The Kingdom of Thailand
Ministry of Higher Education Science Research and Innovation,
National Geo-Informatics Board

Survey for the Establishment of the Experimental Field for the GNSS System Development in the Kingdom of Thailand

Final Report

February 2020

Japan International Cooperation Agency (JICA)

PASCO CORPORATION

Kokusai Kogyo Co., Ltd.

Table of Contents

ANNEX

1) PROPOSED SPECIFICATIONS OF CORS EQUIPMENT
2) REPORT ON SOCIAL EXPERIMENT
3) PRESENTATION MATERIALS OF THAILAND JAPAN SPECIAL SESSION

EXCHANGE RATE

3.47478 yen/Baht (JICA rate as of September 2019)

List of Figures

List of Tables

Abbreviations

Abbreviation	Description
AIT	Asian Institute of Technology
BeiDou	BeiDou Navigation Satellite System
BKG	Bundesamt für Karthographie und Geodäsie (in German)
CAAT	Civil Aviation Authority of Thailand
CORS	Continuously Operating Reference Station
DDPM	Department of Disaster Prevention and Mitigation
DOF	Department of Fishery
DOL	Department of Lands
DPT	Department of Public Works and Town & Country Planning
EEC	Eastern Economic Corridor
EECi	Eastern Economic Corridor innovation
EGSA	European GNSS Agency
FGDS	Fundamental Geographic Data Set
GBAS	Ground-Based Augmentation System
GEONET	GNSS Earth Observation Network System
GIN	Government Information Network
GiNNo	GNSS Innovation Center
GIS	Geographic Information System
GISTDA	Geo-Informatics and Space Technology Development Agency
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
HII	Hydro Informatics Institute
IERS	International Earth Rotation and Reference Systems Service
IGN	Institut Géographique National (in French)
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
JUPEM	Jabatan Ukur dan Pemetaan Malaysia (in Malay)
MADOCA	Multi-GNSS Advanced Demonstration tool for Orbit and Clock Analysis
MHESI	Ministry of Higher Education Science Research and Innovation
MGA	Multi GNSS Asia
MMS	Mobile Mapping System

Abbreviation	Description
MNO	Mobile Network Operator
MVNO	Mobile Virtual Network Operator
NBTC	National Broadcasting and Telecommunications Commission
NCDC	National CORS Data Center
NIMT	National Institute of Metrology（Thailand）
NMEA	National Marine Electronics Association
NSTDA	National Science and Technology Development Agency
OS	Ordnance Survey, Great Britain
PPP	Precise Point Positioning
PWV	Precipitable Water Vapor
QZSS	Quasi-Zenith Satellite System
RGP	Le réseau GNSS permanent (in French)
RTCM	Radio Technical Commission For Maritime Services
RTK	Real Time Kinematic
RTSD	Royal Thai Survey Department
UAV	Unmanned Aerial Vehicle
UNAVCO	University NAVSTAR Consortium
VMS	Vessels Monitoring System

1. Outline of the Survey

Outlined below are the objectives, area, scope, etc. of this Survey.

1.1. Background, Objectives, etc. of the Survey

（1） Background

The Thai government, in its "Thailand 4.0" socio-economy vision for the next 20 years, called the three eastern coastal provinces (namely, Chonburi, Chachoengsao, and Rayong) the "Eastern Economic Corridor (EEC)" as the center for developing high-added-value manufacturing and services and achieving higher competitiveness. The Eastern Economic Corridor innovation (EECi) is one of the Special Services Promotional Zones within EEC, in which technological innovations are being promoted with a special focus on technologies and applications using satellite-based precise positioning data.

The Japanese Government has been promoting research and development of remote-monitored unmanned agricultural vehicles, as well as sophistication of disaster prevention systems, through the provision of precise positioning services, etc. based on Quasi-Zenith Satellite System (QZSS) and Continuously Operating Reference Station (CORS), and is seeking to disseminate these technologies overseas as part of its "initiative towards expanding high-quality infrastructure export."

Thailand is regarded as one of the priority countries for establishing precise positioning services, as it is a host to many Japanese companies. Conducting precise positioning-related social experiments in Thailand will allow various technologies to be developed, which would be difficult in Japan due to many restrictions, and thus is expected to push forward the development of technologies that will benefit both Thailand and Japan.

In Thailand, a number of government agencies, including Royal Thai Survey Department (RTSD), Geo-Informatics and Space Technology Development Agency (GISTDA), Department of Lands (DOL), Department of Public Works and Town & Country Planning (DPT), and Hydro Informatics Institute (HII), have set up their own CORS facilities and are using them for their respective applications. In order to provide precise positioning services, these facilities need to be integrated/networked and operated in a centralized manner. To integrate data, the Thai Government decided to establish the National CORS Data Center (NCDC) in March 2017 towards the development of infrastructure for providing precise positioning services.

（2） Objectives

The objectives of this Survey are to gather information to identify challenges and obstacles to operating the NCDC and network, which are integral elements of the infrastructure that will enable the provision of precise positioning services in Thailand, and to find information that will be useful in developing precise positioning-based technologies and businesses in Thailand by Japanese companies.

（3） Survey Area

The entire land of Thailand (mainly Bangkok Metropolitan Region and Eastern Economic Corridor)

（4） Main Counterpart Organizations in Thailand

Ministry of Higher Education Science Research and Innovation (MHESI), National Geo-Informatics Board (NGB), GNSS Subcommittee, Thailand-Japan Joint Working Group (WG)

- NGB was established in 2003 under the Prime Minister pursuant to the Rule of the Office of the Prime Minister to assist the development of national GIS policies.
- GNSS Subcommittee is one of the subcommittees under NGB. Its purposes are to supervise NCDC, study/analyze/define GNSS standards, collaborate with other organizations in and outside Thailand to promote GNSS-related endeavors, and facilitate and support all other aspects of GNSS utilization and applications, including those concerning national security and socio-economic activities.
- Thailand-Japan Joint WG is one of three WGs formed under GNSS Subcommittee for facilitating cooperation between Thailand and Japan towards the development of CORS infrastructure. This WG is comprised of the following eight organizations:
    1) Department of Fishery (DOF)
    2) Department of Lands (DOL)
    3) Department of Public Works and Town & Country Planning (DPT)
    4) Geo-Informatics and Space Technology Development Agency (GISTDA)
    5) Hydro Informatics Institute (HII) (the Secretariat of the WG)
    6) National Institute of Metrology, Thailand (NIMT)
    7) National Science and Technology Development Agency (NSTDA)
    8) Royal Thai Survey Department (RTSD)

The configuration of NGB, GNSS Subcommittee, and Thailand-Japan Joint WG is shown in Fig. 1-1.

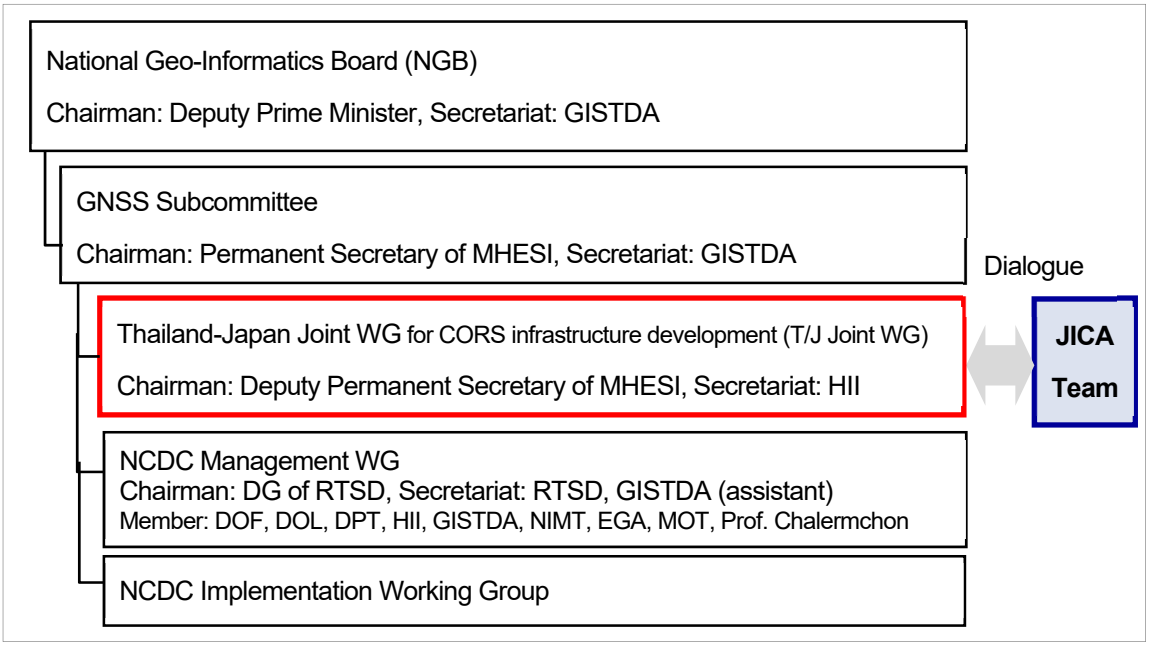


Fig. 1-1: Configuration of National Geo-Informatics Board

(5) Scope of the Survey

This Survey, after preparatory desk study of relevant documents and data, gathers and analyzes information concerning precise positioning services in Thailand by establishing an organizational structure jointly with the Thai Government for conducting the Survey in order to achieve the objectives described in [1-1 (2). Objectives]. Gathered information is sorted out to devise plans for the utilization, distribution, etc. of precise positioning data. The Survey also includes support for precise positioning-based social experiments to be conducted in Thailand as well as invitation of Thai Government personnel engaged in CORS-related duties to Japan for technical visits. During the course of the Survey, an Inception Report, Interim Report, Final Report, etc. are prepared and submitted upon presentation to and discussion with JICA and counterpart organizations in Thailand.

(6) Survey Period

This Survey is scheduled to be carried out from November 2018 to March 2020.

1.2. Overviews of the Main Counterpart Organizations in Thailand

The services, personnel, and budget sizes of the seven Thailand-Japan Joint WG member organizations that were subject to interviews are summarized below.

(1) DOF

A department of the Ministry of Agriculture and Cooperatives (MOAC), DOF is responsible for administration of fisheries. Because it is responsible for not only marine fisheries but also aquaculture, all of Thailand falls within the jurisdiction of DOF. Including 76 provincial offices and 527 county offices, DOF employs about 8,800 personnel. The DOF's Information and Communication Technology Center and Fishing Control and Surveillance Division are engaged in work related to GNSS CORS.

With more and more ICT technology introduced, work such as the setting of prohibited fishing areas and the management of fishery rights using geospatial information is taking place. In addition, a Vessels Management System (VMS) utilizing geospatial information and positioning information has been established to monitor fishing vessels over 30 tons. It also provides information on natural environments and fishery resources through a smartphone app.

While DOF is without CORS, it is considering actively utilizing positioning information, including geospatial information, in the future.

Fig. 1-2: DOF structure (As of September 2019)

Source: DOF website (https://www4.fisheries.go.th/index.php/dof_en/view_role/2)

(2) DOL

A department of the Ministry of Interior, DOL is responsible for general land administration. Its main duties include safeguarding land rights, issuance of land certificates, maintenance of land information, land registration, and so on. DOL has a total of about 10,600 employees, with about 2,500 employees at its central locations and about 8,100 employees in regional areas (prefecture offices, county offices, etc.). DOL's CORSs are mainly used in control point surveys for cadastral survey. The operation and management of DOL's CORS network is conducted by the Mapping Technology Division, which operates 24 hours a day, 7 days a week.

DOL's CORS network currently consists of 134 stations (including those added in 2019), making it the largest of those maintained by any Thai government agency. The network RTK data generated from DOL's CORSs is currently available free of charge for a limited time (https://dol-rtknetwork.com/), aiming to

encourage further utilization to make conducting cadastral surveys more efficient.

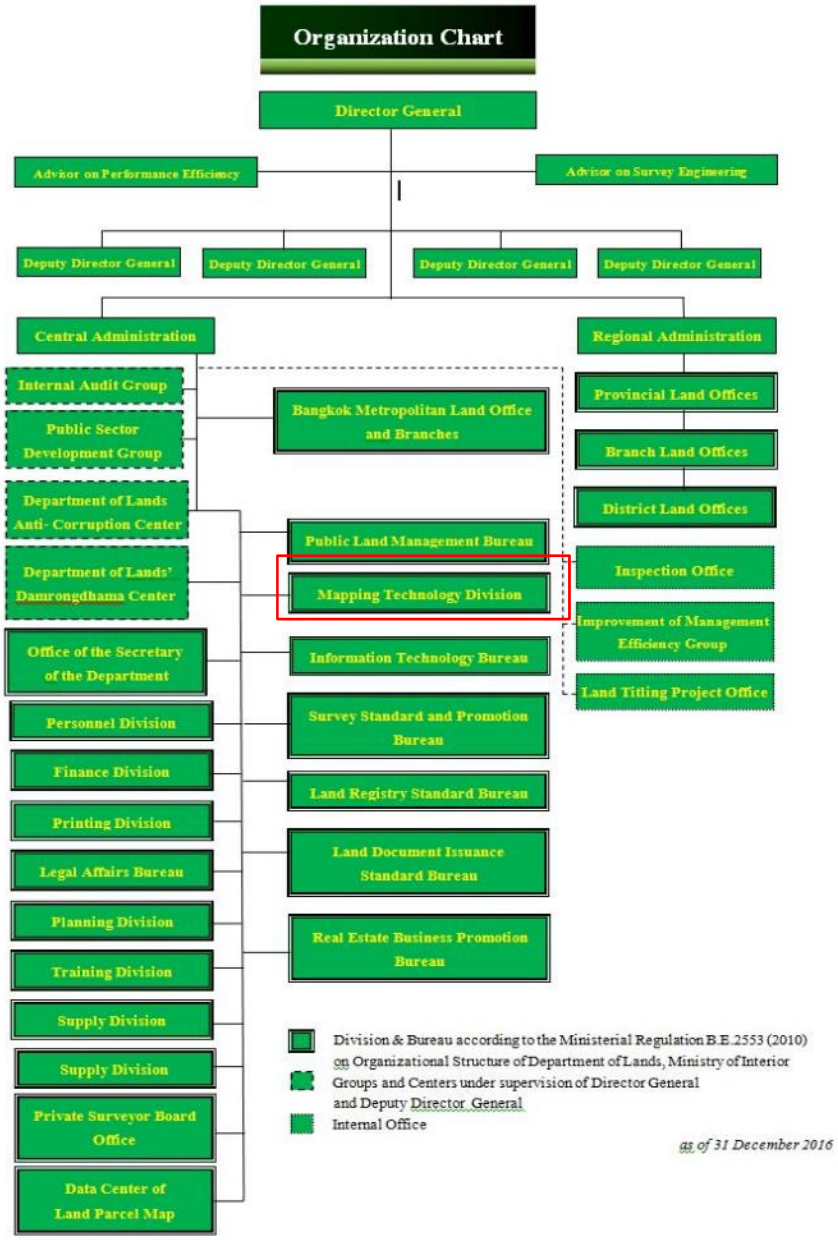


Fig. 1-3: DOL organization chart (As of September 2019)

Source: DOL website (http://www.dol.go.th/Pages/en/Organization-Chart-.aspx)

(3) DPT

A department of the Ministry of Interior, DPT is responsible for public works, spatial planning, and city planning, from the national to the local level. It conducts operations in urban and rural areas, and also has regional offices. DPT's CORSs are used to create large-scale geospatial information (1/1,000 or 1/4,000) necessary for urban planning, urban development, infrastructure development, and other services.

DPT's CORS network is composed of a total of 15 stations located mainly in major cities, including the Bangkok Metropolitan Region. It is managed and operated by the Town and Country Planning Engineering Bureau (about 120 employees).

