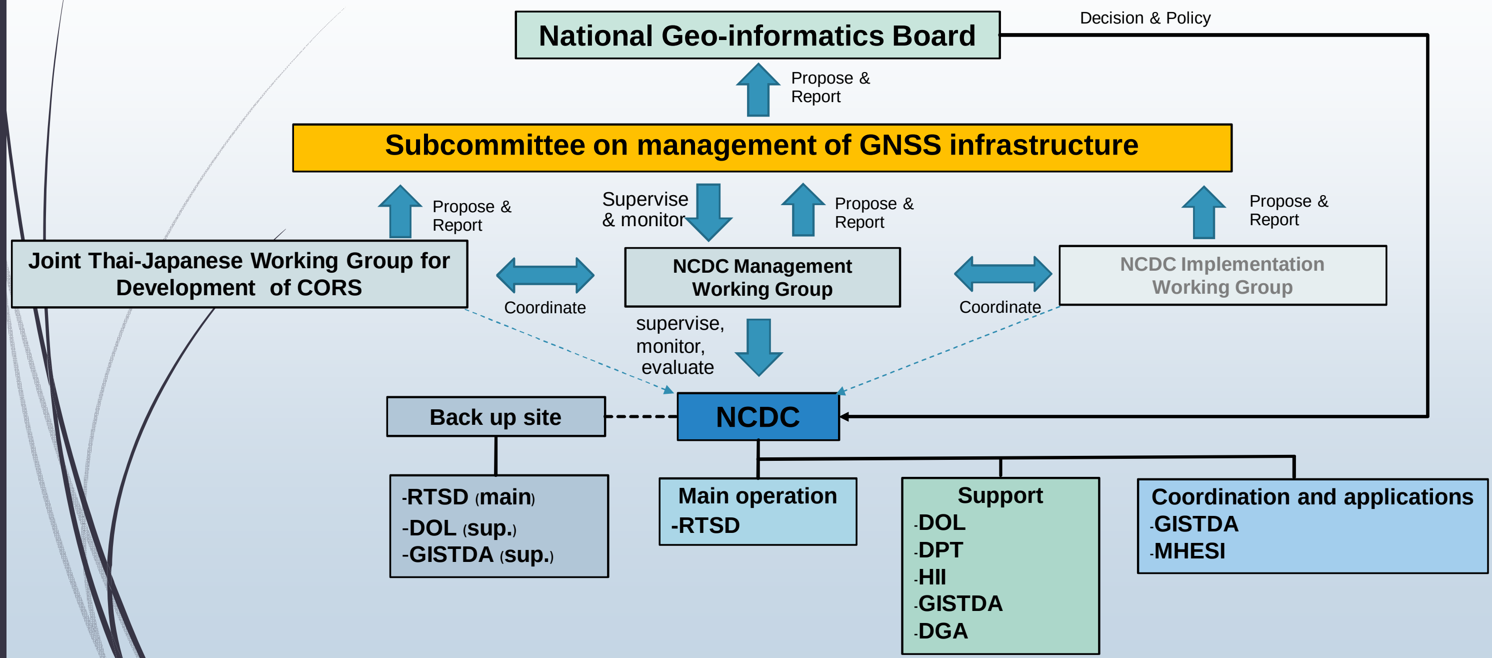
Service: Collection data of CORS, Correction data for precise positioning

Application: Surveying, Logistics, Precise farming, Automatic mobilization

[1] As the 1st NCDC management working group meeting report
[2] DOL 's CORS 45 stations will be added in 2020

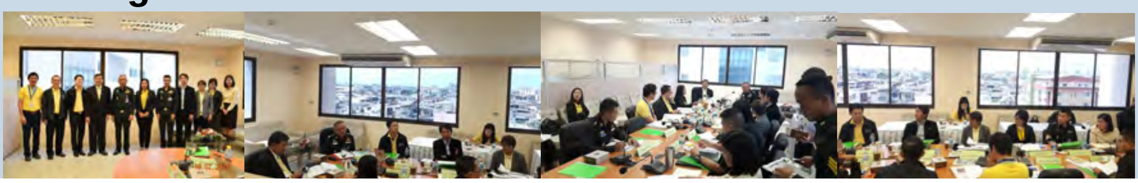
Source: RTSD GeoPortal
https://geoportal.rtsd.mi.th/portal/apps/webappviewer/index.html?id=34f1f8f7a4be423897f0fb930f1dffa7

NCDC: administrative workflow

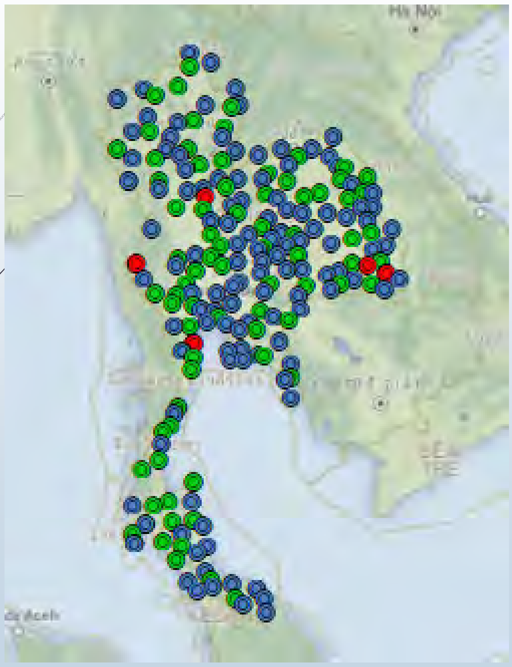


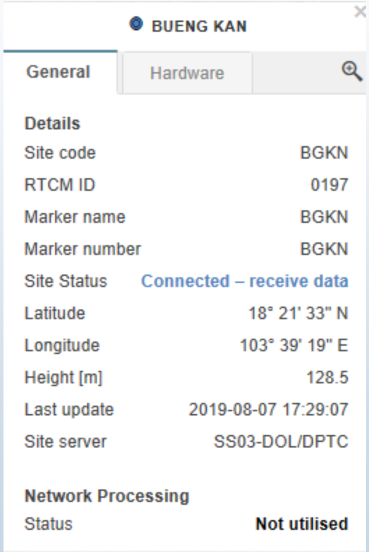
1stNCDC Management Working Group Meeting in 18 July 2019:
Integration/Collection of CORS Data

- Approve to conduct and integrate Data Streaming Testing on Continuously Operating Reference Station(CORS) of associated organization
- **Approved CORS Data streaming test plan** which started operation from August 2019
- **Test both 2 methods; data center to data center and multi-streaming from CORS stations**
- **Data streaming test evaluation for sufficient information to make a decision and report to Sub-committee on management of GNSS infrastructure**



RTSD-DOL CORS Data streaming test





1st NCDC Management Working Group Meeting in 18 July 2019:

CORS Data distribution policies

- Approved data distribution system in Scenario B -Data holder send to data provider with free of charge
- Approved policy to provide CORS data services free of charge in initiate stage in order to promote CORS data usage and review the data charging policy every 6 months

Data holder & NetRTK data creator; NCDC → Free of charge → Data provider; NCDC → Free of charge → Users

Today NCDC

- 9 April 2019, Minister of Defense has approved construction of National CORS Data Center as a new project of MOD in a fiscal year of 2019
- Because of procurement of over 100 million bath worth ICT procurement project, National CORS Data Center project are required to be inspected and approved by Government Computer Procurement Committee under Ministry of Digital Economy and Society (MDES) in aspect of Return on Investment

NCDC in near and far future

- Foster installation the National CORS Data Center through consolation and budgetary allocation from the Royal Thai Government.
- Unifying CORS network/coordinate -members shall use same GNSS CORS network/coordinate after the establishment of NCDC
- CORS maintenances- maintenance cost is integrated to continue and sustain system of NCDC
- CORS data service rules - service rate, scope/term of conditions, limitation, security
- Promote the application of RTK service from National GNSS CORS to the targeted sectors (i.e. agriculture, aviation, construction)

Thank you for your attention

JICA Technical Cooperation

- JICA assists **realization of sustainable operation of NCDC** through its technical cooperation project.
- Not only the provider side (NCDC itself) but also user side are the key success factors to **sustainable operation of NCDC.**

Implementation of pilot projects
to understand **potential user needs** and
applicability of technology in Thailand.

10 Pilot Projects from Thailand & Japan

UAV/i-Construction
AKTIO Corporation

Smart Agriculture
KUBOTA Corporation

Mobile Mapping System
Hydro - Informatics Institute

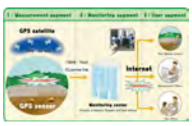
Survey and Mapping
NIKON-TRIMBLE Co., Ltd.

Mobile Mapping System
Iwane Laboratories(Thailand) Ltd.

i-Construction
NISHIO RENT ALL CO.,LTD.
TOPCON CORPORATION

UAV
KAITEKI-KUKAN FC CO.,Ltd
Pasco (Thailand) Co.,Ltd.

Intelligent Transport System
Tokai Clarion, Ltd.
Asia Technology Industry Co.,Ltd.



Real-time displacement monitoring
KOKUSAI KOGYO CO., LTD.