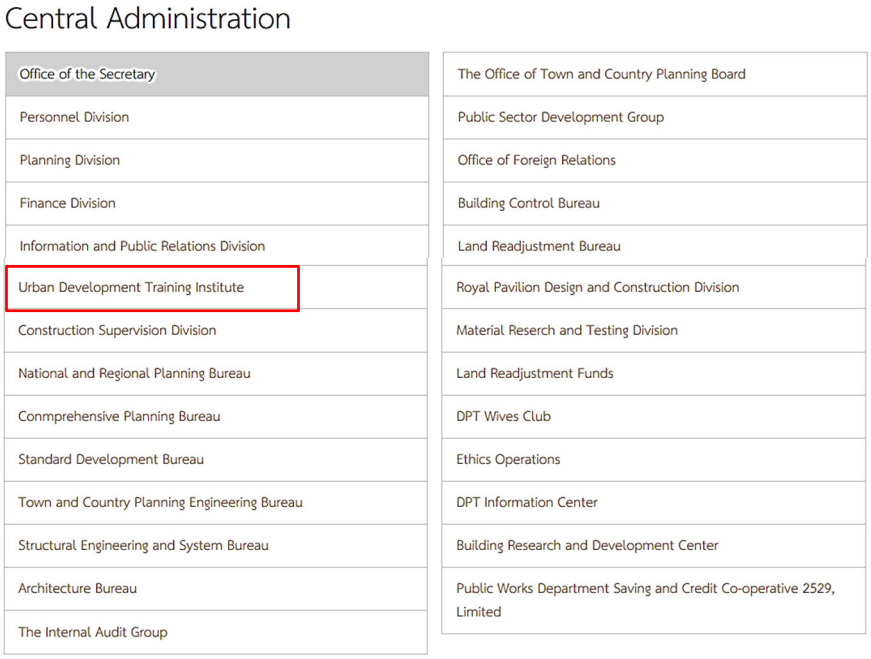


Fig. 1-4: DPT Central Administration organization chart (As of September 2019)

Source: DPT website (https://www.dpt.go.th/en/dpt-administration/central-administration.html)

(4) GISTDA

A public organization[1] under MHESI (formerly the Ministry of Science and Technology), GISTDA conducts research and development on remote sensing, GIS, geospatial information, and space technology. GISTDA is responsible for THailand Earth Observation Satellite (THEOS), Thailand's first Earth observation satellite program. GISTDA's Space Krenovation Park (SKP) facility in Sri Racha, Chonburi Province is home to the THEOS Satellite Observation Center, the base for the program's operations. GNSS satellite and CORS research and development is conducted as part of this geospatial information and space technology development.

[1] Thai public organizations are similar to Japanese incorporated administrative agencies and national research and development agencies.

GISTDA's CORS network consists of 31 stations: 4 GISTDA stations, 10 DOL stations, 15 DPT stations, 1 King Mongkut's Institute of Technology Ladkrabang station, and 1 Chulalongkorn University station (IGS station). Of particular interest is the use of precise positioning technology, such as for autonomous operation of agricultural machinery, machine control of construction equipment, autonomous operation of drones, and infrastructure monitoring.

At the GNSS Japan Pavilion, which opened inside the GNSS Innovation Center's permanent exhibition hall on the premises of the SKP in January 2018, Japanese government agencies and companies introduce GNSS-related technologies using exhibition panels and videos.

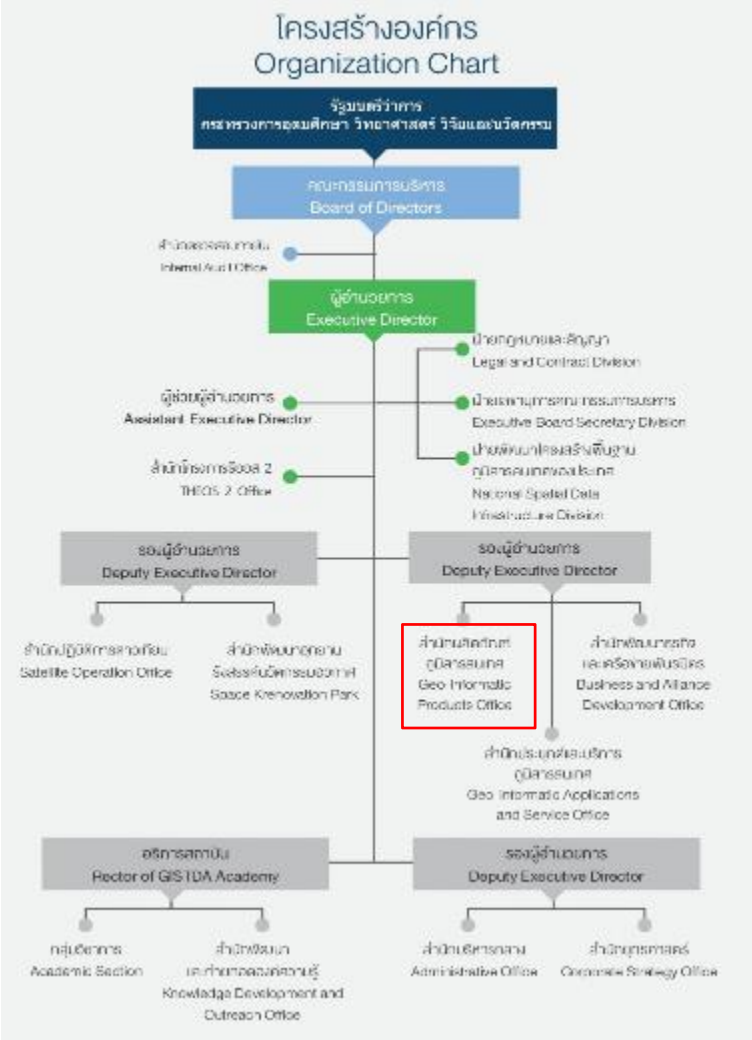


Fig. 1-5: GISTDA organization chart (As of September 2019)

Source: GISTDA website (https://www.gistda.or.th/main/en/node/70)

(5) HII

A public organization under MHESI, HII conducts research and development related to water resources (including monitoring), information collection and the collection methods during disaster response, disaster prevention, and so on. HII researches the utilization of CORS data as part of this research and development. It also serves as the secretariat for the Thailand-Japan Joint Working Group.

HII's CORS network consists of 25 stations: 6 HII stations (1 of which is owned by NIMT), 11 DOL stations, 6 DPT stations, and 2 other stations. This network covers the Eastern Economic Corridor (ECC) area. Of particular interest is the estimation of precipitable water vapor (PWV) using CORS data.

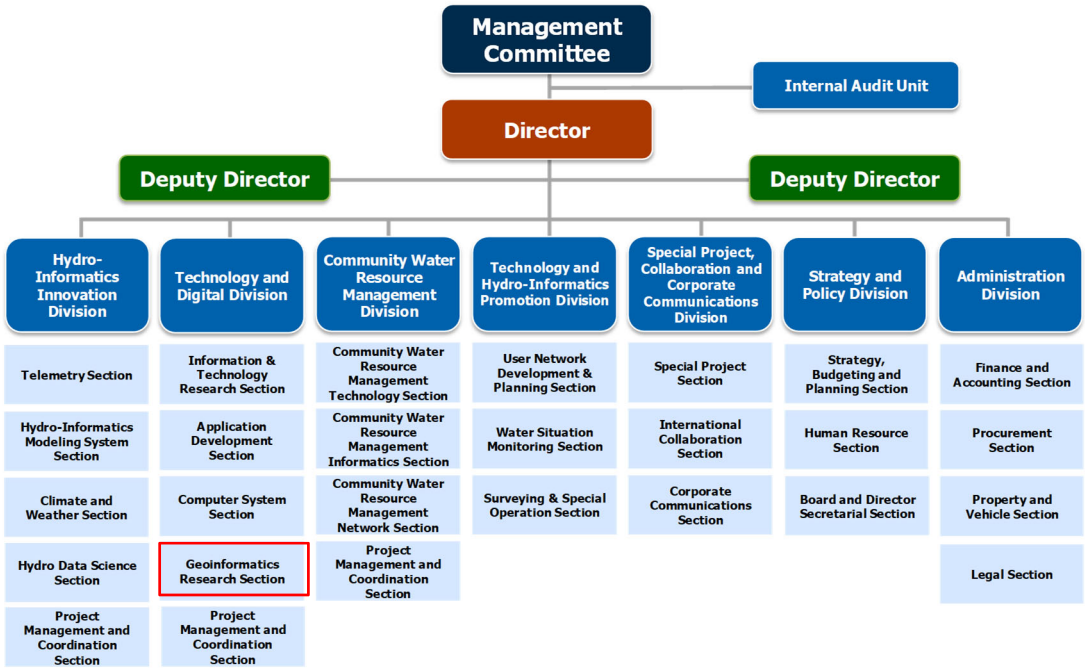


Fig. 1-6: HII organization chart (As of September 2019)

Source: HII

(6) NIMT

A public organization under MHESI, NIMT employees about 200 personnel and is responsible for all measurement standards in Thailand. Its work covers a wide range of subjects, including chemistry, biometrics, measurement (including precision engineering, nanotechnology, etc.), electricity (including time, frequency, etc.), machinery, temperature, and optics. This institute has improved its organization and has seen further development through joint technical projects with Japan.

NIMT has 2 CORSs for monitoring standard time. Contributions to the digitization of Thailand (Thailand 4.0) can be made by providing accurate time based on the CORS network.

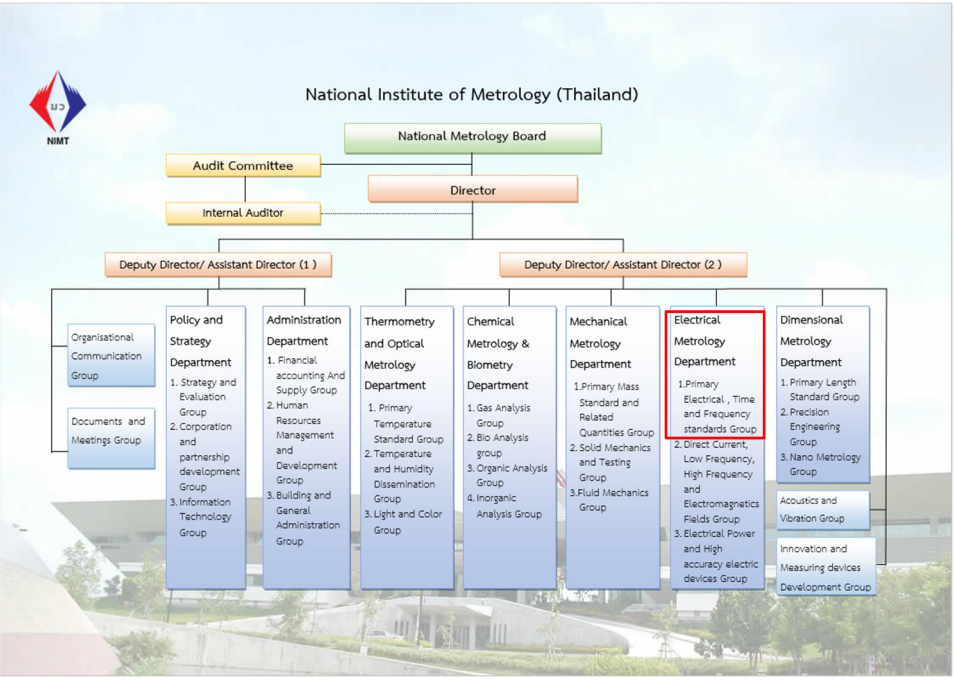


Fig. 1-7: NIMT organization chart (September 2019)

Source: NIMT website (http://en.nimt.or.th/?page_id=2721)

(7) RTSD

Responsible for Thailand's national governing surveying in general, this is the equivalent to the Geospatial Information Authority of Japan (GSI). Its main duties include setting geodetic references, maintaining 1/50,000 topographic maps and other geospatial information, maintaining geodetic networks, and selling maps. In recent years, RTSD has conducted gravity surveys throughout Thailand and constructed a geoid model (Thailand Geoid Model 2017: TGM2017). This geoid model assumes use with CORS data, and increases the ease of obtaining elevation information.

An RTSD CORS network consisting of 80 stations was constructed in FY 2019 (October 2018–September 2019). The Geodesy and Geophysics Division is the main department in charge of the RTSD CORS network. RTSD is also responsible for establishing the NCDC.

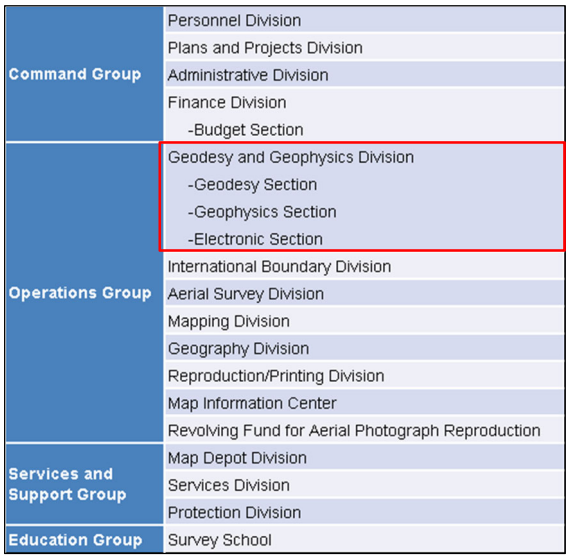


Fig. 1-8: RTSD organization chart (As of February 2019)

Source: RTSD website, edited by the Team

The main operations, personnel, and budgets of the organizations above are summarized in the table below.

Table 1-1: Main Operations, Personnel, and Budgets of the Seven Thai Government Organizations

Organization	Main Operations	Personnel (People)	Annual Budget (Millions of baht)
DOF	Fishery-related operations	Approx. 10,300	4,093 (2019)
DOL	Services related to cadastral surveys	Approx. 10,600	11,296 (2017)[2]
DPT	Services related to city planning and urban development	Approx. 3,000	23,817 (2017)[3]
HII	Research and development and services related to water use	Approx. 140	376.76 (2019)
GISTDA	Research and development and services related to the application of space and geospatial information technologies	Approx. 300	1,810 (2018)[4]
NIMT	General measurement standards	Approx. 400	450 (2020)
RTSD	Services related to surveys and mapping	Approx. 800–1,000	678 (2018)[5]

Source: Results of interviews conducted by the Team or materials released by the respective organizations

[2] DOL website(http://www.dol.go.th/finance/DocLib16/Financial%20Reports%202560.pdf)
[3] DPT website (https://www.dpt.go.th/_html/report_annual/Annual_60/annual_report60.pdf)
[4] GISTDA website(https://gistda.or.th/main/sites/default/files/e-magazine/annual_report2561-20181206.pdf)
[5] RTSD website(https://www.rtsd.mi.th/main/wp-content/uploads/2017/05/O16.pdf)

1.3. Activities

The JICA Team (hereinafter, "the Team") visited seven of the eight organizations comprising the Thailand-Japan Joint WG to gather information. In addition, the Team conducted interviews with companies in Thailand. The Team also gathered information from related organizations and companies in Japan, conducted social experiments, and held a seminar in Thailand.

1.4. Progress of Japan-Thailand Talks

On 17th December 2018, JICA Thailand Office sent the GNSS Subcommittee in Thailand a proposal for conducting the Survey, which was approved for the most part by the Subcommittee on 4th February 2019. Following some adjustments, the proposal was finally agreed upon at the Thailand-Japan Joint WG meeting held on 25th February, during which the Team then presented the Inception Report to call for feedback from the Thai counterparts. To respond to their opinions, questions, and requests, the Team had a meeting with HII, the Secretariat of the WG, on the following day, 26th February, and agreed on how to proceed with the Survey while incorporating the requests, etc. HII reported the details of the discussion to the Chairman of the WG.

The method for coordinating the interview schedules for the seven organizations that make up the Working Group was decided through the above talks. Based on this, the Study Team made initial contact with each of the organizations by 7th March, starting with HII on the 26th. The Team then revisited the organizations or exchanged emails as necessary to ask questions. By doing this, the Team gathered information on their CORSs and data centers and thoughts on the NCDC. The collected information and the NCDC's CORS data distribution system considering this information and materials for consideration concerning system configuration were compiled as an interim report and submitted to related organizations in Thailand and Japan. In addition, the main points were covered at the Thailand-Japan Joint Working Group meeting held on 24th May. Following up on this meeting, representatives of the Thailand-Japan Joint Working Group member organizations, JICA, and the Team met for talks twice regarding the NCDC CORS data distribution system and system configuration proposal during the invitation to Japan in June. GSI and JENOBA Corporation also attended the second exchange meeting and provided advice on sharing knowledge based on the implementation and maintenance of GEONET in Japan and real-time correction data distribution services as well as the implementation of the NCDC in Thailand.

Following this, the first meeting of the NCDC Management WG was held on 18th July. Specific examinations and tests for the establishment of the NCDC were conducted based on the proposals and ideas presented by Japan side.

The Team visited each of the organizations in May, July, and August after the submission of the Interim Report and continued to exchange opinions and confirm details regarding the NCDC. The Team then compiled the Draft Final Report, which was reviewed at the Thailand-Japan Joint WG in December to be finalized as this Final Report.

2. Status of CORS Network in Thailand

In Thailand, several government agencies have established their own CORS networks for their respective applications as outlined in Table 2-1.

Table 2-1: CORS Facilities Established and Planned in Thailand

Agency	CORS / Data Center			Geodetic reference (CORS)	
	No. installed (planned total)	Application	Manufacturer	Reference ellipsoid	Coordinate system
DOL	134 (181)	Cadastral survey	CHC	WGS-84	ITRF2008
DPT	15 (15)	Aerial photogrammetry, ground survey	Leica	WGS-84	ITRF1996
HII	6 (6)	Survey and research of water resources and disaster prevention	Topcon	WGS-84	ITRF2008
GISTDA	5 (5)	Survey, research, etc. of precise positioning	Leica,Topcon, Wuhan	WGS-84	ITRF2008
RTSD	80 (80)	Reference stations	Leica	WGS-84	ITRF2008
Total	240 (287)	---	---	---	---

Source: Result of interviews by the Team (as of August 2019)

One of HII's CORS is owned by NIMT (to be discussed in detail in Sections 2.4 and 2.5).

All the above agencies are using WGS-84 as the reference ellipsoid, and all four agencies but DTP are using the coordinate system based on ITRF2008.

Although the International Earth Rotation and Reference Systems Service (IERS), which maintains and manages ITRF, is recommending the GRS80 ellipsoid (instead of the WGS-84 ellipsoid) when using the ITRF system, they can be used interchangeably in practice, as the semi-major axes of the two ellipsoids are the same while the difference in semi-minor axis is miniscule (approx. 0.1 mm).

When implementing network RTK using CORS, if implementation is possible assuming a distance of up to 70 km between stations, then an area is feasible which is covered with circles with a radius of 35 km centered on each station. The CORSs above cover about 90% of Thailand as areas where network RTK is possible. The baseline length between each station is 30–80 km (Fig. 2-1).

Imakiire and Hosoya presented research results on the relationship between the distance between CORSs and accuracy using CORS data in Japan at the 130th Meeting of the Geodetic Society of Japan (2018). The results are shown in Fig. 2-2. At the same time, disturbances of GNSS radio waves due to the ionosphere are another factor that affects accuracy. Lower latitude regions are known to experience more radio disturbances due to the ionosphere

than higher latitude regions. This means accuracy may fall in lower latitude regions. This possibility should be verified through actual operations.

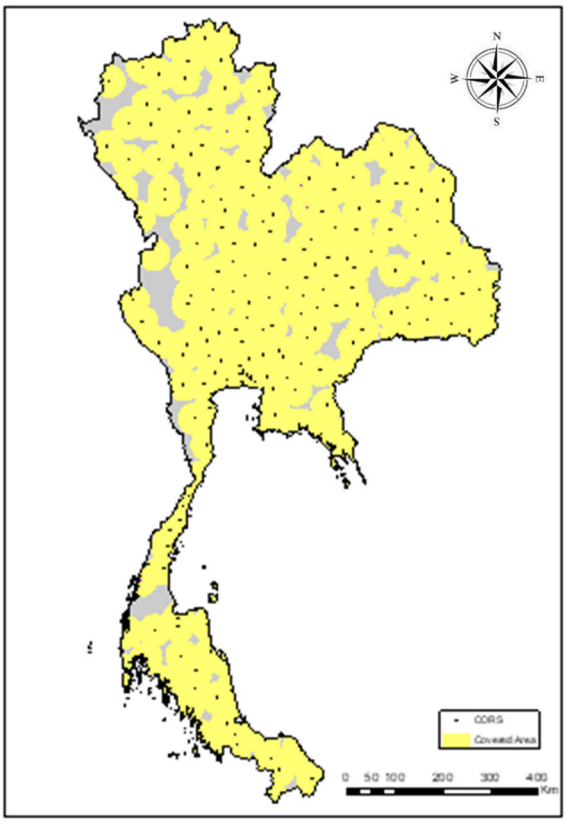


Fig. 2-1: CORS coverage

Source: Created based on findings by the Team

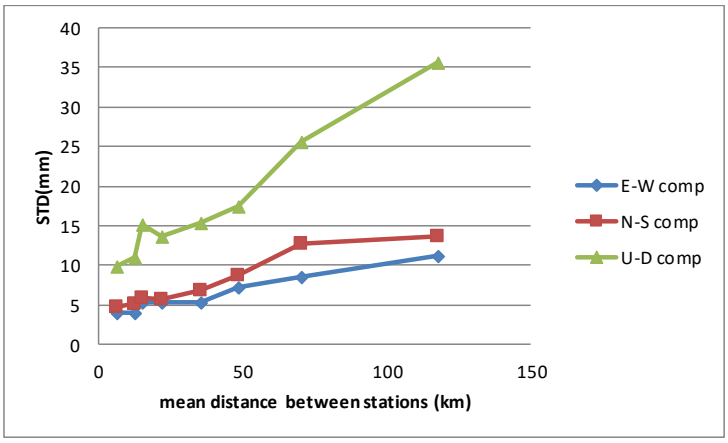


Fig. 2-2: Relationship between the distance between CORSs and network RTK accuracy

Source: Created by the Team based on the Proceedings of the 130th Meeting of the Geodetic Society of Japan (Imakiire & Hosoya (2018))

2.1. DOL

（1） Existing and Planned Facilities

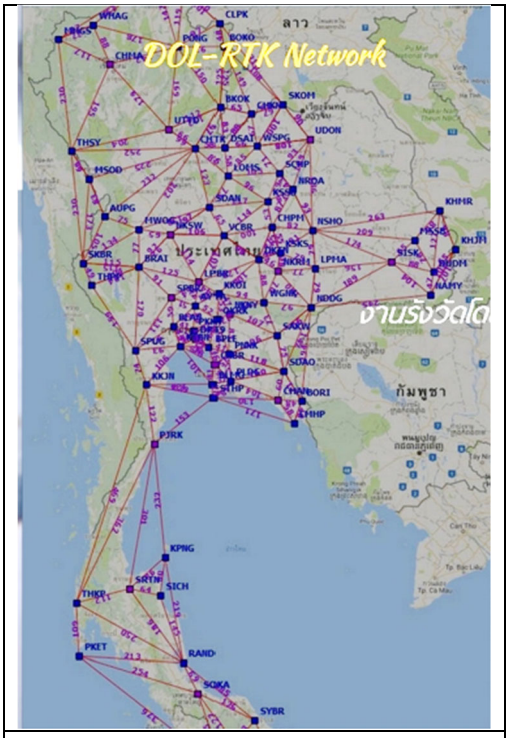


Fig. 2-3: DOL's CORS network
(Established: 2016 – 2019)

Source: DOL web site

DOL has a network of 134 CORSs, 62 of which were established in 2016, 30 in 2017, 36 in 2018, and 6 in 2019. An additional 47 CORSs are to be set up in the future. This means that DOL's CORS network will consist of a total of 181 stations. The CORS network is used primarily for cadastral surveying by DOL personnel, as well as private-sector enterprises commissioned by DOL.

As is the case with RTSD and other agencies, DOL's network uses the WGS-84 reference ellipsoid and the ITRF2008 coordinate system, which, however, are converted to Everest1830 reference ellipsoid and Indian 1975 coordinate system, as DOL has long been using Everest 1830 and Indian 1975 to produce cadastral maps. As this cannot be changed easily, all cadastral maps published by DOL have the two different coordinate systems mentioned above.

DOL began distributing network RTK data collected from its own CORS network on a trial basis for six months (with an extension every six months thereafter) starting on 18th February 2018 (https://dol-rtknetwork.com/). This service is available free of charge to anyone, including private-sector enterprises, and approximately 3,000 users (2,000 out of 3,000 are DOL's staff) were using the service as of December 2019. However, as a Thai identity card (bat pracham tua pracha chon) number is required for user registration, it is virtually impossible for non-Thai nationals to use the service.

The installation status of DOL's CORSs and the specifications of the instruments are shown in the table below.

Table 2-2: DOL's CORS Installation Status and Equipment Specification, etc.

Total number	134 stations across Thailand
GNSS antenna	CHCNAV C220GR2 (Choke ring)
GNSS receiver	CHCNAV N72 (440 channels)
Satellite system	GPS, GLONASS, Galileo, BeiDou *Reception of QZSS is possible, but it is not received. *Not all satellites receive BeiDou.
Installation site	Installed in DOL offices

Mount style	Ground-mount or roof-mount *Temporary use of wall-mount
Antenna pillar height/material	Ground-mount: 5 m Roof-mount: 2–4 m above roof Material: Stainless steel or hot-dip zinc-coated steel
Power supply	Grid power, with UPS installed as a backup power supply Electricity charges are covered by comprehensive contracts with a maintenance contractor.
Telecommunication	Fiber optic cable (fixed IP address) with a backup 3G/4G
CORS management software	CPS (Chinese) GNSS software: TBC/CGO (Chinese)
No. of licenses	Unlimited number of CORSs and users
Real-time data	Format: RTCM (RRS, VRS)
Data for post-processing	Format: RINEX 2.0, 15-second sampling

DOL's CORS are installed in its local offices, meaning the only weather protections necessary are lightning arrestors.

CORS coordinates were calculated by the contractor using TBC/CGO software (Chinese) and approved by DOL. It is unclear whether the coordinates of IGS stations were used in this calculation, but it seems likely that adjustments were made with the RTSD geodetic network.

(2) Status of O&M and Future Plan

DOL's CORS network has a comprehensive contract with a contractor covering maintenance, excluding data center operations. The contract period for the maintenance contract is seven years from the installation of the CORSs, and the contract includes telecommunication and electricity charges. The main points and status of the O&M plan are outlined in the table below.

Table 2-3: DOL's CORS O&M Status and Future Plan

O&M item	O&M plan/status
On-site CORS maintenance	To be implemented mainly by the department in charge (map technology department) and contractors with support from local offices. *Recovery work can be handled within three days
Periodic inspection of CORS	Inspections are performed every four months
Backup CORS equipment	Owned by the contractor
Coordinates calculation, etc.	Calculations at the time of installation are performed by the contractor and approved by DOL.

O&M item	O&M plan/status
Power supply	Grid power, which means the power supply is stable
Telecommunication	Fiber optic cable with a backup (3G/4G), meaning connections are generally stable; no noticeable problems have occurred.
Data center operation	The DOL department in charge is responsible, with cooperation and support from the IT department. If equipment fails, the contractor will also respond. The recovery time in the event of a failure is 12 hours or less.
Data distributed to	Approximately 3,000 (including DOL's staff) users of trial delivery services as of December 2019
IT equipment redundancy	Three backup servers for six main servers
Software maintenance	Included in the contractor maintenance contract

If any failures occur during the maintenance contract period, it is mainly the department in charge (map technology department) and the contractor that handle the recovery with the support of the DOL local office. The recovery time for CORS is three days or less. Currently, there are about five cases per month; most are resolved the same day. The main causes of failures are electrical system issues due to lightning strikes (approx. 60%), router-related issues (approx. 20%), and receiver-related issues (approx. 15%). When an issue with a CORS is detected, alert emails are automatically sent from the data center to the persons in charge.

The operation of the data center is not included in the maintenance contract and is instead performed by DOL itself. However, if a problem occurs, the contractor will also respond. The response time for failure recovery is 12 hours or less. Problems such as cyber attacks have not yet occurred. In addition to installing a firewall in the data center, https communication is used to increase security. There is also a call center in case problems occur.

With a backup line, the communication line used is generally stable. However, communication failures sometimes occur with data streaming from DPT.

DOL's FY 2018 budget for its CORS system was approximately 2.2 million baht. The annual maintenance budget is mainly used for the replacement of rovers. The telecommunication costs are also included in the maintenance contract. When broken down, the total for the main line and backup line is 1,798 baht per month per CORS, and 39,499 baht per month at the data center.

As mentioned above, DOL distributes network RTK data to the general public on a trial basis. Feedback from users gained through this trial are to be used for DOL's own data center operations, and together with findings obtained through the streaming tests with the RTSD data center, used for the future NCDC operations based on decisions made by NCDC Management WG.

2.2. DPT

(1) Installation Status

Between 2006 and 2016, DPT established 15 CORSs, which are now being used for aerial photography (including photo control point surveys), creation and updating of maps for urban planning, and generation of various GIS data, as well as for topographic surveying, road surveying, etc.

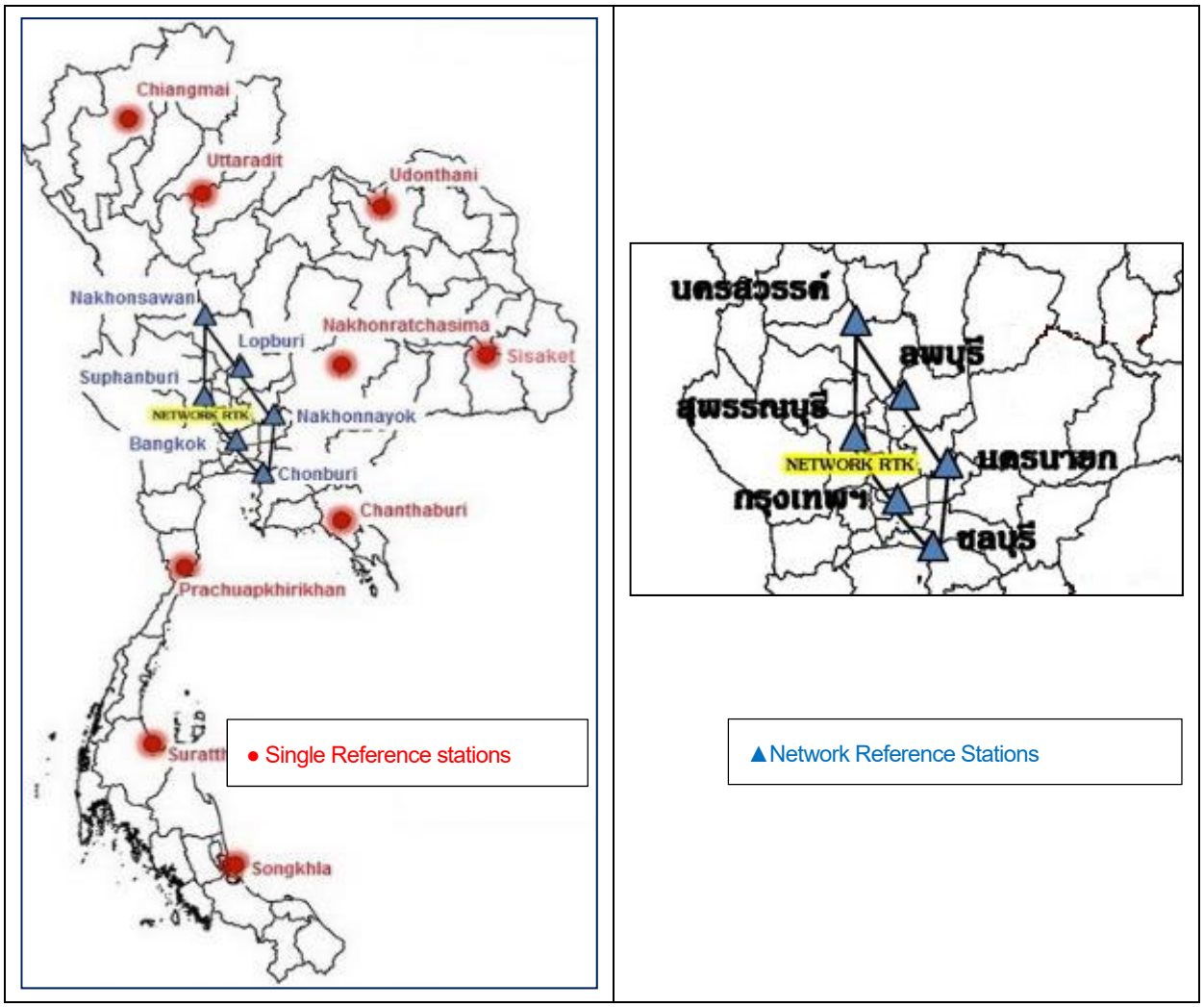


Fig. 2-4: DPT's CORS (Left: Overall, Right: CORS used as part of HII's integrated RTK network)

Source: DPT

6 of the 15 CORSs are forming a network RTK and transmitting real-time data, which can be accessed via a radio or internet connection. These 6 CORSs are also a part of the integrated network RTK services established by HII in 2017. The other 9 are used as single reference stations and are not networked. Data for post-processing (RINEX format) are downloadable from the website. DPT's CORSs are transmitting streaming signals to HII, as well as to RTSD and GISTDA. Equipment specifications of the 15 CORSs are as follows.

Table 2-4: DPT's CORS Equipment and Specifications, etc.

GNSS antenna	Leica GR-AR10 (networked CORS for NRTK*), AR20 (9 single CORS)
GNSS receiver	Leica GR25 (4 networked CORS), GR50 (2 networked CORS and 9 single CORS)
Satellite system	[1] GPS, GLONASS, BeiDou, QZSS, Galileo [2] GPS, GLONASS [3] GPS, GLONASS, BeiDou, QZSS, Galileo Note: [1] is for 9 single CORS, [2] is for 4 networked CORS, and [3] is for 2 networked CORS.
Installation site	Public land or building
Mount style	Ground-mount: 2 stations (5m); Wall-mount: 1 station (1m); Roof-mount: 11 stations (5m) and 1 station (1m)
Power supply	Grid power and a 48-hour battery for backup
Telecommunications	Currently introducing optical fiber lines (14 lines for 14 CORSs) and backup 4G mobile lines (14 lines for 14 CORSs) on a trial basis.
CORS management software	Leica GNSS SPIDER
No. of licenses	Stationary stations: unlimited; Mobile stations: unlimited
Real-time data	Format: RTCM 3 (FKP, MAC, VRS); 1-second sampling
Date for post processing	Format: RINEX; 5-second intervals
Baseline analysis software	Leica Geo Office

*NRTK: Network RTK

Antennas are made of aluminum coated with paint. CORS near the coast are considered to require extra maintenance to prevent salt damage.