Smart Agriculture
YANMAR AGRIBUSINESS Co., Ltd.

UAV Photogrammetry Using GNSS Markers for Aerial Photogrammetry

August 28, 2019

株式会社アクティオ AKTIO Corporation
Shigeo Hinami

AKTIO Corporation Profile

Company Profile

AKTIO Corporation

Address 〒103-0027
3-12 Nihonbashi, Chuo-ku, Tokyo, Asahi Building 7F
TEL：03(6854)1411
FAX：03(3276)3221

Representative Chairman & CEO Mitsuo Konuma
President & COO Naoto Konuma

Establishment January 10, 1967

Capital 500 million yen（Aktio HD 10billion yen)

Company Profile

Annual sales : 187,110million yen
（Aktio HD 2,718 billion 98 million yen)
* Fiscal 2018 results

Number of employees : 4,379（Aktio HD 8,359）
* December 31, 2018

Aktio HD :

42 consolidated subsidiaries

Overseas：AKTIO THAILAND CO.,LTD.
AKTIO PACIFIC PTE.LTD.
AKTIO MALAYSIA SDN.BHD. Other 8 corporations.

4 Equity method affiliates 3 Non-consolidated subsidiaries

Company Profile

AKTIO

Business : Construction machinery rental,

Rental and lease construction equipment.

Main offices : Tokyo, Osaka, Sapporo, Sendai,

Nagoya, Fukuoka etc.

Division : Railway, Forestry, Dismantling, Handy machine,

Under structure machinery, Engineering, Cranes,

Road machinery, Event,Trading,

376 locations. (in Japan)

125 factories. (in Japan)

Description of Testing

AKTIO

Outline:

Use GNSS markers as airphoto signals in UAV photogrammetry.

Examine whether the markers can be used as surveying equipment. (GCP (ground control point) surveys)

Anticipated Results:

Contribute to the improvement of survey efficiency and precision through high-precision aerial photogrammetry employing GNSS markers.

Increase efficiency by simplifying GCP surveys.

Testing Overview

Equipments

AKTIO

・DJI Co,.Ltd MATRICE 210 RTK

* Camera : ZENMUSE_X5S 1unit

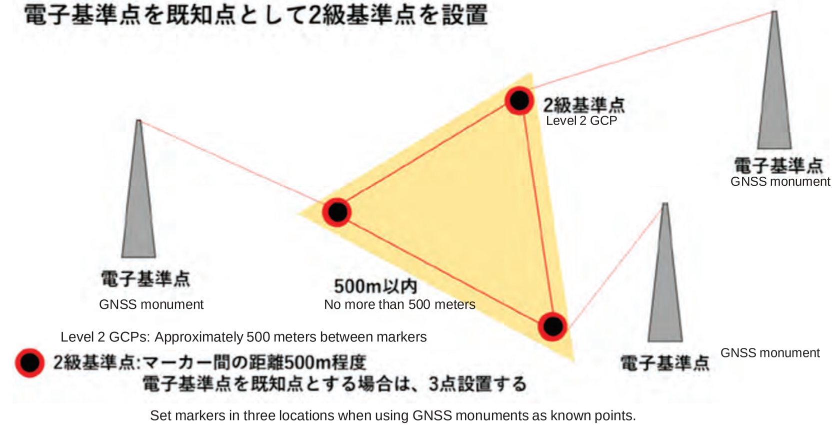
・Aerosense Inc. GNSS Marker 10cars

Description of Demonstration

- GCPs not available in the periphery

Set Level 2 GCPs using GNSS monuments as the known points.

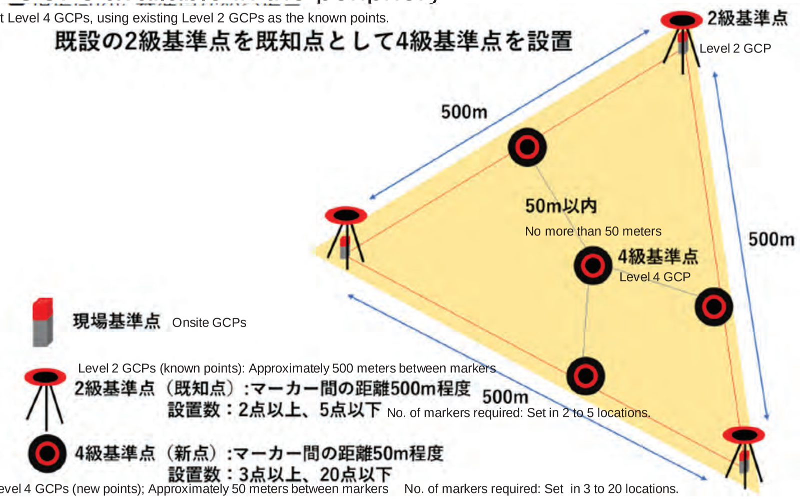
電子基準点を既知点として2級基準点を設置



- GCPs available in the periphery

Set Level 4 GCPs, using existing Level 2 GCPs as the known points.

既設の2級基準点を既知点として4級基準点を設置



Adopted the "GCPs Available" Scenario

① Place markers within the field to obtain location information.

② Perform UAV photogrammetric survey of the field.

③ Upload the photographs taken to cloud for analysis.

(Conceptual diagram)

Anticipated Effects

AKTIO

- From "surveying by professionals only" to "surveying by any and all'.

	Total Station トータルステーション（TS）	Aerobo Marker エアロボマーカー	Rover ローバー
			
方法 Method	放射法 Radiation method	スタティック測位 Static positioning	RTK (Realtime Kinematic)
精度 Accuracy	＜ 1cm	1cm － 2cm	数cm Few centimeters
観測時間 Observation Time	n/a	1時間 1 hour	最短10秒程度　(環境による) Minimum of about 10 seconds (Dependent on environmental conditions)
購入価格 （※当社調べ） Purchase price (*Per our research)	＞100万円　1 million yen	20万円　200 thousand yen	＞100万円　1 million yen
使い易さ Ease of Use	• レーザーの為、遮蔽物がある場合、迂回計測が必要 • 作業に2人必要 Need to measure around obstacles due to the use of lasers Requires 2 workers	• データ解析はクラウドで自動計算。ソフト購入不要。 • スイッチ押すだけで操作完了 • 1人で可能 Automatic data analysis by cloud computing; no need to purchase software Simply press a switch to complete operation 1 worker suffices	• 補正情報を受信する必要あり。（もしくは基地局設営必要あり） • 1人で可能 Need to receive correction information (or install a base station 1 worker suffices

AKTIO

- GNSS marker (class 2 certified),can make half volume of work. High quality positioning is available within ±1cm.

飛行・解析条件	既存手法	AeroSense
使用機体	他社製ドローン	エアロセンス製 AS-MC02-P
カメラ	Sony α6000	Sony DSC-QX30
オーバラップ（進行方向・横方向）	80%・60%	80%・60%
マーカーの測量方法	GNSS ローバ	エアロボマーカーによるスタティック測位 Static positioning
結果・比較		
GCP	14 pieces	10 pieces
GCP time	4 hours	1/2 → 2 hours
モデルの精度	±50mm	±50mm
地上解像度	20mm	20mm
Solution time	12 hours	1/4 → 3 hours

Presentation material for:
Aerosense Inc.

AKTIO

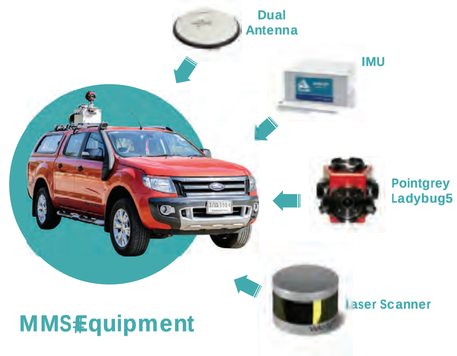
Mobile Mapping System (MMS) and Continuously Operating Reference Stations (CORS) Combination for 3D Dike Model Generation

Hydro – Informatics Institute (Public Organization)
Ministry of Higher Education, Science, Research and Innovation

CONTENT

1. HII MMS Introduction
2. Experiment Purpose
3. Experiment Procedure
4. Results and Conclusion

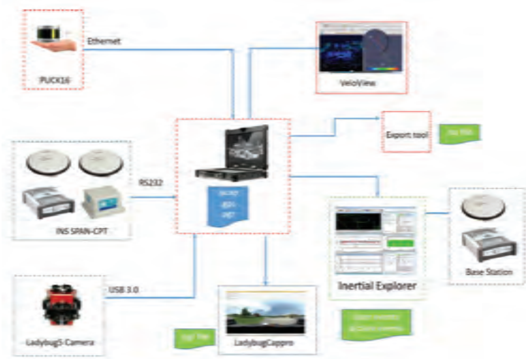
HII MMS Introduction



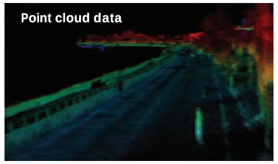
Mobile Mapping System (MMS) has been developed to be used to collect topographic data, especially water resource data for supporting disasters management.