CORS are protected against high temperature, humidity, lightening, and water droplets and are covered with bird nets. Strength of the equipment is determined based on the wind velocity measured in advance at each installation site. Roof-mount-type instruments are fixed with anchor bolts.

(2) O&M Status and Future Plan

DPT's CORS network has a comprehensive contract with a contractor covering maintenance. Telecommunications reception is not poor, and communication failures, if any, are usually restored within several hours to one day. Due to the nature of its services, DPT's CORSs are situated in urban areas, where communication failures rarely occur because of the reliable infrastructure that was developed under the assistance of the Ministry of Interior.

Table 2-5: DPT's CORS O&M Status and Future Plan

O&M item	Current status and future plan
On-site CORS maintenance	All maintenance work is outsourced. Trouble is responded to within 72 hours in rural areas or 48 hours in urban areas.
Periodic inspection of CORS	Monitored daily.
Coordinates calculation, etc.	Daily coordinates calculation is performed by DPT.
Power supply	Stable
Telecommunications	No significant problems with telecommunications. The telecommunication charges for optical fiber lines total 430,000 baht/year. Mobile lines are currently being provided free of charge by a telecommunications company for the trial implementation stage.
Data center operation	Operated by DPT staff.
Software maintenance	Covered by a comprehensive maintenance contract, which includes telecommunication charges, maintenance, daily remote management, and repair services.

2.3. GISTDA

（1） Installation Status

GISTDA has established a network of 5 CORSs, 3 of which were installed in 2013 and 2 in 2015[6]. GISTDA uses its CORS network primarily for research and development purposes. The network is also utilized by researchers (universities, students, etc.) and agricultural machinery manufacturers and other private companies.

In addition, GISTDA has established an integrated network of 31 CORSs for research and development comprised of 4 of the above 5 CORSs, as well as 10 CORSs of DOL, 15 of DPT and 1 each of King Mongkut's Institute of Technology Ladkrabang and Chulalongkorn University. The server is situated inside GISTDA's Bangkhen Office, and the network began collecting data three years ago. GISTDA has been upgrading the network by finding glitches and room for improvement towards more stable operation through its use in various applications, research and development activities, tests, etc. Users can use the data free of charge, however, only for research and development purposes.

Fig. 2-5: GISTDA's CORS network (Established: 2013 – 2015)

Source: GISTDA

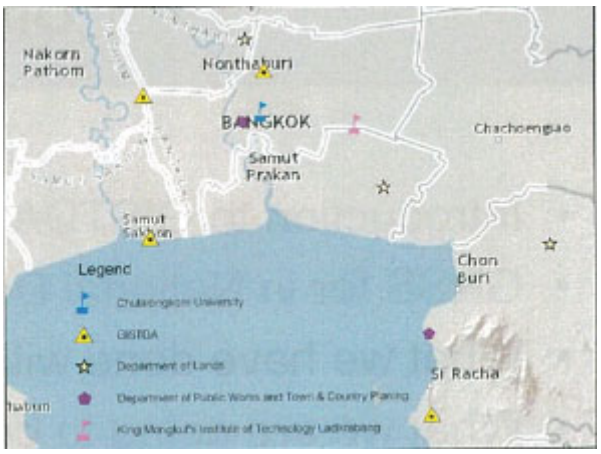


Fig. 2-6: A segment of integrated CORS network for research and development

Source: GISTDA

Installation status, equipment specification, etc. of GISTDA's 5 CORSs are outlined in the table below.

[6] In addition to these five stations, China installed CORS equipment (all made by GIIT) in four points within GISTDA- SKP for tracking the trajectory of BeiDou in 2013. However, GISTDA is merely providing the site without electricity or telecommunication services. None of the four points are currently in operation.

Table 2-6: GISTDA's CORS Installation Status and Equipment Specification, etc.

No. CORS equipment (manufacturer) installed	1 set each at Bangkhane (Wuhan), Nakhonpathom (Leica), and Samutsakhon (Leica) and 2 at Sri Racha SKP (Wuhan and Topcon)	
GNSS antenna[7]	Topcon CR-G5C (Choke-ring)	Leica AR10
GNSS receiver[8]	Topcon Net-G5	Leica GR30
Satellite system	GPS, GLONASS, Galileo, BeiDou, QZSS	
Installation site	Government land or building	
Mount style	Roof-mount or wall-mount	
Antenna pillar height/material	Roof-mount type: 1.6m from rooftop / iron	
Power source	Grid power (backup power is installed for Leica equipment)	
Telecommunication	Fixed terrestrial links with no backup, VPN connection	
CORS management software	GNSMART (Geo++) Distributes data for RTK, network RTK, and post-processing (for network RTK, provision of the service involves other agencies' stations because the CORS in SKP is too far away.)	
No. of licenses	Unlimited within Thailand	
Realtime data	Format: RTCM 2, 3 (RRS, VRS), 5-second sampling	
Data for post-processing	Format: RINEX 2.0, 3.0, 5-second sampling	
Baseline analysis software	Bernese GNSS Software	

Coordinates of the CORSs were established under the advice of Professor Chalermchon Satirapod of Chulalongkorn University, using Bernese GNSS Software. Their accuracy has not been validated in comparison with the CORS networks of RTSD and other agencies, but will be in near future.

Among the five agencies, GISTDA is one of the leading ones in promoting the dissemination and use of precise positioning data. It is organizing related seminars and events and managing the GNSS Innovation Center (GiNNo) that exhibits GNSS technologies, including permanent booths of Japanese government agencies and private companies.

(2) O&M Status and Future Plan

GISTDA has signed a maintenance contract that covers only the software of the data center. The current contract is effective for three years beginning in 2018 and scheduled for renewal upon expiration. While data

[7] Of the five CORS, those of Bangkhane and SKP are made by Wuhan. Equipment specification is unknown.
[8] Of the five CORS, those of Bangkhane and SKP are made by Wuhan. Equipment specification is unknown.

distribution service is provided 24/7, the data center is unmanned at night. To ensure stable operation, each CORS is constantly monitored for signal reception and undergoes a periodic inspection/maintenance once every three months. No major accidents or failures have occurred thus far, except some minor trouble in the telecommunication system.

The O&M system is kept at the current scale because the networks are presently used for research and development purposes. All O&M-related duties are performed by GISTDA's maintenance team without outsourcing.

The O&M status and future plan are outlined in the table below.

Table 2-7: GISTDA's CORS O&M Status and Future Plan

O&M item	Current and future status
On-site CORS maintenance	Performed by GISTDA's maintenance team; no outsourcing
Periodic inspection of CORS	Performed once every 3 months by GISTDA's maintenance team
Coordinates calculation, etc.	Signal reception is constantly monitored.
Power supply	Stable as it uses grid power.
Telecommunication	Fixed terrestrial links (3,000 Baht/month)
Data center operation	Operated by GISTDA-SKP staff. Service is provided 24/7, but the center is unmanned at night.
Data distributed to	Researchers (universities, students, etc.) and private companies (for research and development purposes only)
Software maintenance	Maintenance contract is to be renewed next year.

GISTDA intends to continue operating its own CORS networks and data center even after the completion of NCDC, and expects technical assistance from Japan for the provision of RTK services, O&M of the CORS networks, and utilization of precise positioning data.

(3) Small-RTK

At the beginning of this survey, GISTDA was preparing and examining the construction of Small-RTK using inexpensive GNSS receivers. With Small-RTK, the plan was to provide a data distribution service for network RTK over four years starting in 2019. This service assumed a wide range of applications in agriculture, logistics, and so on in addition to the infrastructure development sites in the EEC area. More than 50 users per year were expected to use it. Another idea was to provide data to the NCDC via Small-RTK servers.

GISTDA launched this concept when the prospects for the establishment of the NCDC was still unclear. However, due to the expected establishment of the NCDC, the idea was changed around June of this year. The Small-RTK concept has now been canceled and replaced with a plan of research on GNSS and 5G.

The outline of the Small-RTK concept is shown below.

Table 2-8: Outline of GISTDA's Small-RTK

Area and no. of stations	40 – 100 stations are to be installed in and around the EEC area.
GNSS antenna	Low-cost GNSS antenna
GNSS receiver	Low-cost GNSS receiver
Satellite system	GPS、GLONASS、BeiDou
Distributed data	VRS (network RTK)
Data format	RTCM

2.4. HII

（1） Installation Status

During FY 2017 (October 2016 – September 2017), HII established 6 CORSs in and around Bangkok jointly with NIMT, which is another subordinate organization of MHESI, and the Department of Disaster Prevention and Mitigation (DDPM). HII's CORS network was established for the purpose of investigating how CORS can be utilized in water resource and disaster management. The network is also used by NIMT to increase the accuracy of Thai Standard Time, as well as by DDPM for research, etc. related to disaster management. NIMT's CORS site has two sets of equipment with one being a backup to ensure continuous operation, and only one of them is connected to the network.

1. Angthong 	2. NakhonPathom 	3. Chachoengsao 
Station code: ANGT (ground mount)	Station code: NKPT (wall mount)	Station code: CCSO (wall mount)
4. Prachinburi 	5. Samutprakarn 	6.NIMT 
Station code: PCBR (roof mount)	Station code: BGNA (roof mount)	Station code: THAI (roof mount)

Fig. 2-7: Installation Status of 6 CORS of HII

Source: HII

Collection of GNSS observation data began in August 2017, and HII intends to keep the data for a year or so.

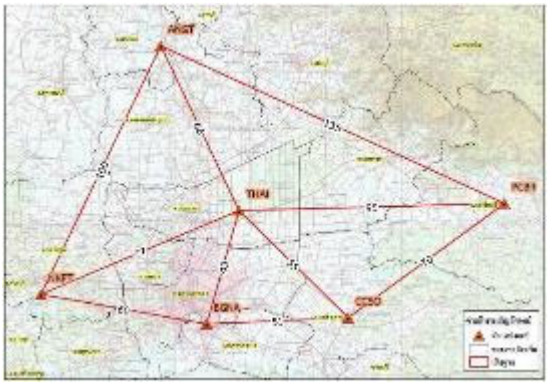


Fig. 2-8: HII's CORS network
(Established: 2016 – 2017)

Source: HII

Fig. 2-9: CORS network in the EEC area
(Established: 2018)

Source: HII

In 2018, HII also established a CORS network comprising a total of 25 stations based on the above 6 stations plus DOL's 11 stations, DPT's 6 stations, and 2 stations of other organizations. The network is designed to effectively cover most of the EEC area. However, as the CORS of other agencies are not directly connected to HII's data center, their observation data (for real-time data only, 1-second sampling) are first sent to their respective data centers and then to HII's data center to provide network RTK service. Data for post processing are distributed only from HII's 6 CORSs and can be downloaded via the internet. These services are available not only to government agencies but also to educational institutions and private-sector enterprises, however, for non-profit purposes only under the current terms of service.

Installation status and equipment specification, etc. of HII's 6 CORSs are summarized in the table below.

Table 2-9: HII's CORS Installation Status and Equipment Specification, etc.

No. stations; inter-station distance	6 in Bangkok and its environs; approx. 43 – 135km
GNSS antenna	Topcon　CR-G5 (Choke-Ring Antenna)
GNSS receiver	Topcon　Net-G5
Satellite system	GPS、GLONASS、BeiDou、QZSS、SBAS
Installation site	Public land or building
Mount style	Ground-mount (1 station), wall-mount (2), roof-mount (3)
Mount style	Ground-mount: 3.2m; Roof-mount: 3.2m / Stainless steel
Weather protection	Lightning arrestors; Receivers, etc. stored indoors (except in one station)
Power supply	Grid power with a backup battery (48 hours)
Telecommunication	Fiber optic (FTTX with backup); VPN connection
Telecommunication	GNSMART (Geo++), distributes network RTK data

CORS management software	Stationary stations: 40 licenses; Mobile stations: unlimited
No. of licenses	Format: RTCM 2, 3 (FKP, MAC, VRS), 1-second sampling
Real-time data	Format: RINEX 2 (1-second sampling, GPS/GLONASS only), Hatanaka (compressed RINEX, 15-second sampling), hourly files
Baseline analysis software	Bernese GNSS Software

According to HII, when installing the 6 CORSs it was not possible to find an ideal site for every CORS that is not affected by the multipath effect or the external radio interference. In less than ideal circumstances, CORS sites were selected by conducting 72-hour GNSS observation to determine if the required accuracy was achieved. The main protection against weather conditions is a lightning arrestor, as all GNSS equipment, etc., except for ground-mount type instruments, are installed/stored indoors. Only one site with ground-mount equipment has an outdoor equipment storage, which is not attached with a cooling device, etc. No equipment failure, etc. seems to have occurred to date. Similarly, no trouble seems to have occurred with roof-mount-type instruments that are fixed by concrete without anchor bolts, etc.

Coordinates of the 6 CORSs were established by HII staff with the help of RTSD, using Bernese GNSS Software. Adjustments to the coordinates were made based on the coordinates of the IGS station in Chulalongkorn University in Thailand, as well as those in the Philippines and India. Coordination with RTSD's geodetic network was done with the support and cooperation of RTSD.

Accuracy of the CORS network was verified by analyzing the RTK measurements (using RTSD's geoid model) and static measurements of the 17 stations. The horizontal and vertical deviation from RTSD's reference station was negligible of only 4 cm and 5 cm, respectively.

(2) O&M Status and Future Plan

HII's CORS networks, including the maintenance cost of the CORS software, are covered by a 5-year maintenance contract until 2022. Items that are not covered by the contract needs to be cared. The current and future O&M plans are outlined in the table below.

Table 2-10: HII's CORS O&M Status and Future Plan

O&M item	Current and future status
On-site CORS maintenance	Performed by the contractor; Contract does not cover major failures.
Periodic inspection of CORS	There is no particular schedule, as problems can be easily fixed by service providers in the Bangkok area.
Backup CORS equipment	No backup equipment or replacement parts are in place. Repair work is assumed to take 3 months or so.
Coordinates calculation, etc.	Daily monitoring and coordinates calculation are performed by HII.

O&M item	Current and future status
Power supply	Stable, as it uses grid power.
Telecommunication	Mostly stable, as it uses the Government Information Network (GIN) line free of charge.
Data center operation	Operated by HII's data center department with the support of IT department.
Data distributed to	Government agencies and private entities (for non-profit purposes only). A private survey company is using the data for research purposes.
IT equipment redundancy	Redundancy is not ensured at present, but installation of additional equipment in the next year or so is being considered.
Software maintenance	Support (including remote access) is available as needed from the software developer or its agent under the maintenance contract that is effective until 2021. Increasing the number of licenses is being considered for the coming years.

If any trouble occurs during the maintenance contract period, the contractor is to restore the equipment, etc. within two days, as CORS are situated in and around Bangkok. However, in case of major failures, which are not covered by the contract, HII staff are to assess the situations and request repair services to the contractor.

Since GNSMART (Geo++) is not a widely-used software application and is used only by a limited number of users for managing CORS, local staff of the contractor alone cannot be expected to provide sufficient support and services in case of trouble. For this reason, the maintenance contract stipulates that HII can receive support from the software developer, etc. through supporters in Thai universities, etc.

The government's telecommunication line (GIN) becomes unstable once a month or so for a few minutes at a time, disabling the data center to receive observation data. Once the communication is restored, observation data are resent to the data center.

Coordinates calculations, etc. are performed using the Bernese GNSS Software (for Windows). In HII, only three persons can use the software, which needs to be augmented.

HII is also considering to provide/receive CORS data to and from other agencies and especially interested in accessing RTSD's CORS data. In order to process data received from other organizations using GNSMART (Geo++), HII will need the same number of licenses as the number of CORS from which to receive data. Accordingly, HII is considering acquiring additional licenses from the next year on.

The maintenance cost from 2022 is estimated to be about 5 million Baht per year. Terms and conditions of the maintenance contract will need to be reviewed and revised to align with where the country as a whole is headed in operating and maintaining its CORS networks after the completion of NCDC.

2.5. NIMT

（1） Installation Status

NIMT owns GNSS receivers and antennas of the following two types:

1) Topcon GPS receivers for clock comparison and JAVAD antennas installed in 1999

2) Topcon receivers and Topcon antennas for geodetic observation and clock comparison installed in 2017

Clock comparison is the primary purpose that NIMT installed these GNSS receivers and antennas. NIMT is a state agency tasked to develop and maintain the national time and frequency standards and provide calibration and time-signal services. It owns and manages three cesium atomic clocks and one hydrogen maser clock, all of which must be kept precisely to Thai Standard Time called UTC (NIMT)[9] that is aligned to Coordinated Universal Time (UTC) created by the International Bureau of Weights and Measures based on the atomic clocks stored there. Clock times are compared via the signals transmitted by the GNSS. This report does not go into detail but shows the basic principle in the illustration below.

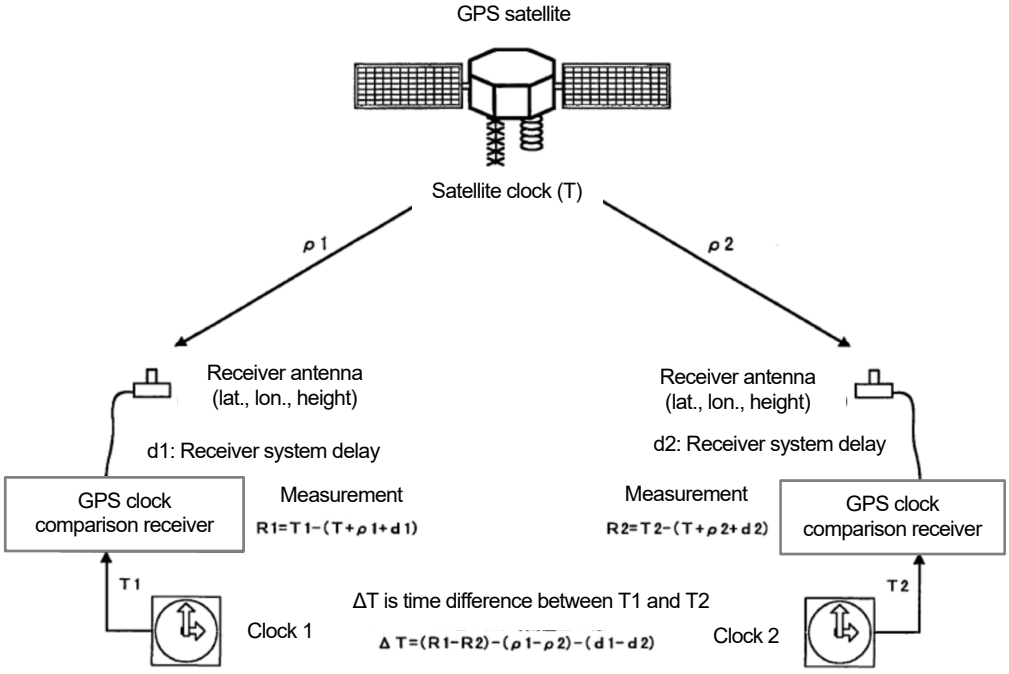


Fig. 2-10: Clock Comparison Using GNSS

Source: Review of the Communications Research Laboratory Vol.45, Nos.1/2 (1999)

To perform clock comparison, NIMT adopted Topcon EURO-80 receivers (supplied by an OEM) with antennas made by JAVAD in 1999, which have been continuously in operation for 20 years.

[9] In Japan, the National Institute of Information and Communications Technology (NICT) manages Japan Standard Time called UTC (NICT) for distributing time signals while the National Metrology Institute of Japan manages UTC (NMIJ) to maintain the national time/frequency standards. NIMT is solely responsible for performing both.

In FY 2017, NIMT was installed with two GNSS receivers (Topcon Net-G5) and GNSS antennas (Topcon CR-G5) of the same specifications by HII (see Section 2.4 (1)) for the purpose of clock comparison and also for using them as CORS for geodetic observation. One of the two antenna/receiver sets is a part of HII's CORS network, and data received are sent real-time to HII. The other set is for backup. Only NIMT is installed with backup equipment because clock comparison needs to be carried out without any interruption.

According to the NIMT personnel the Team interviewed, the clock comparison operation has yet to achieve its initial target. They said that if precise comparison is realized, Net-G5 receivers will replace the current EURO-80 models.

Fig. 2-11: GPS receiver antenna for clock comparison (the cone-shaped radome at left; the tower at right is a lightning rod)

Source: NIMT

Fig. 2-12: 2 GNSS receiver antennas

Source: The Team

All antennas are set up on the roof of the government building in which NIMT's Time and Frequency Standards Group is situated. Also mounted on the roof are a lightning rod and Faraday cage to protect not only the antennas but also the whole building from lightning.

Specifications, etc. of the equipment installed in 2017 are not discussed in this section, as they are described in 2.4 (1).

(2) O&M Status and Future Plan

Personnel of both HII and NIMT said that the instruments installed in 2017, which are being used as part of HII's CORS network, are owned by NIMT. Although NIMT is responsible for the operation and maintenance of the instruments as their owner, it does not recognize the need for preparing a budget for O&M because the 5-year maintenance contract is still effective until 2021. The NIMT personnel the Team interviewed was expecting an O&M budget to be in place when their CORS are integrated with those of other agencies.

The coordinates of NIMT's CORS as part of HII's CORS network have been established based on

ITRF2008. However, NIMT thinks it necessary to define their coordinates based on ITRF2014 as well so that time service users have different coordinates options to choose from. Defining the precise coordinates of each CORS will be critical for comparing clocks with increasing precision in future.

NIMT has initiated a research project for improving the precision of CORS coordinates by inputting accurate clock signals to the CORS (not only those installed in NIMT). However, the Team was told that sufficient progress has not been made to improve the precision of the coordinates.

NIMT intends to contribute to the CORS network with its timing capability (one of the PNT [Positioning, Navigation, and Timing] functions of GNSS). Accurate clock comparison based on GNSS is a foundation for transmitting reliable time signals, which are considered indispensable to the provision of time stamp and other services that will facilitate future socio-economic development. NIMT is hoping that the importance of GNSS in this regard will be recognized more widely.

One of the two receiver/antenna sets installed in 2017 are counted as part of HII's CORS network. The other set is for backup and not counted as an independent reference station in this report to avoid redundant counting. Those installed in 1999 are not included in this Survey, as they are not operating as CORS.

2.6. RTSD

（1） Installation Status

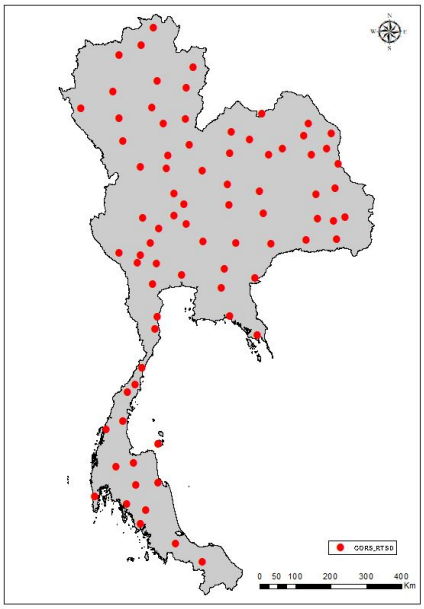


Fig. 2-13: RTSD's CORS network (as of August 2019)

Source: RTSD

In 2019, 80 CORSs and the data center have been installed, and test data distribution started in November 2019 (https://gnss-portal.rtsd.mi.th/portal/apps/sites/#/gnss).

The CORSs are installed in government land and building properties surrounded by fences, etc. for enhanced security.

RTSD's CORSs are equipped with cooling devices and lightning arrestors for protection against extreme weather conditions. For the data center, security measures, such as installation of firewalls, access management, and system user authentication, are being considered.

ITRF2008 was applied to, and RTSD's survey results of 2013 were used for the establishment of CORS coordinates.

Installation status and equipment specifications, etc. of RTSD's 80 CORSs are as shown in the table below.

Table 2-11: RTSD's CORS Installation Status and Equipment Specification, etc.

No. stations; inter-station distance	80 throughout Thailand; approx. 150km
GNSS antenna	Leica AR-20 (Choke-Ring Antenna)
GNSS receiver	Leica GR-50
Satellite system	GPS、GLONASS、Galileo、BeiDou、QZSS
Installation site	Public land or building
Mount style	Ground mount: 65 stations; Roof-mount: 15 stations Although yet to be finalized, most CORS will be mounted on the ground.
Antenna pillar height (material)	Ground mount: 5m or higher (concrete pillar covered with stainless steel) Roof mount: 2m or higher (hot-dip zinc-coated)
Weather protection	Cooling device, lightning arrestor, etc.
Power supply	Grid power with a 72-hour battery for backup
Telecommunications	Fiber optic cable with a 3G/4G backup line; VPN connection

CORS management software	Leica Spider
No. of licenses	Stationary stations: 250; Mobile stations: unlimited
Real-time data	Distributed to both public and private sectors.
Data for post processing	To be distributed to both public and private sectors (not finalized).
Baseline analysis software	Bernese GNSS Software

(2) O&M Status and Future Plan

Since RTSD's CORS network has just developed recently, this section discusses the future plan for O&M. RTSD invited bidders for CORS network project contracts, including a 5-year O&M contract (starting on completion of installation and acceptance inspection of all instruments) that obligates the contractor to ensure smooth operation and maintenance of CORS. It is a comprehensive contract that includes the establishment of the coordinates of CORS, periodic inspection and replacement of equipment, telecommunication and electricity charges, etc. However, under the contract, equipment is to be replaced only if it is damaged during normal use, which excludes damage or loss resulting from theft or natural disaster. Other expenses, such as relocation cost of CORS, are not covered either.

The data center is to be attended full-time by at least one employee (or more to ensure optimum operation) of the private contractor (for the normal working hours during the day). The chain of command between RTSD and the contractor has yet to be established in detail. The Team was told that RTSD would allow the contractor to make minor decisions on their own but require them to consult with RTSD on important matters.

The main points of the O&M plan are outlined in the table below.

Table 2-12: RTSD's CORS O&M Plan

O&M item	O&M plan
On-site CORS maintenance	To be carried out by the contractor with support from other agencies as necessary.
Periodic inspection of CORS	Twice a year (by the contractor, including cleaning)
Backup CORS equipment	RTSD does not have backup equipment; the contractor is to make necessary arrangements.
Coordinates calculation, etc.	Initial coordinates calculation is to be done by the contractor (calculation method has yet to be determined).
Power supply	Grid power with a 72-hour battery for backup. Battery replacement (once every 2 years) and electricity charges are included in the maintenance contract.
Telecommunications	Fiber optic cable with a backup 3G/4G; VPN connection

O&M item	O&M plan
	Telecommunication charges are included in the maintenance contract.
Operation of data center	Operated by the contractor (at least 1 person is stationed full-time). Observation/operation is to be carried out 24/7, but the data center can be unmanned at night.
Data distribution	Ministry of Defense: 50 users, institutions: 100 users, private companies: 30 users and others, Total: 250 users
IT equipment redundancy	If equipment fails, the contractor is to restore it immediately according to the contract.
Software maintenance	Included in the operation/maintenance contract.

RTSD's contractor is deemed fairly experienced, as it has a track record of successfully delivering, operating, and maintaining the CORS network for DPT.

The Bernese GNSS Software (for Windows), a baseline analysis program to be used for establishing the coordinates, has already been used in the provision of services by RTSD. Although only a few of its personnel can proficiently use the software, RTSD is receiving technical support from Chulalongkorn University.

RTSD's CORSs have been working without serious troubles as of December 2019 except that communication speed occasionally becomes slow for short period. Under the maintenance contract, which also covers telecommunication charges, the contractor is responsible for all aspects of the telecommunications system. However, it appears that RTSD needs to build a direct relationship, not via the contractor, with the communication company.

No plan has been devised as to what to do with regard to O&M after the expiration of the 5-year contract. RTSD will reconsider the terms and conditions of the contract and reestablish its own O&M structure while taking into consideration how the country as a whole will address the O&M aspects of the CORS networks after the completion of NCDC.

2.7. Determination of the Geodetic Reference System and Coordinates of CORS in Thailand (baseline analysis)

Which geodetic reference (i.e., reference ellipsoid, coordinate system, origin point) to adopt is an important question to consider in the installation, operation, and maintenance of CORS. Towards integrating and sharing data among various CORS networks that are currently operated by different agencies, the Team sorted out the present situations in Thailand as follows.

（1） Geodetic Reference System

In Japan, the geodetic reference system is defined under the Survey Act and related ordinances, with which the government agencies and local governments are required to comply in conducting surveys (including creation of GIS, topographic maps, etc.). In Thailand, on the other hand, no laws or rules expressly provide for a particular geodetic reference, which resulted in multiple reference systems adopted by different agencies. Likewise, private survey companies in Thailand are using different geodetic reference systems that are agreed upon with their respective clients. In order to enable sharing of data among various CORS and make effective use thereof, it will become increasingly necessary to integrate these reference systems into a unified one.

Government agencies have also been endeavoring to merge the reference systems through various activities, including cross-agency efforts towards the development of NSDI and the establishment of FGDS. As of the time of this Survey, other agencies have converted or are planning to convert their CORS reference systems into that of RTSD (see Table 2-1). In addition, NCGI, GNSS Subcommittee, etc. are also in the process of discussing and establishing common rules, etc. related to geodetic reference.

However, for DOL, which owns and manages a huge volume of cadastral and other geospatial information, it would be too burdensome and difficult to convert all geospatial data and transition to a new reference system. Accordingly, DOL is currently using both the old system (INDIAN 1975) and the new system (ITRF2008) in performing its services. Its CORS are using ITRF2008, and survey data are converted into those of the INDIAN1975 datum as necessary.

The geodetic reference system of RTSD, the national surveying agency of Thailand, has transitioned as shown in the table below.

Table 2-13: Transition of RTSD's Geodetic Reference System

Item	INDIAN1975	ITRF94	ITRF2000	ITRF2008
Survey period	Unknown	1991~1999	2000~2006	2007-2014
Year adopted	Unknown	1999	2006	2014
Ellipsoid	Everest 1830	WGS-84	WGS-84	WGS-84
Coordinate system	Indian1975	ITRF94	ITRF2000	ITRF2008

Item	INDIAN1975	ITRF94	ITRF2000	ITRF2008
Origin point	Local origin point on the ground: Khau Sakaerang (latitude/longitude)	Geocentric	Geocentric	Geocentric

Source: Compiled by the Team based on EPSG registry http://www.epsg-registry.org/ and RTSD's reply.

RTSD has been updating its geodetic reference system relatively early on, as it was required to revise the reference system as part of the GEODYSSEA (Geodynamics of South and South-East Asia) project. The GEODYSSEA project is funded by the European Commission and carried out by a consortium of European and Asian participants headed by the GFZ (German Research Centre for Geosciences). RTSD and other organizations of other participating countries are also performing their own analysis, etc. at their own expense.

At present, RTSD has no policy regarding the transition into the latest reference system. However, considering the fact that more and more Thai agencies will comply with RTSD's reference system along with expanding utilization of CORS, RTSD's transition will have increasing impact on various social activities. For future, it would be desirable for RTSD to proceed with the transition process towards the unification of the geodetic reference systems over the whole country, including coordination with relevant agencies, before the use of CORS expands to a larger scale. At the same time, they should also actively engage in research into new geodetic reference systems.

(2) RTSD's Geodetic Network

In installing CORS, obtaining compatibility with the neighboring countries' IGS stations, as well as the existing geodetic networks, will enable integrated operation with high-precision geospatial information (including topographic maps and GIS data). Towards this goal, the Team sorted out and outlined the geodetic networks in Thailand (RTSD's geodetic networks) as follows. Data collected by RTSD's geodetic networks are considered a component of the Fundamental Geographic Data Set (FGDS) and expected to be utilized and shared among various agencies.

The horizontal reference system is comprised of 8 Reference Network stations, 19 Primary Network stations (including 8 Reference Network stations), and 94 Secondary Network stations (including 8 Reference Network stations and 11 Primary Network stations). Maintenance of the Reference and Primary Networks is done by re-observing GNSS for seven days every year and analyzing the results at RTSD and Delft University of the Netherlands.

		
Reference Network	Primary Network	Secondary Network
8 stations Maintenance: GNSS re-observation for 7 days every year	19 (including 8 Reference-Network stations) Inter-station distance: 200 – 25km Maintenance: GNSS re-observation for 7 days every year	94 (including 19 Primary-Network stations) Inter-station distance: 50 – 10km Maintenance: GNSS re-observation for 7 days every 2 – 3 years

Fig. 2-14: RTSD's Geodetic Networks (horizontal)

Source: RTSD (Material used in December 2017 Seminar)

RTSD has set up a vertical control network since 1912, using mean sea level at Ko Lak, Prachaup Kirikhan Province as a vertical datum. The network is divided into two parts (northern part of Ko Lak and southern part of Ko Lak) consisting of about 1,700 Primary Network stations and about 7,300 Secondary Network stations.

In addition, RTSD conducted an airborne gravity survey over the whole of Thailand to create Thailand Geoid Model 2017 (TGM2017) based on the Earth Gravitational Model 2008 (EGM2008). TGM2017 has a height accuracy of 5cm and can be used to measure height in RTK surveying. This geoid model can be used not only in GNSS surveying and RTK but also in a variety of other applications and is available free of charge to everyone, including private entities and foreigners.