To improve system performance, Ladybug5 camera and Laser Scanner has been applied to high speed collect high resolution point could data in widely range. Moreover, Dual Antenna and IMU can support to increase the quality and accuracy of collected data using GPS time.

HII MMS Introduction

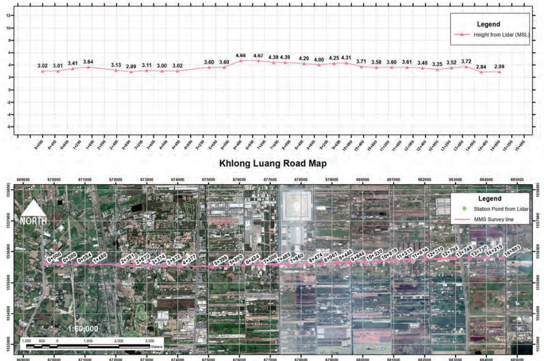


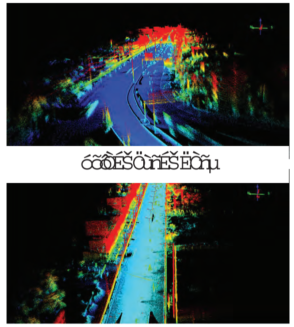
Experiment Purpose



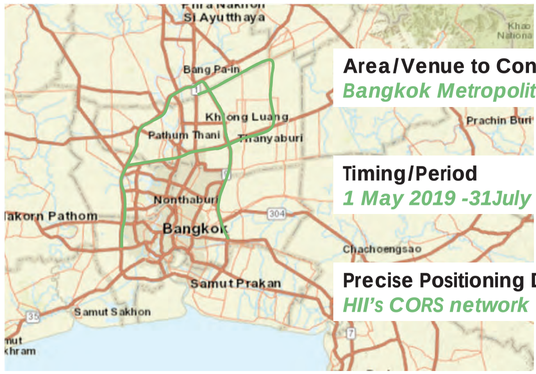
1. To find a suitable method of MMS for surveying dike 3D model
2. To generate 3D dike model by using MMS and CORS data
3. To compare dike surface height between MMS data and RTK data
4. To survey the vertical height of the Bangkok Metropolitan Region Road

Results and Conclusion





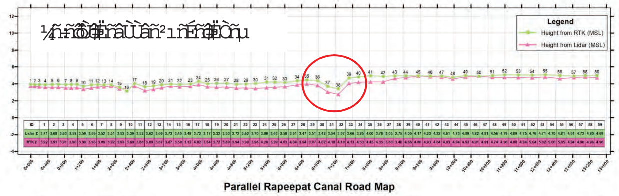
Experiment Procedure

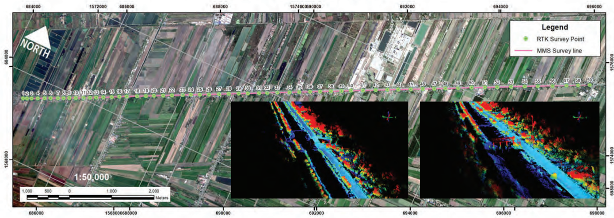


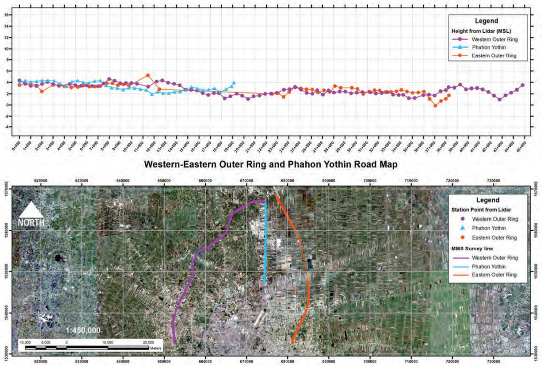
Area/Venue to Conduct the Project
Bangkok Metropolitan Region

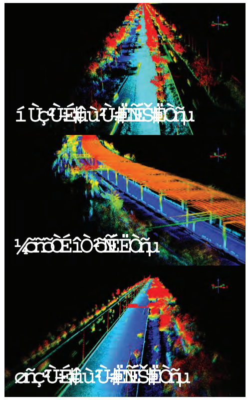
Timing/Period
1 May 2019 -31July 2019

Precise Positioning Data to be used
HII's CORS network









Results and Conclusion

This experiment evaluates HII-MMS performance using GNSS CORS, the experiment results show as follows:

1. HII-MMS system can be used to leveling as well, especially in a wide area, following this experiment that HII MMS be able to collect the data 100 kilometers within 1 day, which accepted accuracy at 35 centimeters.
2. MMS can obtain the multi-data including lidar data from Velodyne , trajectory from IMU and GNSS, and high resolution image from Lady bug for generating the dike 3D model.
3. The HII-MMS performance was evaluated by compare accuracy of retrieved elevation between MMS and RTK GNSS CORS, RMSE shows 0.386.
4. From the experiment results (point cloud and 3D model) display the elevation pattern of western-eastern outer ring road, so these results can explain that western-eastern side are higher than the center of BKK (Phahon Yothin). That means the center of BKK is a low river plain.

Hydro – Informatics Institute

Hydro – Informatics Institute (Public Organization)
Ministry of Higher Education, Science, Research and Innovation, THAILAND
tel +66 2 5180901 fax +66 2 5180910
www.hii.or.th www.thaiwater.net

3D Geo Imaging Technologies based on Advanced CV Technology

Iwane Laboratories, Ltd.

Iwane Laboratories

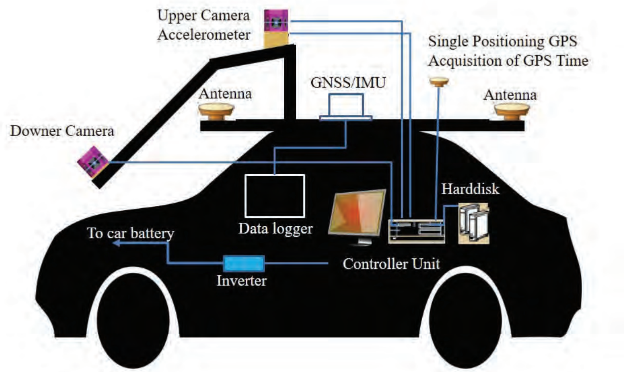
40 years unchanging mission : make the eyes of the robot!

About Iwane Laboratories

- ✓Manufacture of Mobile Mapping System (MMS)
- ✓Collection of MMS Digital Content on Demand
- ✓Web based Application
- ✓*Developing Artificial Intelligence based solutions - Analyzing 3D Space and Recognize Objects*
- ✓*3D Space for Autonomous car*

IMS3 BY IWANE LABORATORIES,LTD

Simple & Robust

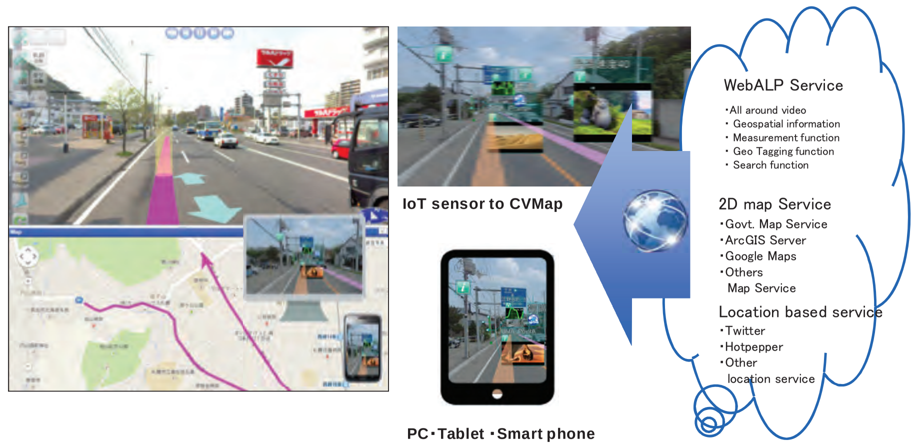


HIGH END POSITIONING FOR MAPPING !