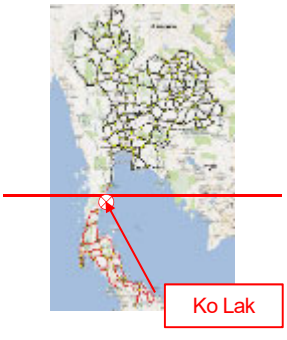
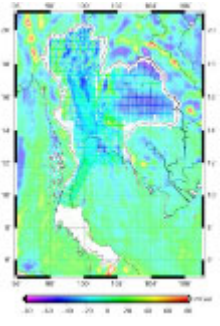
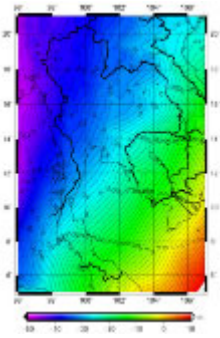
		
Vertical control network	Combination of Airborne + Terrestrial + EGM2008 + DTU13 Free-air anomalies	Geoid model (TGM2017)

Fig. 2-15: RTSD's Vertical Control Network and Geoid Model

Source: RTSD (Material used in December 2017 Seminar)

(3) Establishment of the Coordinates of CORS (baseline analysis)

Establishing the coordinates of each CORS is indispensable to starting the operation of CORS. One example of various methods of defining the coordinates of a CORS is to carry out GNSS observation at the CORS for seven days and analyze the information along with the data of IGS stations and existing geodetic network, etc. using a baseline analysis software, the use of which, however, is said to require high-level technical knowledge and skills.

The table below summarizes the coordinates defining method used by each agency when installing their own CORS and other related information.

Table 2-14: Establishment of CORS Coordinates and the Software Used

Agency	Baseline analysis software	Year of establishment	Use status of baseline analysis software, etc.
DOL	TGC/CBO (CHCNAV)	2016 (62 stations) 2017 (30 stations) 2018 (36 stations)	CORS coordinates calculation is performed by the contractor and approved by DOL. The use of the coordinates of IGS stations is unclear, but adjustments were made with the RTSD geodetic network.
DPT	Leica Geo Office	2013, 2016	Baseline analysis was performed initially by the contractor and is now done by DPT. 20 or so employees of DPT are capable of operating the software.
HII	Bernese	2017	Performed by HII staff (3 persons can operate the software) with the support from RTSD.
GISTDA	Power Network⇒ Bernese	2013, 2015	Currently, Bernese Software is used (two persons can operate it). Coordinates are established by GISTDA with support from Chulalongkorn University.
RTSD	Bernese	2019	A few employees of RTSD can operate the software with support from Chulalongkorn University.

Source: Result of interviews by the Team

Bernese GNSS Software developed by the University of Bern is a world's renowned baseline analysis software. According to the JICA expert dispatched to Thailand, agencies using Bernese GNSS Software are likely performing baseline analysis (defining the coordinates) by following the operation manual prepared by Chulalongkorn University. University of Bern has also produced an operation manual, which, however, consists of some 850 pages and requires knowledge on geodesy, as well as mathematics, geophysics, and other fields to understand the content. Chulalongkorn University in Thailand also uses Bernese GNSS Software in its Master's level courses. Furthermore, although not a regular course, the university also makes a training course on Bernese GNSS Software available where it is possible to learn the basics of the software.

According to RTSD, constant crustal deformation of about 2cm per year is being observed in and around Thailand. Considering this, there may be minute discrepancies among the coordinates due to differences in the timing of baseline analysis, the software used by different agencies, etc. In order to establish a high-precision CORS network by integrating the CORS of different agencies, it is deemed necessary to reestablish the coordinates by verifying the accuracy of the present coordinates and reconsidering the approach to defining the coordinates more precisely.

In addition, comments on GSIs baseline analysis software are summarized below.

In the case of general baseline analysis, if RINEX format files can be analyzed, any software is acceptable. However, general software cannot handle regular analysis, multi-point analysis, or long baseline analysis. The following features are required.

- Ability to create automatic processing programs
- Ability to perform simultaneous average network calculations at multiple points
- Ability to fine-tune analysis settings

GSI uses Bernese GNSS Software. However, regardless of what software is used, it is assumed that a single software will be used, and that the same version will be made available. As a result, it becomes easier to share analysis settings and compare the results.

(4) Laws and regulations concerning CORS

According to RTSD, the following three act/rules are related to CORS and geodetic reference system.

- Official secrets protection act B.E. 2483
- Rule of national security B.E. 2517
- Rule of the office of the prime minister of security in hiring private sector to conduct survey and mapping

1) Official secrets protection act B.E. 2483 (enacted in 1940)

This act is not limited to military affairs; it covers a wide range of areas related to national security, and is therefore under the jurisdiction of the Minister of Interior. CORSs vary depending on the installation site, and this act applies to those located on military sites. Since most of RTSD's CORSs are located on DOL sites, meaning this act does not apply.

2) Rule of national security B.E. 2517 (enacted in 1974)

Under this rule, government services are classified into four categories: (1) Top Secret, (2) Secret, (3) Confidential, and (4) Restricted. This rule may apply if the CORS services are for military purposes. It does not apply if the services are for civilian purposes.

However, in order to execute government services efficiently as a security precondition in the definition of Clause 38, government facilities and equipment need to be protected against theft, espionage, and

sabotage. This applies to all CORS.

3) Rule of the office of the prime minister of security in hiring private sector to conduct survey and mapping (enacted in 1991, revised in 2001)

This rule is imposed on all government agencies by the Office of the Prime Minister when a government agency outsources work such as surveying and the creation of geospatial information to commercial providers. The handling of geospatial information and security measures are also stipulated by this rule.

According to RTSD, this rule also applies to commercial providers' own work, as well as that of foreign companies. Moreover, while it is clearly stated that the rule applies to surveying and the creation of geospatial information through international cooperation, restrictions by commercial providers are not clearly stated. However, it is best to comply with this rule.

RTSD also mentioned that the observation data, correction data, and point data for the CORS are all interpreted as being included in the map data, and this rule is applied. In addition, revisions that apply new technologies may be made to this rule in the future.

3. Situation surrounding precision positioning services

3.1. Distribution of CORS real-time data and provision of positioning services in Japan

This section describes the roles and inter-relations of organizations providing CORS real-time data and positioning services in Japan, details of the distributed data and other relevant matters based on the information the Team has gathered.

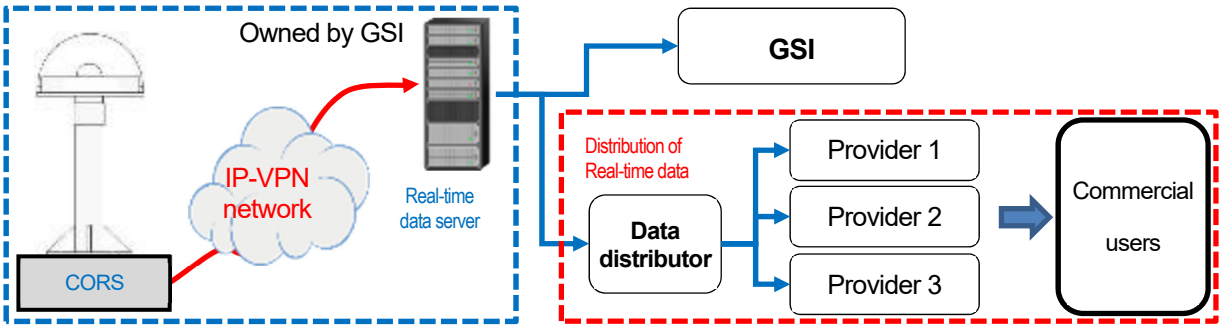


Fig. 3-1: Distribution of CORS real-time data in Japan and the organizations involved

Source: Based on the results of surveys conducted by the Team

The diagram above shows the flow of CORS observation data distributed as real-time data. CORS observation data are centrally collected at the real-time data server run by GSI, and then transferred to GSI and a distributor. The distributor provides real-time data to commercial providers, so that private companies etc., can use RTK correction real-time data.

The table below summarizes the roles and inter-relations of the organizations involved in the distribution of real-time data.

Table 3-1: Distribution of CORS real-time data in Japan and the organizations involved

Organization	Primary roles and relations	Primary roles and relations
GSI	- Operate the GEONET in a stable manner (24/7 observation)	Provide RINEX data for post-processing on the website
Data distributor	- Receive and distribute data in a stable manner. - Interface with commercial providers in relation to distribution services, etc. - Operate and maintain the systems used for data distribution.	- Conduct the distribution service as a non-profit business. - The costs of distribution systems, etc. are recovered from the commercial distribution service providers.
Commercial	- Distribute data to the private sector (as a paid	- Conduct the distribution service as a business for

Organization	Primary roles and relations	Primary roles and relations
distribution service providers	service.) - Provide customer support and services.	profit. - Currently three companies are engaged in distributing CORS real-time data commercially.

Source: Based on the results of surveys conducted by the Team

3.1.1. Geospatial Information Authority of Japan (GSI)

GSI is a government agency under the Ministry of Land, Infrastructure, Transport and Tourism responsible for governing surveying, established based on the Act for Establishment of the Ministry of Land, Infrastructure, Transport and Tourism and the Survey Act of Japan. This section describes the GNSS Earth Observation Network System (GEONET) managed by GSI.

（1） Overview of GEONET

Fig 3-2: Composition of a CORS

Source: GSI HP

The GEONET is an operational GNSS-based observation network, composed of about 1,300 CORSs installed with intervals of approximately 20 km across Japan and a data center called the GEONET Central Station. Its roles include the following:

- Monitor crustal deformation.
- Survey using CORSs.
- Maintain the geodetic reference point system.
- Support location-based services.

The GEONET observation data are widely made use of by not only GSI but also universities, research institutes, and private-sector companies.

CORSs are usually set up on the ground in the premises of elementary schools and other public-use sites. The stations are connected to the GEONET Central Station via communication line, such as ISDN line or mobile phone network. CORSs are also set up in environmentally harsh areas, such as the top of Mount Fuji and remote islands.

A CORS is made of a stainless steel pillar with a height of five meters, with an antenna, which receives electromagnetic waves from GNSS satellites, on the top, and the receiver, communication device, and other systems housed in the body of the pillar. The GNSS antennas and receivers used at some 1,300 CORSs in the country are provided by different manufacturers, whereas the observation data are received and monitored etc., by GSI's proprietary software.

(2) Satellite positioning systems observed by the GEONET

The GEONET observes four satellite positioning systems that are the Global Positioning System (GPS, USA), the Global Navigation Satellite System (GLONASS, Russia), Galileo (EU), and the Quasi-Zenith Satellite System (QZSS, Japan). Their observation specifications are as in the following table.

Table 3-2: Satellite positioning systems observed by the GEONET and their observation specifications

Satellite positioning system	Measurement signals covered
GPS	L1 (C/A, C), L2 (C, P), L5
GLONASS	L1 (C/A, P), L2 (C/A, P)
GALILEO	E1, E5a, E5b, E5-AltBOC
QZSS	L1 (C/A, C), L2 (C), L5

Source: GSI

The GEONET receives data from satellites at an elevation angle of 5° or higher, but uses data observed at an elevation angle of 15° or higher for analysis.

(3) Major functions of the GEONET Central Station

The GEONET Central Station centrally collects observation data from about 1,300 CORSs across Japan; analyze, convert, and store them; distribute real-time data, and engage in other activities. It also monitors the operations of the CORSs and maintains them.

Table 3-3: Major functions of the GEONET Central Station

Category	Software	Major functions
Data collection and distribution	GEONET data collection and distribution system	Communication with CORSs; conversion, storage, and provision of RINEX data; acquisition, provision, and storage of calendar data; analysis control; operation of the GEONET, etc.
	Provision of real-time data to third parties	Distribution of real-time data
Analysis	Steady-state analysis	Baseline analysis with the Bernese GNSS Software (CORS coordinates calculation)
	Provision of information to third parties	Creation of data based on steady-state analysis results for publication
	Monitoring of crustal deformation	Creation of CORS, baseline, transformation vector and other maps
	Real-time analysis	CORS real-time positioning

Category	Software	Major functions
Services	Provision of data and maintenance information	Acquisition of observation data, etc. from websites
	Clearing house	Collection and disclosure of information from observation stations on the website
	Management of CORS attribute data	Management, reference, search, html conversion, etc. of CORS information

Source: GSI

（4） Operation of the GEONET

The GEONET is operational around the clock seven days a week. It has been very stably operational with an acquisition rate of observation data from CORSs[10] being 99.5% per year or higher. There has been only one case over the past decade in which the data acquisition underperformed 99.5%. To sustain such a stable operation of the CORSs, the GEONET program carries out upgrades and maintenance activities in a thorough fashion. Missing data results mainly from the aging of GNSS receivers or power supplies and from trouble in the communication or electrical system. That being the case, the equipment is upgraded on a scheduled basis in the light of the life of the hardware used. For instance, the life of GNSS receivers is considered as seven years; approximately 200 receivers are upgraded every year. Additionally, measures to minimize possible trouble are taken by putting the UPS functionality (for 72 hours) in place for GNSS receivers and communication devices.

Table 3-4: Past records of acquisition rates of GEONET observation data

Japanese fiscal year (JFY)	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Acquisition rate (%)	99.58	99.57	99.39	99.53	99.78	99.63	99.51	99.81	99.77	99.86

Source: GSI

To implement and materialize such stable operation, external resources are employed in addition to GSI staff. External resources are contracted separately for field support and for the operation of the data center, but

[10] Acquisition rate (%): (No. of actual datatakes / No. of datatakes expected when all the CORSs are in full operation※) x 100
※No. of datatakes expected when all the CORSs are in full operation = No. of datatakes acquired every 30 seconds (twice a minute) x 60 minutes x 24 hours x No. of all CORSs
Thus, the missing rate of 0.5% is equivalent to roughly 2,370-days-worth observation data of all CORSs combined, or roughly 1.8-days-worth observation data of a single CORS per year.

they are working in liaison. For immediate recovery from a failure, the contractors are also part of the emergency communication and response structure during the nighttime and holidays.

Table 3-5: Role-sharing between external resources in relation to O&M of GEONET

Operation and maintenance of the data center	Maintenance of CORSs
• Download observation data. • Monitor data collection, troubleshoot, and recover CORSs. • Monitor the operational status of hardware and software. • Convert and distribute observation data • Support the recovery of dysfunctional CORSs.	• Recover any dysfunctional CORS (by replacing devices or components, switching on or off the breaker, etc.) • Investigate the cause of the failure of the recovered hardware (to identify the cause of the failure or accident.)
24/7	Response via phone, on-site support service

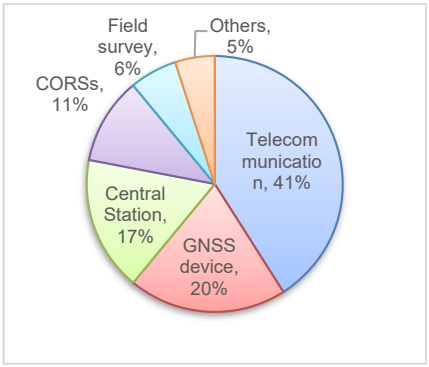
Source: GSI

(5) Budget for operation and maintenance of the GEONET

The budget for operation and maintenance of the GEONET is about 600 to 700 million yen per year. It does not cover the labor cost of personnel at the GSI but includes outsourcing costs for personnel in charge of maintenance of CORSs and the Central Station (data center). The breakdown of the budget is as in the following table.

Table 3-6: Budget for operation and maintenance of the GEONET (FY2017)

Item	Percent(%)	Notes
Telecommunication charge	41%	Telecommunication between CORSs and Central Station
GNSS device upgrade costs	20%	Upgrades of receivers and other devices
Maintenance costs of Central Station	17%	Commission for operation of the data center
Maintenance costs of CORSs	11%	Field response, etc.
Field survey costs	6%	Regular inspections, etc.
Other costs	5%	Electricity, travel expenses, portable devices, etc.



Source: GSI

GNSS receivers are scheduled to be upgraded roughly in every seven years. As the GEONET is composed of about 1,300 CORSs, some200 GNSS receivers are replaced with new ones each year.

(6) Handling failures to the GEONET

What happens typically when a failure occurs to the observation or communication capability of a CORS is that an operator at the data center performs checks on the communication line and tries to restore the function through remote access. If the problem requires a replacement of a device or component or any other action that cannot be taken remotely, intervention on the site is needed for restoration. Considering that CORSs are distributed in all parts of Japan and that some of them reside in areas with severe seasonal conditions, the length of time allowed for restoration is set to 7 days at the maximum.

The table below summarizes the failures experienced at the approximately 1,300 CORSs in Fiscal Year 2017. The majority of restoration efforts have been the replacement of devices and components.

Table 3-7: Failures to CORSs (JFY2017)

Hardware / Activities	Receiver	Antenna	Router	Clinometer	Protocol converter	Breaker	Other devices
Preventive maintenance	0	0	81	0	0	0	8
Replacement	39	61	16	14	0	1	97
Initialization	3	0	0	0	0	0	0
Breaker On/Off	0	0	0	0	0	20	0
Others	1	1	0	1	0	1	45
Total	43	62	97	15	0	22	150

Source: GSI

The table below summarizes the failures experienced at the GEONET Central Station. Communication line investigations and communication checks account largely for the outages. Communication checks with the communication companies are performed as the first response immediately after the occurrence of a failure. For this, GSI has built close relationships with the communication companies, thereby having a developed readiness for prompt response to failures.

Table 3-8: Failures to the GEONET Central Station (JFY2016-2017)

Japanese fiscal year (JFY)	Comm. line investigation, communication check, etc.	Failure to hardware	Failure to software, security control	Total
2016	1,180	6	223	1,409
2017	731	22	294	1,047
※Hardware failure: Replacement of disks, fans, power units, etc. ※Software failure/security control: System design change, address change, vulnerability control, etc.				

Source: GSI

In addition, the GEONET program is coordinating well with the power suppliers and the communication companies so that it can receive information on power outages and telephone line interruptions early on and notify users of the outages of CORSs. Likewise, it shares information on the maintenance of CORSs, with the distributor of CORS data without delay.

(7) Periodical inspection and relocation of GEONET CORSs

The following activities are performed in addition to the above-described operation and maintenance tasks, to ensure the stable operation of the GEONET.

Table 3-9: Other operation and maintenance activities for the GEONET

Activity	Description	Remarks
Onsite investigation at CORS sites	• Investigation at CORS site: investigate and inspect CORS and its surrounding conditions. • Inclination measurement: measure the inclination of the mount of CORS. • Height difference measurement: measure the height difference between the CORS and its ground marker.	This investigation covers all of the approximately 1,300 CORSs in multiple years, not in a single year.
Replacement of lead-in poles and others at CORS sites	Replace lead-in poles made of steel pipe (for power supply and communication) with concrete poles for disaster prevention.	For CORSs installed at educational institutes.
Relocation of CORSs	Relocate CORS, if the observation environment has adversely changed (e.g., a new high-rise building constructed nearby.)	A few CORSs are relocated every year.

Source: GSI

（8） Distribution of GEONET observation data

The program archives the 30-second RINEX data files (for post-processing) acquired since the start of observation. These files can be downloaded via the internet.

Table 3-10: Downloadable GEONET observation data

Type of observation data	Description	Remarks
CORS data	Observation data files (RINEX format, data sampling interval: 30 seconds)	Data for April 2010 and onward. Data before then are provided by JAS.
Daily coordinates of CORSs	Analysis result files: geo-centric coordinates (XYZ), lat./lon./ellipsoidal height, updated every week.	
IGS Precise Ephemeris	Information on precise orbits of GPS satellites provided by IGS.	Available for downloading from IGS.
Scientific data	GEONET data and analysis results made available to researchers.	An application form needs to be submitted.

Source: GSI Website

The real-time data of GSI-operated CORSs have been provided openly to the public since May 2002 so that the private sector can also utilize the data as control points for their GNSS-based surveying. The data were made open via a neutral, non-profit organization, rather than directly from GSI to the user company, because there were several private companies that wanted to use the real-time data distribution service at that time. The mediate distributor, delivery agent, had to have expertise and experience in GNSS-based surveying and was selected through a public tender for a five-year term. Currently, the Japan Association of Surveyors (data distributor) undertakes the job. See the succeeding section on JAS for the details of data distribution services.

3.1.2. Japan Association of Surveyors (JAS)

The Japan Association of Surveyors (JAS) was founded in 1951 by voluntary representatives from the governmental, academic and industrial spheres as a membership organization of surveying technicians, following the enactment of the Survey Act of Japan and the establishment of national licenses for surveyors and assistant surveyors in 1949. It was later certified by the Cabinet Office as a public-interest incorporated association in 2013.

Table 3-11: Outline of JAS

Foundation	13th January 1951
Location	Head office: Tokyo, Branch: 10 across Japan, Surveying Technology Center: Tsukuba
No. of employees	105 (as of 1st August 2016)
No. of members	Regular members: 10,284, Associate members (students): 406 Special members (corporations): 2,196 firms (as of the end of March 2018)
Outline of activities	1) Activities for members (publication of monthly journal "Survey", hosting of events, etc.), 2) Publication of surveying-related books, 3) Continuing Professional Development (CPD) (hosting of seminars and technical sessions, certification tests, etc.), 4) Survey consulting, 5) GIS consulting, 6) Certifications (for devices, survey results, etc.), 7) Construction technology review and certification (for surveying technology), 8) Distribution of CORS data

Source: Edited from JAS Website

(1) Distribution of real-time data

In May 2002, JAS started distributing real-time data from 200 CORSs located in major cities of the *Kanto*, *Chukyo*, and *Keihanshin* regions. In the following month, private companies which provide location-based services (hereinafter referred to as "commercial providers") started their distribution services using the data they receive from JAS. Currently, the real-time data available through these providers cover the approximately 1,300 CORSs.

This distribution business is based on a five-year agreement concerning the distribution of real-time data from CORS signed between JAS and GSI. This agreement allows JAS to receive real-time data from GSI and distribute it to the commercial providers after inspecting the data quality. JAS is also in charge of monitoring any delay under the agreement.

The agreement prohibits any profit-making activity, although JAS may collect the actual expenses incurred in the process of data distribution from the commercial providers.

This distribution business is conducted with three pillars noted below:

- Distribute real-time data to commercial providers.
- Communicate anomalies, if detected by the data quality inspection process, to the commercial providers and GSI.

Communicate to the commercial providers' information on outages and other matters relating to CORSs provided by GSI.

（2） Operation of the data center for distributing real-time data

While CORSs real-time data are rendered available around the clock, the monitoring staff are not stationed at the data center around the clock. However, a system has been developed which sends an email message reporting the latest status every hour and sends an emergency message or makes an emergency phone call automatically if and when an anomaly has occurred. With such a system in place, the personnel at the data center may consist of an elect few JAS employees and outsourced operators equipped with both surveying and ICT skills. The past records up until now show that the services are successfully provided with major trouble faced just once.

In the light of the current situation where the application of CORS real-time data is expanding to include autonomous operation of agricultural machinery and construction machine, in addition to just surveying projects, JAS is looking to a possible transition to 24/7 monitoring.

The table below provides a breakdown of the initial investment and recurring expenses for operation at the data center.

Table 3-12: Initial investment and recurring cost for real-time data distribution at the data center

Category	Account	Remarks
Initial investment	Purchase of hardware	Acquire ICT equipment on a scale that is sufficient for the approximately 1,300 CORS.
	Development of software	Software was especially developed rather than using commercially-available software.
Recurring operational costs	Lease payment for the data center	Space outside is rented for the data center.
	O&M cost	Subcontracts with outsources, additional cost for night-time operation
	Upgrade of hardware	Five years are a guideline for hardware upgrades.
	Troubleshooting of software	This account is outside the maintenance cost; this is on an accrual basis.

Source: Interview with JAS

These investment and costs are to be borne by the commercial providers who undertake the distribution service. Currently, three distribution service providers (commercial providers) and one experimenting enterprise cover the costs. Experimenters and non-profit organizations, such as universities and research institutes, bear less than the distribution service providers do.

（3） CORS data services

The services JAS provides include not just the distribution of real-time data to commercial providers but other services based on CORS data. These are paid services, but as JAS is a non-profit organization, the prices

are so set as to cover the necessary costs only.

Table 3-13: List of CORS data services provided by JAS

Service	Description
GPS precise analysis information service (Quicklook satellite positioning information)	Provide information on variations of privately- and publicly placed GPS continuous observation points. Provide precise positional information and information on quality evaluation and status monitoring.
CORS real-time data	Distribute real-time data to commercial providers.
CORS RINEX data (30-second)	Provide data between 1994 and 2014 on DVD-R or by other means.
CORS RINEX data (1-second)	Provide data taken during disasters, atmospheric or ionospheric disturbances, and other natural events on DVD-R or by other means.
CORS BINEX data (1-second)	Provide data taken during disasters, atmospheric or ionospheric disturbances, and other natural events on DVD-R or by other means.
CORS daily coordinates	Provide GSI-provided daily coordinates of CORSs on CD-R.

Source: Edited from JAS Website

(4) Public relations and promotion

In 2001, the Promotion Council of Real Time Positioning using GPS-based Control Stations (PCRG) was established with an aim to request GSI to make its CORS real-time data open and promote the utilization and spread of real-time data. JAS acts as the secretariat of the Council. PCRG is comprised of 39 ordinary members (private companies), including private providers, surveying hardware manufacturers and users, and 24 educational and public institutes (as of June 2018.) The activities of PCRG include the following:

- Spread real-time positioning widely.
- Encourage GSI to make available the data acquired by the ever-increasing number and variety of positioning satellites.
- Raise the awareness of the advantages of real-time data over post-processed 30-second data.
- Raise the awareness of the fact that the data are used in public surveys.

Table 3-14: Overview of activities of PCRG

Activity	Details
General assembly	Held once a year.
Board meeting	Held six times a year with an attendance of 15 board members.
Exchange meeting with GSI	Held twice a year.

Activity	Details
Seminar on application techniques	Held once a year (for the members as well as general participants)
Working groups	Application Promotion WG, Infrastructure Technology WG. Experimental observations, exchange meetings with other organizations and other events are held as needed.
Public relations	Publication of journals (semi-annually), management of PCRG Website
Others	Participation in seminars, briefing sessions, exhibitions and other events hosted by JAS and other relevant organizations.

Source: Edited from JAS Website and interviews with JAS

3.1.3. Distribution services by commercial providers

As of March 2019, three private companies undertake the service of distributing RTK correction real-time data. These companies are providing services on a national scale. There have been some commercial providers providing services on a regional or local scale as well, but only the three have remained through shakeout. In the meantime, there are some movements of new entrants; JAS receives several inquiries.

Incidentally, the commercial providers are prohibited from letting third parties use the raw real-time data.

Table 3-15: Commercial providers distributing real-time data

Company	JENOBA Corporation	Nippon GPS Data Service Corporation	Terasat Japan CO., LTD
Date of foundation	28th January 2002	25th April 2002	12th December 2013
Place of head office	Tokyo	Tokyo	Osaka
Primary services	• Distribution of real-time data • Distribution of post-processed data	• Real-time service • Post-processing download service	• Distribution of real-time data • Distribution of post-processed data
Data interval (post-processed data)	Select from 1, 2, 5, 10, 15, 20, 30, and 60 seconds	Select from 1, 2, 5, 10, 15, and 30 seconds	Unpublished
Service hours	24 hours / 7 days		
Coverage	All parts of Japan (including coastal areas, with an exception of some remote islands)		

Source: Edited from the websites of the commercial providers

（1） Main users

Main users of real-time distribution include a variety of surveying projects, ranging from aerial photogrammetry to airborne laser surveying, ground surveying, and mobile mapping system (MMS) and also the construction industry, registered land and house investigators, and compensation consultants. Main applications other than general surveys are listed below.

Table 3-16: Major use cases of real-time data

Category	Application	Benefits
ICT construction	Control of bulldozers	Network RTK helps works in steep terrain conditions without base stations.
	Control of construction machine	Multi-GNSS provides a sufficient number of satellites visible at sites around cedar forests.
Construction supervision	Construction of plants, land development	Network RTK makes construction supervision more efficient than TS.
General surveys	Control point surveys	Network RTK contributes to the efficiency of installing 4th class and complementary control points.
Investigations	For restoration of sewers	Post-disaster investigation on dislocated manholes (measuring elevations) is streamlined.
	For creating sewer registries	Network RTK contributes to the efficiency of drawing land boundaries and acquiring the positions of manholes.
	For sounding	Network RTK contributes to the efficiency of sounding in rivers and other water bodies.
Cadastral surveys	For delimitation surveys of lots	Network RTK contributes to shorten GNSS observation time.
	For construction site surveys	Used for restoring land boundaries by converting maps of registry office (defined in Article 14 of Real Property Registration Act) in an old coordinate system into the world geodetic system.

※GSI's General Standard of Operation Specifications for Public Surveys allow the use of network RTK-based surveying in installing 3rd and 4th class control points. Control points serve as a reference in horizontal position, and 3rd or 4th class represents the hierarchy in the control point system.

Source: Edited from the websites of the commercial providers

Explained below is an example of one of the three providers.

From the perspective of use time, ICT-based construction (i-Construction) accounts for more than a half of the services provided. A half of the remainder includes surveys, including ground surveys, aerial photography, and MMS. The use for autonomous operation of agricultural machinery does not count much at the moment; this is probably because farmers are using their own RTK systems. New services for MMS are upcoming. The use of the real-time data is expected to grow. The number of users (subscribers, including multiple users from

a single company) is in the magnitude of thousands.

(2) Structure of service provision

Explained below is an example of one of the three providers.

The services are provided 24 hours 7 days, but staff are not available during the nighttime and on holidays. Thus, a system has been put in place which sends an alert to the mobile phone of the on-call staffer if and when an anomaly occurs. Remote access is also possible. Since the past records have proven that anomalies do not occur so frequently and the level of data use at night is low, staff is not stationed around the clock. The organization, however, is examining a new operation structure with a view to a possible increase in the number of users going forward. Furthermore, they are planning to enhance the function of monitoring GSI CORSs in order to enhance user support.

Post-processed data are stored for approximately six months, to meet the demand for post-processed data taken a little earlier in the fields of aerial photogrammetry and MMS.

(3) Challenges faced in the provision of services

The following provides a summary of challenges to be tackled in the course of real-time data distribution examined by the Team based on the opinions expressed by the distribution service providers. These challenges must be addressed for appropriate distribution of real-time data.

Table 3-17: Challenges in the provision of real-time data distribution

Challenge	Description
Equipment provided by different manufacturers	How to process biases between different satellites differs among hardware manufacturers.
Latency in communication	Hardware manufacturers consider it necessary to send data within two seconds to users.
Correction of crustal deformation	Crustal deformation needs to be corrected.
User management	Billing users for the service will require reliable user management.
Irregular response	It is necessary to consider irregular response to the rollover of week numbers of GPS satellites (every 20 years or so)(likely to be dissolved in the future) and leap seconds.

Source: Edited from interviews with the commercial providers

（4） Tariffs

The commercial providers set their real-time data distribution service prices on a pay-as-you-go or fixed-rate basis. If a fixed-rate plan is chosen, the user can subscribe to a monthly or annual service. The pay-as-you-go plan is available for users who only use a limited volume of data or who want to use real-time data as a trial. The table below provides a synopsis of their tariffs.

Table 3-18: Primary prices set by the commercial providers providing real-time data distribution service

Company		JENOBA Corporation	Nippon GPS Data Service Corporation	Terasat Japan CO., LTD
Registration fee		20,000 yen	20,000 yen	20,000 yen
Base fee (monthly, fixed rate)		24,000 yen	21,000 yen	21,000 yen
Base fee (annually, fixed rate)		240,000 yen	180,000 yen	180,000 yen
Pay as you go	Base fee	2,000 yen/month (Including free use for 20 minutes)	2,000 yen/month (Including free use for 25 minutes)	2,000 yen/month (Including free use for 25 minutes)
	Usage fee	100 yen/minute	80 yen/minute	80 yen/minute
Post-processed data (VRS, RRS)		40 yen/minute	40 yen/minute	40 yen/minute

※Before tax.

Source: Edited from the websites of the commercial providers

3.1.4. Other CORSs

The GEONET is not the only CORS network in Japan; other organizations have set up GNSS-based continuous observation points as well. The data taken by these CORSs are not necessarily connected on-line with GSI's GEONET but are shared among stakeholders. As a notable example, the government has set up the Headquarters for Earthquake Research Promotion, chaired by the Minister of Education, Culture, Sport, Science and Technology and composed chiefly of administrative vice ministers of relevant ministries and agencies, with an aim to promote comprehensive measures in earthquake disaster prevention and management nationwide, and GSI's GEONET CORSs and other CORSs alike are made active use of for investigations and studies in this discipline.

The Japan Coast Guard had set up and operated 27 DGPSs all over Japan, though they discontinued the service as of 1st March 2019, for the purpose of assuring safe maritime operations. More recently, Japan has a plan to add GNSS-based continuous observation points as a part of its effort to implement the Ground-Based Augmentation System (GBAS), which utilizes satellites to assist aircraft in precise approach to runways; currently operational assessments are in progress.

These CORSs are not connected on-line with the GEONET because the installation, the purpose of operation,

maintenance conditions, and other factors are not the same.