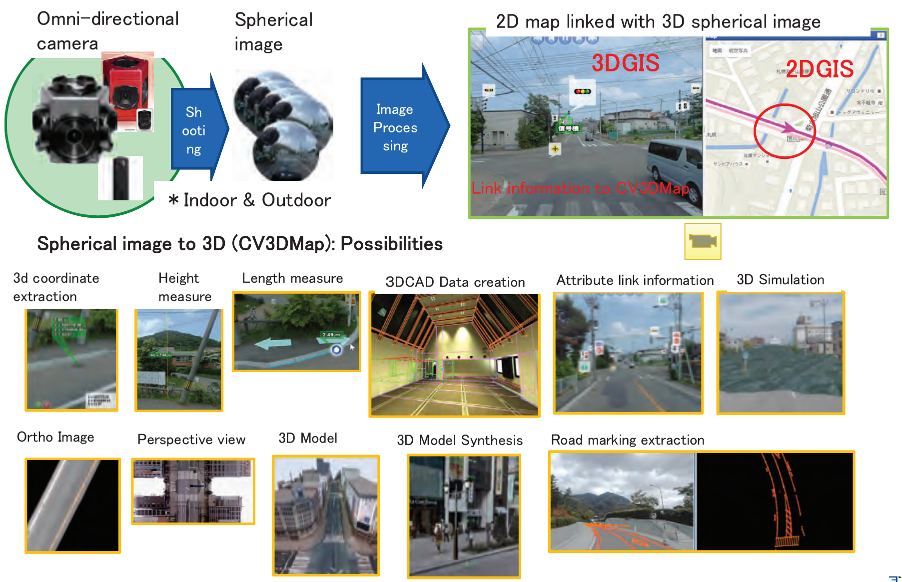
High end positioning with CVMap and it's capabilities

2D map linked with 3D spherical image

POSITIONING DATA ON WEB & MOBILE FOR SMART CITY



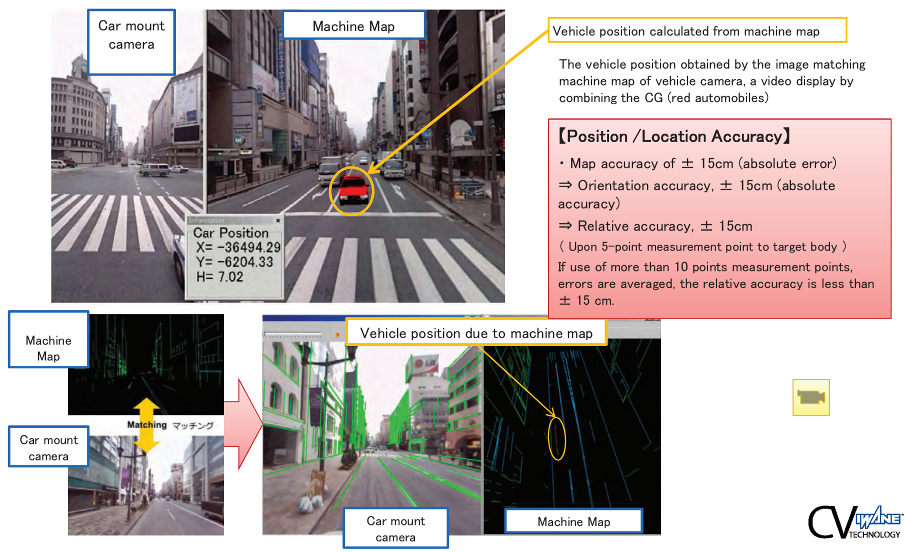
Measurable 3D Video



Machine Map and Auto drive

Under Dev.

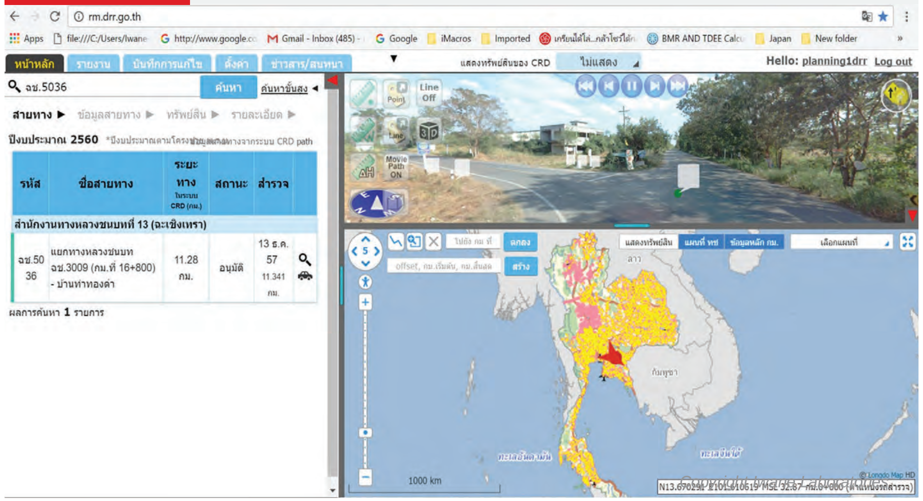
Determine the vehicle position by matching of machine map developed from the on-board camera with the pre-recorded machine map. ＊Position & orientation of vehicle position and also represent speed & direction



Thailand

Thailand

Department of Rural Road use to manage road asset and road safety with web application 47,000 km



HongKong

HongKong

Road Station has completed the whole of Hong Kong (approximately 6,500 km)

Thailand

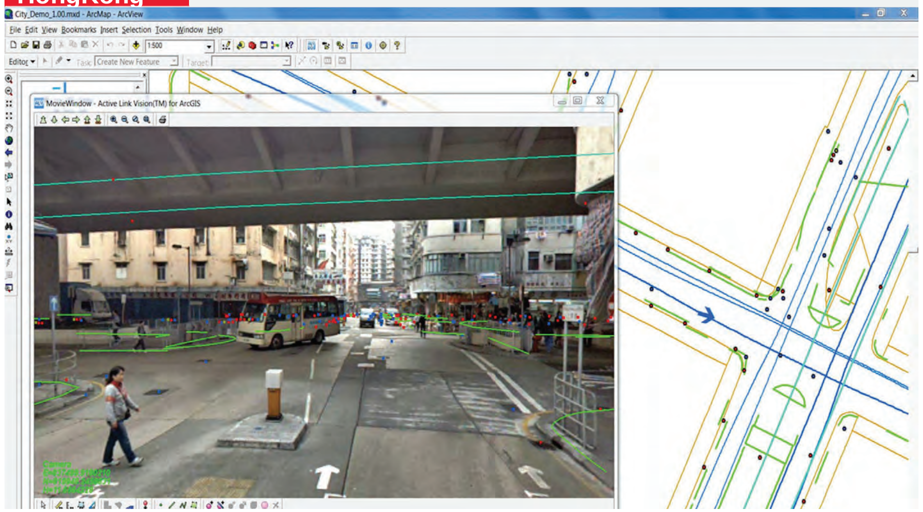
Thailand

Department of Public Works and Town & Country Planning use to manage Land parcel and Land use

HongKong

HongKong

Extract all road facilities from CV images
Management by WebGIS (Smart City)



Social experiment

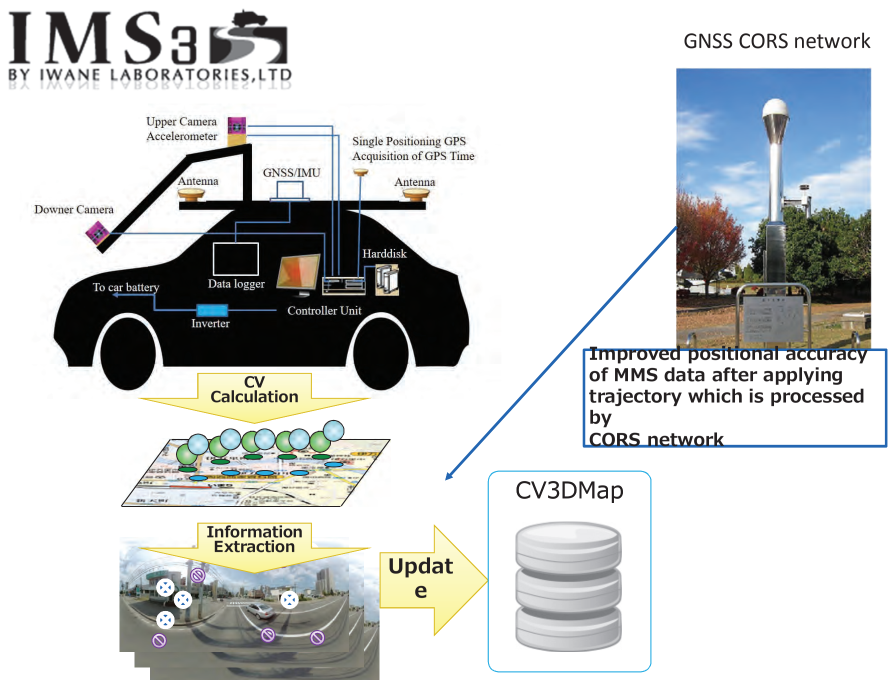
Accuracy Assessment
of
Mobile Mapping System (MMS)
using
CORS network

Contents

Capture image data on the roads using MMS and calculate the positional accuracy with GNSS and GNSS (post-process using CORS network)

Objectives

To determine the accuracy of MMS using CORS network in urban and rural areas



Equipment

CV IWANE TECHNOLOGY

Area

SKP : Sriracha

CV IWANE TECHNOLOGY

Thank you

Iwane Laboratories, Ltd.

CV IWANE TECHNOLOGY

快適空間 FC Flexible Conversion

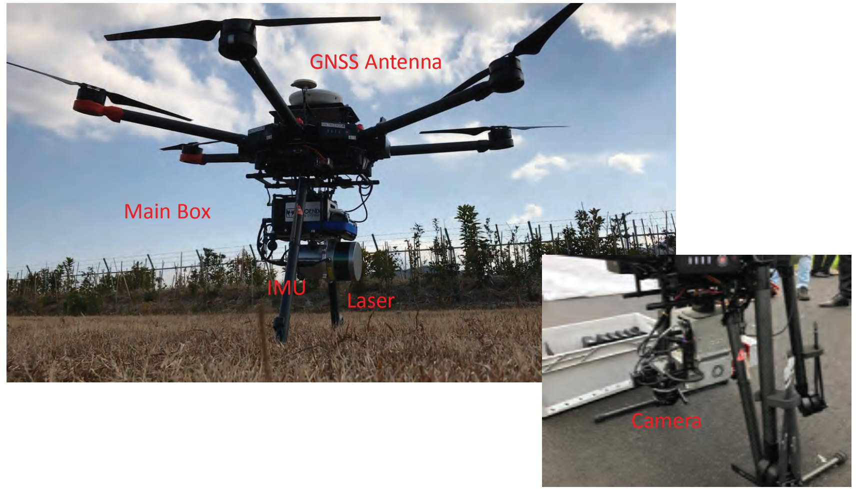
Natural Disaster Evaluation Based on UAV Aerial Survey Data Acquisition and Accuracy

株式会社　快適空間FC

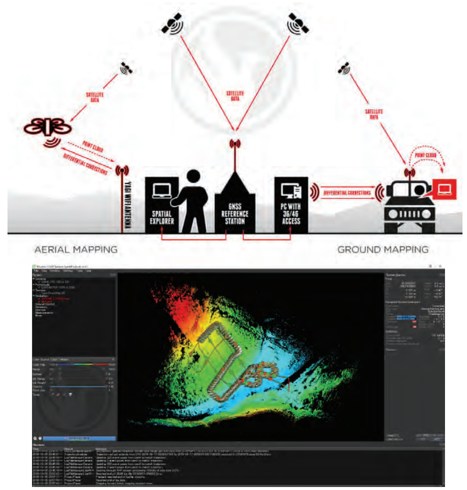
Details of Demonstration Experiment

- The UAV on-board small laser system performs 3D topographic measurement from the air.
- The quality of 3D measurement data depends on the quality of GNSS positioning and the vegetation situation on the ground.
- In this demonstration experiment, we will evaluate the location accuracy and data acquisition status, and evaluate whether it contributes to the use in the field of disaster prevention.

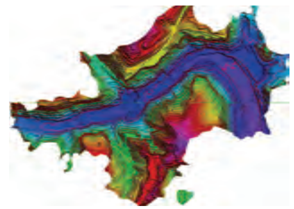
UAV System



Overview of Laser Surveying



- Streaming CORS data to LiDAR system on UAV using wireless communication or 4G data.
- Generate 3D data in real time and display terrain data on a personal computer monitor on the ground.



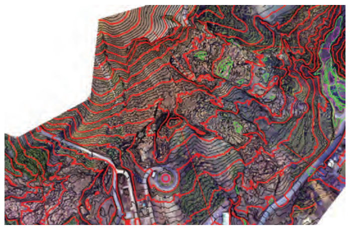
Demonstration Experiment Aims

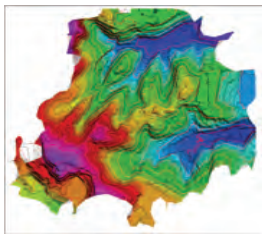
- How much does the decrease in positioning accuracy due to ionospheric disturbances occurring in the low latitudes affect UAV lasers?
- Understanding of differences in measurement data due to differences in CORSs installed at each organization
- Understanding the applicability of MADOCA method in UAV laser measurement

Expected Outcome

快適空間 Flexible Conversion

- By applying it to disaster prevention plans and public works in Thailand, the construction period can be shortened from the survey stage to the design stage and the project can be advanced smoothly.





Japan Asia Group
KOKUSAI KOGYO CO., LTD.

Information gathering and verification survey related to constructing social experiment field by maintaining global navigation satellite system
Social experiment using high precision data in Thailand

Behavior Grasp of a Local Base Point and Correction for GNSS-based Displacement Monitoring by Using its Neighboring CORS

August 28, 2019

Koichiro IIJIMA, Chikako ARAYA, Koichi TSUNO

KKC at a Glance (as of March 2018)

Corporate Name:	**KOKUSAI KOGYO CO., LTD.** (KKC)
Established:	**1947**
Head office:	**Tokyo, JAPAN**
Net asset value :	**US$ 224 million** (Consolidated)
Net sales:	**US$ 441 million** (Consolidated)
Number of Employees:	**2,798** (Consolidated)
Domestic Offices:	**47**
Overseas Offices:	**Hanoi, Jakarta, Taipei, Beijing, etc.**
Scope of Business:	**"Geospatial Centric Service Provider"** **- Geospatial information services** **- Disaster Risk Management and Environment** **- Infrastructure Engineering** **- Renewable Energy**

JAPAN ASIA GROUP and KKC

- Major Group Companies:

JAPAN ASIA GROUP LIMITED

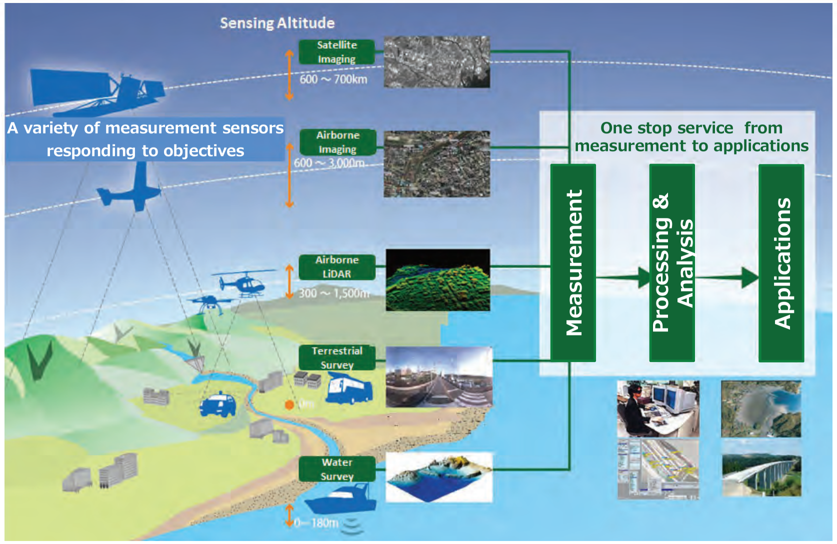
(First section of the Tokyo Stock Exchange: code 3751)

Geospatial information consulting	**KOKUSAI KOGYO CO., LTD. (KKC)** ASNAL CORPORATION CO., LTD. Toyo Sekkei CO., LTD. EONEX CO., LTD. RISUISHA CO., LTD. KOKUSAI BUNKAZAI CO., LTD. RYUKYU KOKUSAI KOGYO CO., LTD. Meiji Consultant Co., Ltd.
Green energy	JAG Energy Co., Ltd. JAG Power Engineering Co., Ltd. JAG Investment Management Co., Ltd. Miyazaki Solar Way Co., Ltd. JAG Seabell Co., Ltd. KOKUSAI BUILDING MANAGEMENT CO., LTD. KHC Ltd. KATSUMI JYUTAKU CO., LTD. DAIWA-KENSETSU CO., LTD. AKASHI-JYUKEN CO., LTD. PAL CONSTRUCTION CO., LTD. Labo Co., Ltd.

KKC's Business Domains

- KKC keeps contributing to the futures of societies and earth environments under the concept of "Save the Earth, Make Communities Green."

KKC's One Stop Service

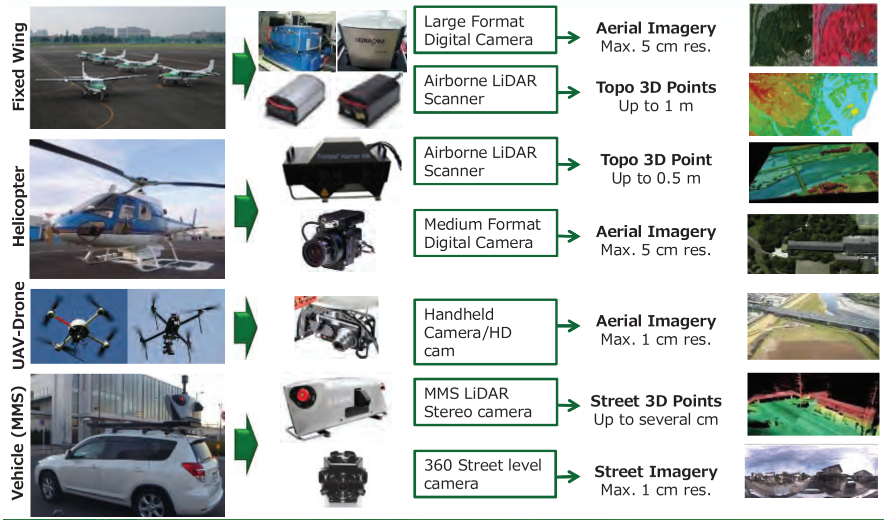


KKC's Satellite-based Remote Sensing

- KKC provides its own remote sensing services through the affiliations with major satellite imagery providers.

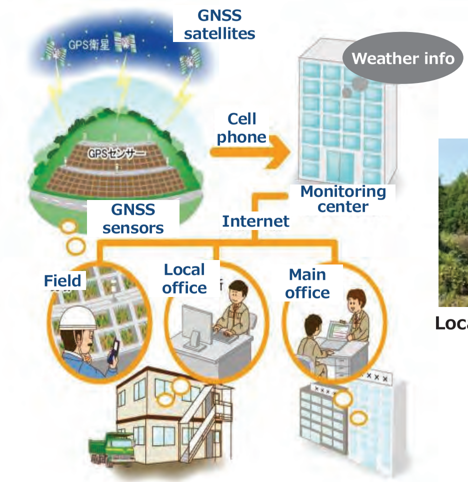
KKC's Airborne & Mobile Sensing

- KKC provides sensing services with a variety of platforms with sensors.



shamen-net Service

shamen-net : Real-time displacement monitoring service

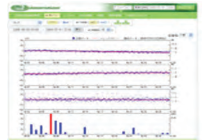


Local Sensor

- Up to **1 mm** displacement detection through **Trend Model Analysis** (KKC's IP)
- Monitors the area **24/7**
- KKC **custom technology**
- **800+ sensors** operations

Noticing, Warning, Reporting & Analyzing

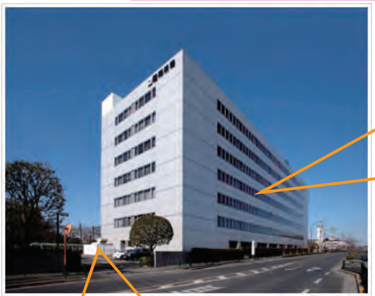
Displacement vector



Data graph

Monitoring Center

24 hour-operating Monitoring Center available



24 hour operating **Monitoring center at KKC**

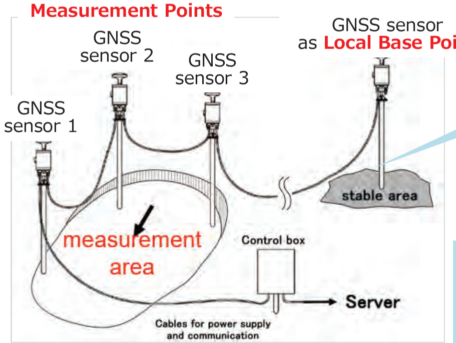
Server with UPS (Uninterruptible Power Supply)

Duty of Monitoring center

Automatic data-analysis
Diagram and data delivery
Displacement monitoring
Machinery monitoring

Issue about Local Base Point

- A local base point for mm-class monitoring of ground, infrastructure, etc. using GNSS survey (static positioning) is usually installed in the neighborhood of a target area to be monitored.



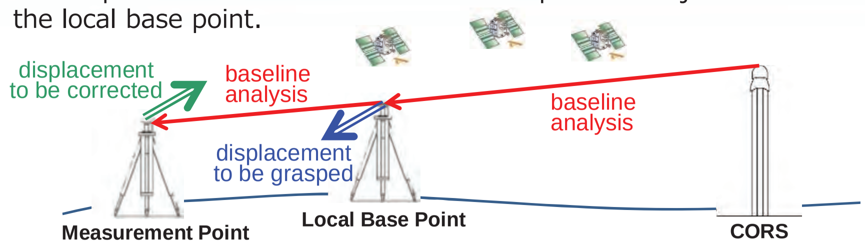
Local Base Point → should not move

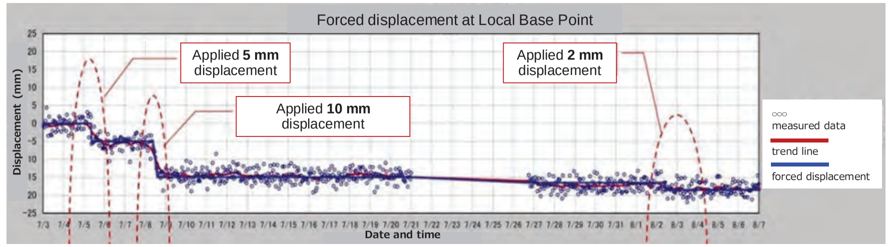
But, if the base point moves …

Is it possible to calculate the displacement of the point by using the closest CORS and to correct the displacement data?

Correction of Displacement Data

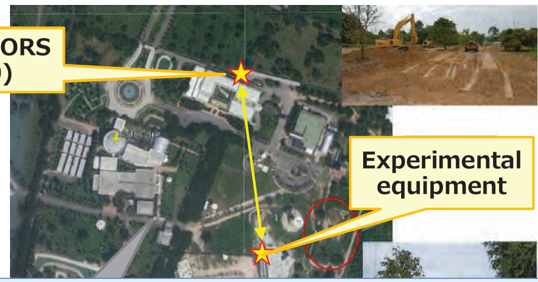
- The displacement data at a measurement point is subject to that at the local base point.





Experimental Method

- **The experiment is currently being conducted at the SKP site.**

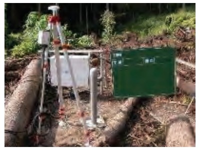


- **Install two GNSS sensors in the SKP experimental area.**
- **One GNSS sensor acts as a measurement point, and the other GNSS sensor acts as a local base point.**
- **Assume tripod fixation to install the antennas and install storage boxes dedicated for receivers near the tripods.**
- **Use a forced displacement jig to assume that the local base point moves.**
- **The amount of the local base point's move can be corrected through the analysis using the CORS data in SKP.**

Details of Experiment

item	contents
Experiment period	August 23 through August 30, 2019
Experimental equipment	・GNSS antenna and receiver AS-10・GR-10 (Made by Leica): 2 sets ・Tripod and materials for fixation: 2 sets ・Dedicated storage box (receiver and power supply unit): 2 sets ・Forced displacement jig : 1 set
Information on the engineers who work in the field	・KOKUSAI KOGYO CO., LTD.: 2 people (Chikako ARAYA and Koichi TSUNO)
Data that KKC wants to take out of Thailand	Data: GNSS positioning data Reason: To carry out baseline analysis in Japan


GNSS antenna and receiver



Experimental image

Closing - Possible Impacts

- **It is expected to improve measurement accuracy in a variety of target fields including:**
  - ➢ Monitoring large landslides
  - ➢ Monitoring wide area ground subsidence
  - ➢ Monitoring important large scale infrastructures such as bridges, dams, etc.


Large landslides


Ground subsidence


Large scale infrastructures

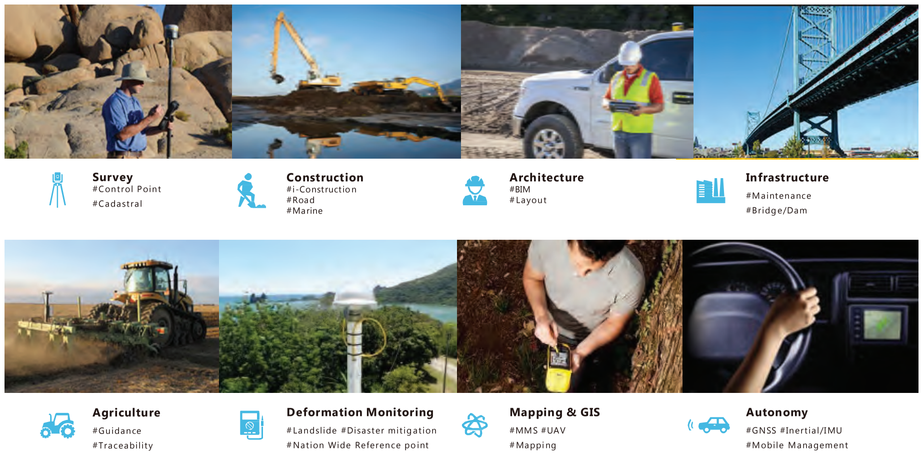
Comparison of positioning availability by GNSS only and GNSS with IMU in Thailand

Masayuki Kanzaki, NIKON-TRIMBLE Co., Ltd.
28th August 2019

Utilization of GNSS/CORS information

CORS is reference information for Geo Spatial activities

Never suspend, always provide the reference information



Mobile Mapping System

There are many of applications that using GNSS for navigation and surveying instruments.

Especially, precision navigation such as autonomous driving need very accurate geospatial information so called "3D Digital map" for safe.

The purpose of this project is to grasp the availability of satellite positioning system in advance, in anticipation of geographical information gathering using mobile mapping system (MMS) becoming popular in Thailand in the future. Specifically, positioning comparison is actually performed and grasped about the area which can not be measured unless the area which can be measured only by GNSS and GNSS and IMU (inertial measurement unit) are combined.

MMS (Mobile Mapping System)

Trimble MX9 – state of the art mobile mapping system

Key component of MMS (in case of Trimble MX9)

LiDAR
- 2 x RIEGL VUX-1HA
- Up to 2 MHz
- 500 scan lines per/sec
- Max range (target reflectivity >80%)
  - 235 m at 2 MHz
  - 420 m at 600 KHz
- 5 mm accuracy / 3 mm precision
- Adjustable lasers

Camera
- 1 x Spherical camera
- 2 x Front looking, 1 x downward looking cameras (5MP)
- Adjustable direction for front looking cameras

GNSS+IMU
- Applanix AP 60

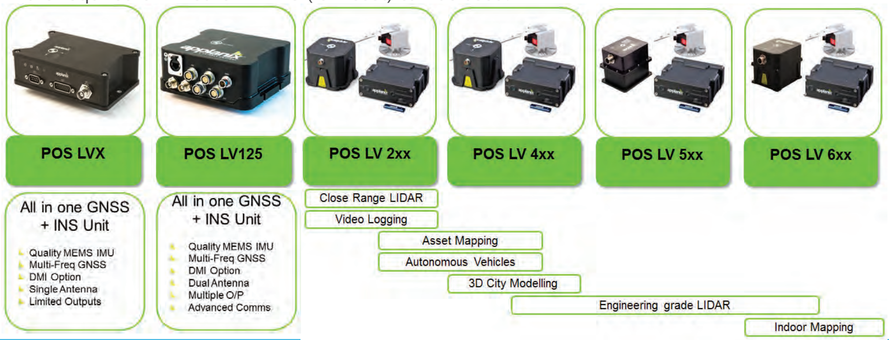
How to evaluate utilization of MMS in Thailand?

We have probed how MMS (MX9) works in Japan by many of test and actual surveying.

Different between Japan and Thailand is environment of satellite visibility and obstacles of signal receptions in the urban area.

The IMU is powerful instrument to realize robust and high rate precise positioning at anywhere, so it typically used in MMS to measure sensor position.

By grasping the degree of dependence of the IMU, it is possible to study a specific system configuration, such as whether high-performance devices FOG or LRG (both are expensive) are required or whether MEMS (low cost) can be used.

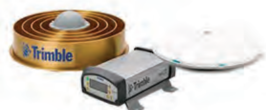


Configuration of comparison

Driving car around Bangkok urban area with Applanix LVX (turn-key GNSS-Inertial device), capture the positioning results and its status with diagnostics information of positioning. POSPAC software can be retrieve detail of diagnostics information such as satellite signal receptions, so we can evaluate the difference of performance between GNSS only and GNSS+IMU from it.

Other sensor such as LiDAR (Laser) and camera are not depends on the location, so we do not use them to experiment. we planning to use only Applanix LVX to avoid the export issue.

GNSS antenna on the roof of vehicle (Dual antennas for GAMS)



GNSS receiver and antenna for Private control station as fiducial.

GNSS receiver with IMU for Positioning at Bangkok urban area.

Test Course in Bangkok and GISTDA SKP Demonstration

ATI Designated Route in Bangkok

HII Designated Route

Demo Course in GISTDA SKP
ATI Autonomous car driving

Ratchadaphisek Rd. 10Km
Rama9 Rd. 11Km

Future discussion

It is significant reduce the cost to build the MMS if we can use MEMS sensor to measure robust and accurate position. Of course, it is best to use Trimble MX9 but it expensive…

MMS is powerful tool to create accurate map, measure the assets and the road, so it is productive that to use much number of MMSs with reasonable cost.

You can find affordable MMS units with GNSS+IMU at LiDAR USA company as follows.

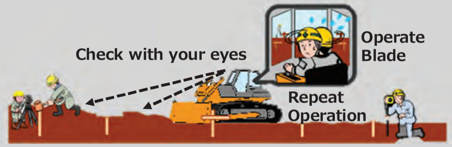
i-Construction trial in Thailand

NISHIO RENT ALL CO., LTD
TOPCON CORPORATION

Conventional vs ICT Construction

Conventional Style - Manual-

Blade movement depends on his skills.



- **Spend massive time & Man hour** for Surveying & Setup Stakes
- Impossible to work out required flat surfaces all the way.

ICT Construction - Automation -

Automation of construction work

- **Reduce time & Man hour** Surveying & Setup Stakes
- Much faster than conventional style speed
- Easy to work out required flatness all the way

i-Construction Trial

i-Construction is based on advanced technology.

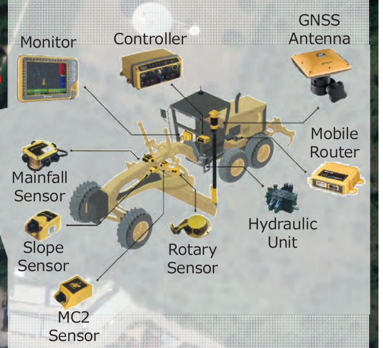
- GNSS Positioning system
- Machine Control system
- Digitization technology

We trial i-Construction in Thailand.

i-Construction Trial

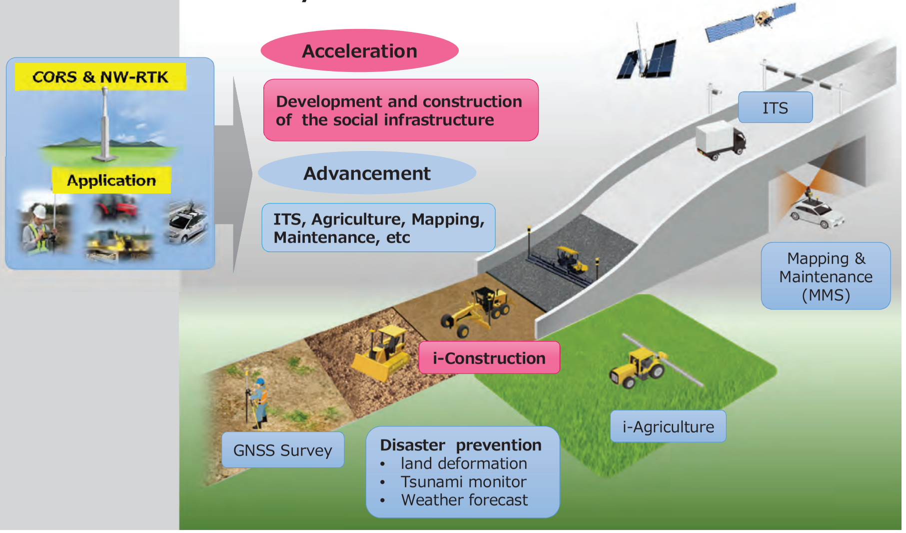
GISTDA Space Krenovation Park

Demonstration on August 30th



CORS Application Expansion

CORS and Application of Precise GNSS will provide acceleration and advancement of society.



Thank you

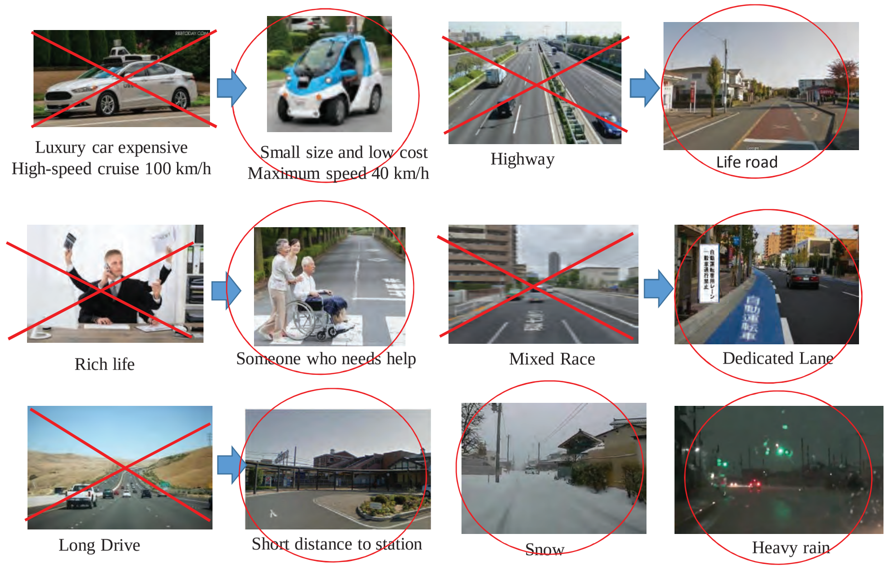
Asia Technology Industry

BlueTag

EV – A Micro EV – Automated Driving Project

Asia Technology Industry

Micro EV – Target Performance



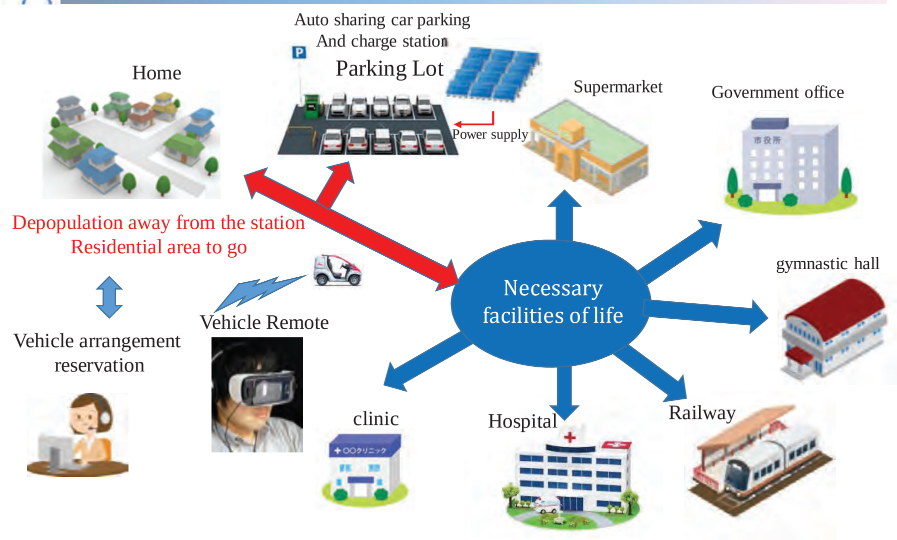
Asia Technology Industry

Joint research

Chulalongkorn University and Asia Technology Industry
Joint Research and Development of Micro EV Low Cost Autonomous Driving Vehicle using High precision Satellite Positioning

Asia Technology Industry

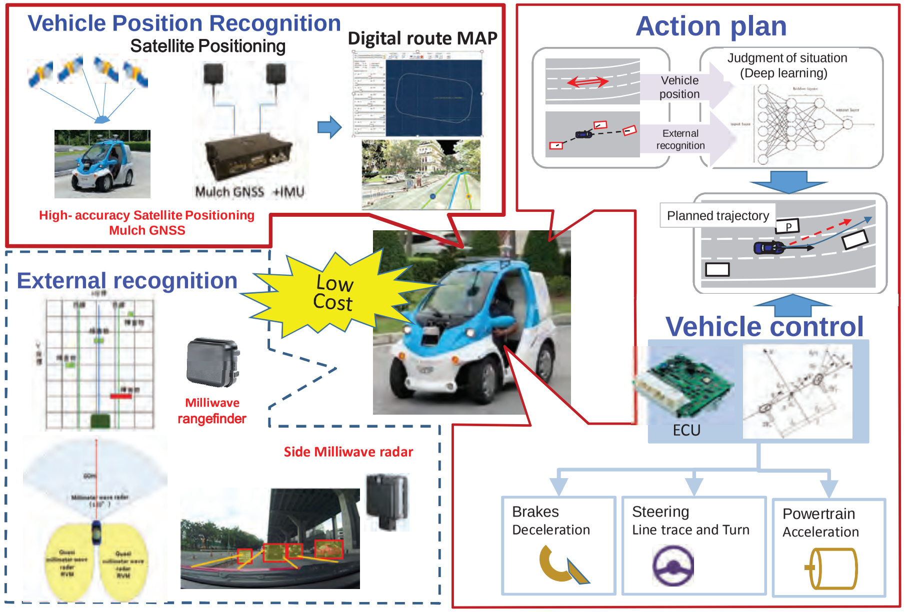
Micro EV – Automated Driving Project Service



Provide the minimum scale of services necessary for residents' lives

Asia Technology Industry

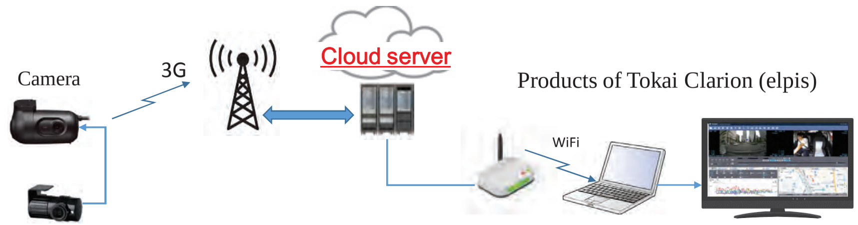
Configuration Diagram of Automated Driving System



Automatic Driving Live Monitor System

Automated driving vehicle monitoring system

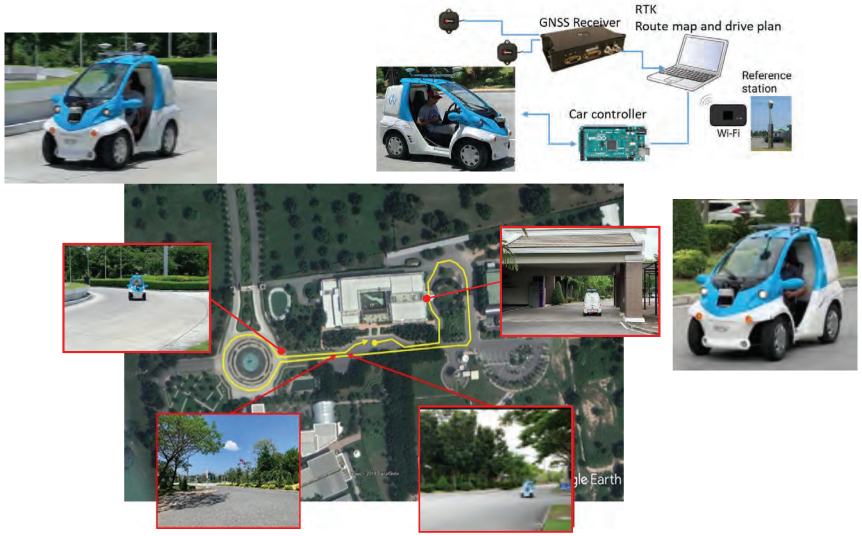
- View real-time footage of the forward and driver's seat landscape
- Display location information on the map
- Graph the behavior of the vehicle



Live broadcast for the front view camera and driver monitor camera during automatic driving

Asia Technology Industry

Demonstration course of Automatic Driving in SKP



Stable positioning is possible even in harsh environments for satellite reception

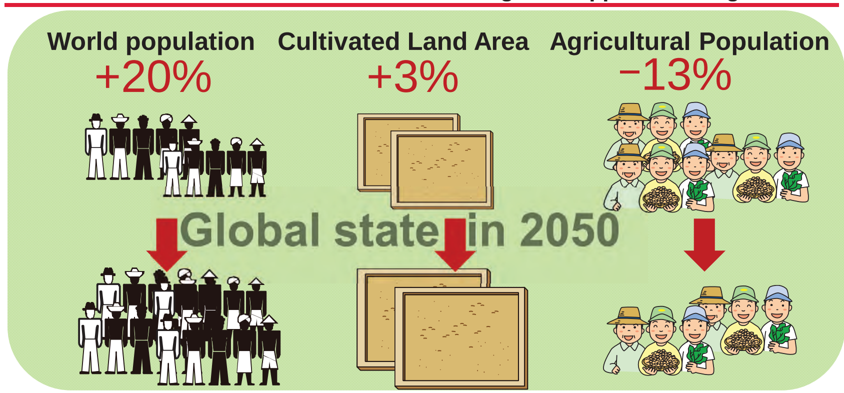
END

Autonomous Driving Demonstration by Agricultural Machines

August 28, 2019

YANMAR AGURIBUSINESS Co., Ltd.

With the environment surrounding agriculture changing worldwide, there can be no sustainable future unless we change our approach to agriculture.



Age when a few ag producers must meet an ever-growing food demand

Need for robot tractors that can be operated easily by anyone

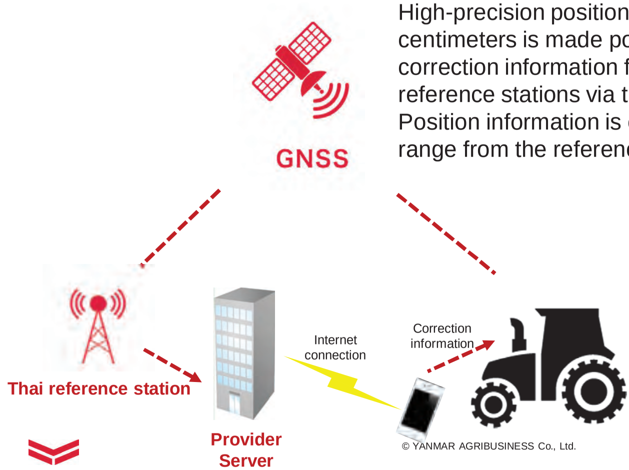
Robot Tractors

- Monitor and control operations with a tablet from a short distance without getting into the tractor.
- Two sets of correction information (GNSS and base station) enable high-precision positioning within a few centimeters.
- Built-in laser and ultrasonic safety sensors detect and measure distances from people and obstacles.
- Equipped with safety brakes that halt the tractor when the engine stops while self-driving.

Overview of Positioning Method Used in This Test

■RTK-GNSS (N-trip) Positioning

High-precision positioning within a few centimeters is made possible by obtaining correction information from GNSS and reference stations via the Internet.
Position information is obtained within a short range from the reference stations.



Description of Social Testing

☐ Overview
Operate Robot Tractors in a field near reference stations in Thailand.

☐ Matters to Be Confirmed
Perform operations comparable to those in japan
1. Self driving (straight line, turns) 2. Agricultural operations
3. Emergency stops

☐ Conditions
Period: 23,24 July
Location: Farmland in Thailand
Model:Rotary,Minicombine(Subsoir), SugarKenPlanter

Robot Tractors

Simultaneous operation of unmanned & manned units

Visual Sample of Robot Tractors in Operation

10 Pilot Projects from Thailand & Japan