Table 3-19: GNSS-based continuous observation points set up by other organizations

Organization	Purpose of CORSs	Remarks
National Research Institute for Earth Science and Disaster Resilience (NIED)	Build a network for continuously monitoring seismic and volcanic activities (GNSS-based continuous observation points are set up at 13 places out of 16 volcano monitoring stations.)	Equipped with not only GNSS equipment but other observation hardware comprehensively for earthquake and volcano monitoring.
National Institute of Advanced Industrial Science and Technology (AIST), Geological Survey of Japan (GSJ)	Monitor seismic and volcanic activities, conduct research and investigation, and gather and organize information.	11 CORSs in *Kii* Peninsula and *Shikoku* Island (as of 1st April 2018)
Japan Meteorological Agency (JMA), Meteorological Research Institute (MRI)	Monitor seismic and volcanic activities, and conduct research on application of CORS data to weather forecasting.	They use CORS data received from GSI as well.
National universities	Monitor seismic and volcanic activities and tsunamis, and conduct research and investigations (CORSs installed at 50 locations and more)	Participate in the government's Headquarters for Earthquake Research Promotion (with the attendance of other nine governmental agencies)
Maritime GPS Promoting Solutions	Provide RTK and DGPS services for maritime/coastal works (DGPS stations set up at 16 ports across Japan)	They do not exchange data with governmental agencies.
Japan Coast Guard (JCG)	Provide DGPS services for the safe operations of ships (DGPSs set up at 27 locations across Japan)	Discontinued as of 1st March 2019. Since then ships have been using correction information of MSAS and QZSS.
Ministry of Land, Infrastructure, Transport and Tourism (MLIT), Japan Civil Aviation Bureau (JCAB)	Set up DGPS base stations at airports in order to generate error correction information needed for GBAS.	Plan to start full operation at Haneda Airport, etc., in 2020.

Source: Results of surveys conducted by the Team

3.2. Examples of precise positioning services around the world

3.2.1. Examples of precise positioning services outside Japan and Thailand

This section presents examples of the GSNN-based control station (CORS) data distribution services in the United States (U.S.), Europe and Southeast Asia.

（1） CORS data distribution services in the U.S.

In the U.S., 200 or more organization responsible for creating CORS networks in the government, academia and industry have set up CORSs in accordance with their respective purposes, with the National Geodetic Survey (NGS) being the overarching coordinator and the focal point of data sharing.

The total number of CORSs in place is approximately 2,000, of which NGS manages 42 only. The University NAVSTAR Consortium (UNAVCO)-Plate Boundary Observatory (PBO) owns 427 CORSs, the largest number among the CORS operators. The university-governed consortium conducts geoscience research and the PBO is designed to monitor plate boundaries.

As in the case of PBO, the purpose of CORSs depends on the history of what each organization does; typically, it ranges from creating the backbone of national geodetic reference network, surveying and mapping, monitoring plate movements (as the U.S. lies basically on the continental plate, the network makes parallel movements only and no deformation, excepting some areas such as California), general positioning services, and so on.

The U.S. CORS network is characteristic in that it is a compound of several CORS networks developed for different purposes; thus, the distribution of CORSs is not even across the country. The data centrally gathered at NGS are intended for post-processing and not for real-time distribution. Some private companies provide real-time data but they do not cover the entire U.S. territory, as shown below.

(Overview of CORSs in the U.S.)

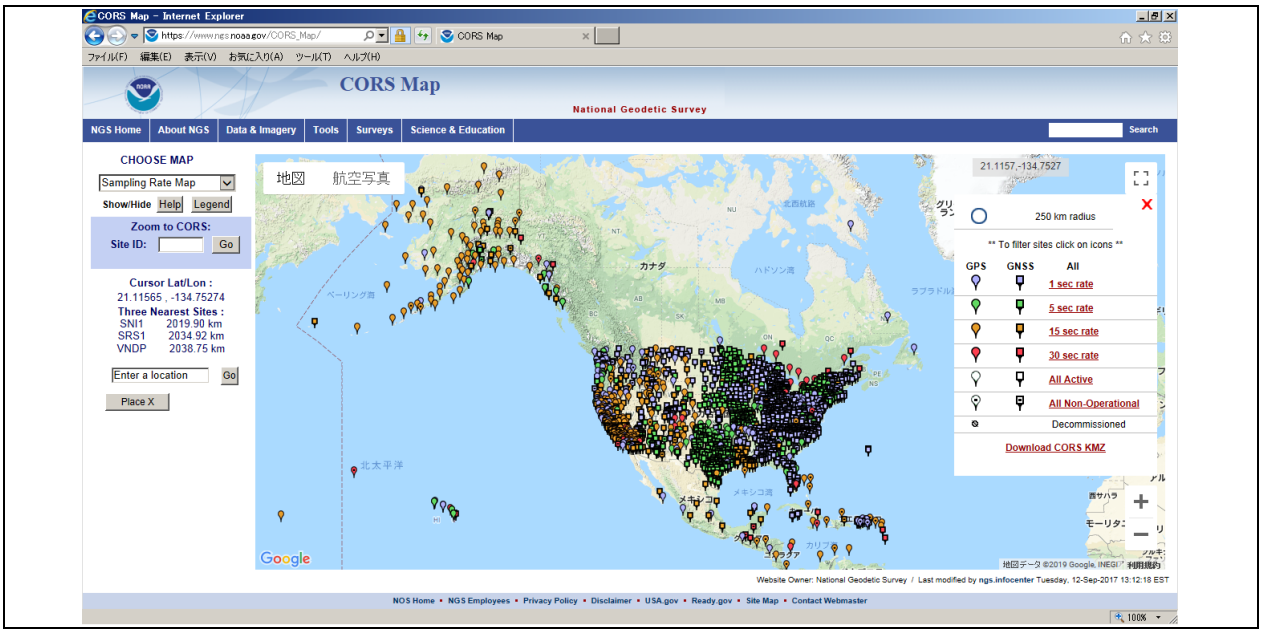


Fig. 3-3: NGS's CORS Map

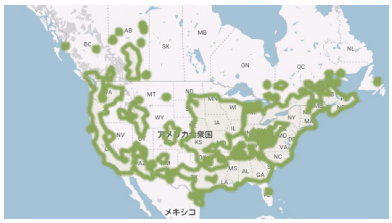
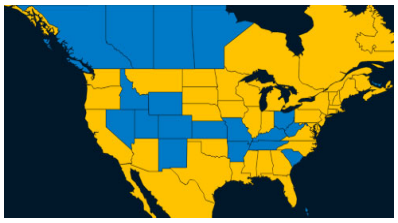
Source: NGS Website (https://www.ngs.noaa.gov/CORS_Map/)

- Three commercial data distributors are introduced below as representative examples.
  - ➢ Name of service: Trimble VRS Now - Provider: Trimble

    The area coverage centers around the states of Georgia, Alabama and Florida (Fig. 3-4, left).
  - ➢ Name of service: SmartNet North America - Provider: HEXAGON (Leica) Geosystems

    The area coverage is larger than VRS Now (Fig. 3-4, middle).
  - ➢ Name of service: TopNET live - Provider: Topcon

    The area coverage (yellow areas in Fig. 3-4, right) looks about the same size as SmartNet.

		
Trimble VRS Now	SmartNet North America	TopNET live

Note: The owner organizations of the CORSs each of these providers uses are unknown.

Fig. 3-4: Coverage of US commercial data distributors

Sources (from the left to the right)：Trimble Website(https://www.trimble.com/Positioning-Services/VRS-Now.aspx)、HEXAGON Geosystems Website(https://hxgnsmartnet.com/de-DE/local-coverage)、Topcon Website(http://www.topnetlive.com/)

(2) CORS data distribution services in Europe

The CORSs set up in Europe have some characteristics in common: 1) they use ETRF89 (European Terrestrial Reference Frame 1989), a unified system developed based on ITRF89, as the coordinate system; 2) the distribution of CORS on each country's coordinate system is densified based on ETRF89; and 3) Europe resides on a single crustal plate and the movement of the region caused by the plate motion is considered as a parallel shift.

Europe also has commercial data distribution services. Receiver manufacturers and other firms run network RTK-based data distribution services in many of the European nations. Some companies provide network RTK correction data, RINEX data (for post-processing) via the web, and computation services.

Underneath are three leading commercial data distributors.

- ➢ Name of service: Trimble VRS Now - Provider: Trimble

  Trimble provides the service in Belgium, Czech, Estonia, Germany, the Netherlands, Sweden, the U.K., Ireland and some parts of Spanish (Fig. 3-5, the left).

  https://www.trimble.com/Positioning-Services/index.aspx
- ➢ Name of service: SmartNet - Provider: HEXAGON (Leica) Geosystems

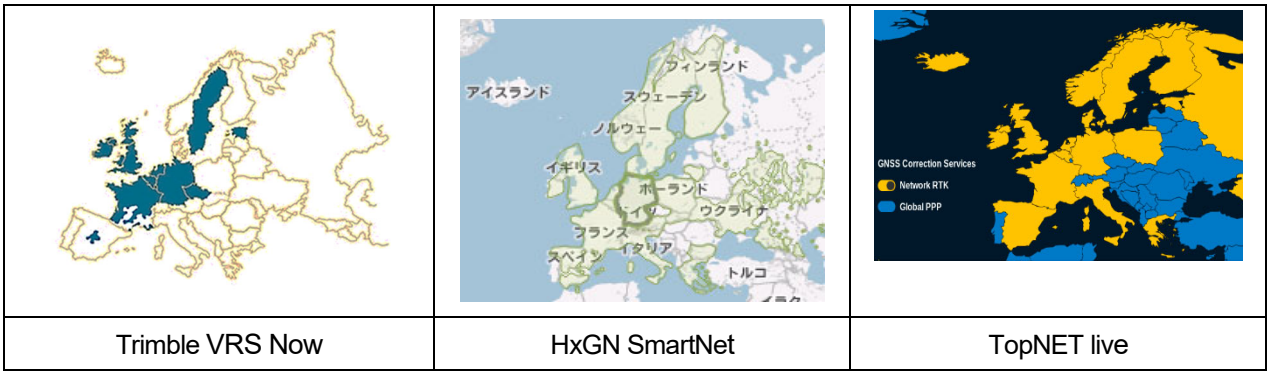
HEXAGON (Leica) provides the service in Belgium, Bulgaria, Denmark, Finland, Germany, Greece, the Netherlands, Ireland, Italy, Norway, Poland, Spain, Sweden, Ukraine, the U.K. and some parts of Russia(Fig. 3-5, the middle).

https://hxgnsmartnet.com/de-DE/

- Name of service: TopNET live - Provider: Topcon

Topcon provides the service in Belgium, Denmark, Estonia, Finland, France, Germany, Greece, the Netherlands, Iceland, Ireland, Italy, Norway, Poland, Spain, Sweden, the U.K. and some parts of Russia (Fig. 3-5, the right).

http://www.topnetlive.com/



Trimble VRS Now	HxGN SmartNet	TopNET live

Fig. 3-5: Coverage of European commercial data distributors

Sources (from left): Trimble Website(https://www.trimble.com/Positioning-Services/VRS-Now.aspx)、HEXAGON Geosystems Website(https://hxgnsmartnet.com/de-DE/local-coverage)、Topcon Website(http://www.topnetlive.com/)

Some other companies, as introduced below, also provide data distribution services but only in one or two countries.

- Name of service: TERIA Network - Provider: TERIA

Private-sector enterprise operating only in France (to be described later in Subsection 3.2.1.（4）)

http://www.reseau-teria.com/

- Name of service: FarmRTK - Provider: AXIO-NET

ASCOS-Allsat and EADS jointly established AXIO-NET GmbH in 2008. It was acquired by Trimble in 2016. The business provides not just network RTK services but FarmRTK services, focused specifically on agriculture, in Germany and the U.K.

http://www.axio-net.eu/startseite/

- Name of service: EssentialsNet - Provider: Soil Essentials

The enterprise provides network RTK services for agricultural machinery control in the U.K.

https://www.soilessentials.com/product/rtk-correction-service/

(3) CORS data distribution services in Germany

The CORS governing agencies in Germany are the surveying authorities of the sixteen German states; their CORSs are joined by the ones set up by the Federal Agency for Cartography and Geodesy (Bundesamt für Kartographie und Geodäsie: BKG) for the purpose of sustaining the national geodetic network, called the Integrated Geodetic Reference Network of Germany (Integriertes Geodätisches Referenznetz Deutschlands: GREF), as the backbone. The network consists of 270 CORSs in the country plus 30 CORSs set up in neighboring nations, a total of 300 stations, providing a service called Satellite Positioning Service of the German State Survey (Satellitenpositionierungsdienst der deutschen Landesvermessung: SAPOS) maintained by the Working Committee of the Surveying Authorities of the States of the Federal Republic of Germany (Arbeitsgemeinschaft der Vermessungsverwaltungen der Länder der Bundesrepublik Deutschland: AdV), a controlling authority jointly founded by the sixteen states of Germany.

The CORSs installed inside Germany include 25 stations operated by BKG that form the backbone of the GREF and 245 stations operated by the surveying authorities of the German states. All the CORSs have coordinates compliant with ETRF89, the unified reference frame of Europe.

The applications of these CORSs include the backbone of the GREF, surveying and mapping, monitoring the plate motion (parallel shift only, no deformation to the network) and general positioning services.

(Overview of CORSs in Germany)

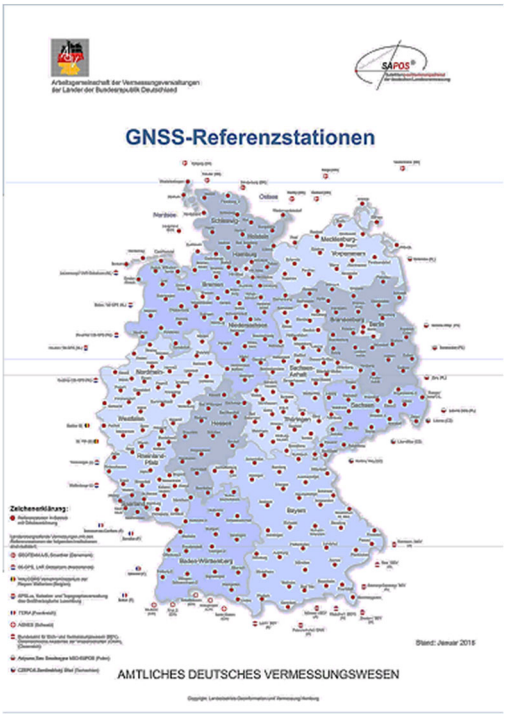


Fig. 3-6: Germany SAPOS network

Source: A presentation slide downloaded from AdV – SAPOS's Website (http://www.adv-online.de/Products/SAPOS/)

The SAPOS provides both RINEX data for post-processing and correction data for network RTK as paid services, but other commercial distributors also provide their own RTK services in Germany.

(4) CORS data distribution services in France

The structure of CORS governing agencies is more complicated in France than any other countries.

France GSI (Institut Géographique National: IGN) has created and operates the CORS network (Le réseau GNSS permanent: RGP), with the CORSs developed by IGN and a partnership agreement among the government, academia and industry. Thus, the network contains stations set up by local governments, universities and research institutes, and private companies, not just those by IGN.

TERIA is a private company established by the capital of the Order of Expert Surveyors (Ordre des Géomètres Experts: OGE) of France. It owns the greatest number of CORSs among any private companies and runs the TERIA Network. In addition to TERIA, some companies have put their own CORSs in place. IGN receives CORS data from these private companies, including TERIA, local governments, universities and research institutes free of charge and uses them as a part of RGP in order to calculate coordinates on the French national geodetic network, RGF93 (Réseau Géodésique Français 1993). RGF93 is, like other European nations, compliant with ETRF89.

The number of RGP CORSs in place is 518 in total, of which 24 belong to IGN, 168, the greatest number, to TERIA and 125, the second greatest number, to SATINFO. IGN is responsible for approximately 5 % of the RGP CORSs, public agencies about 17 % and private companies roughly 78%.

The applications of these CORSs include agriculture, construction, surveying and mapping and general positioning services.

(Overview of CORSs in France)

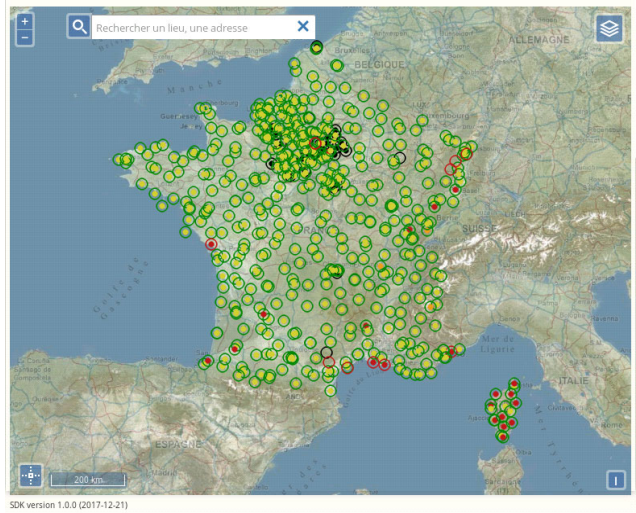


Fig. 3-7: RGP network of France

Source: IGN Website (http://rgp.ign.fr/)

The majority of the data distribution in France is undertaken by the private sector. IGN provides RINEX data for post-processing free of charge, while TERIA, SATINFO and other private companies provide network RTK correction data as paid services. The sum of the numbers of CORSs possessed by different companies turns out to be greater than the number of RGP CORSs, suggesting that the companies probably have their own CORSs.

(5) CORS data distribution services in the U.K.

The CORS governing agency in the U.K. is the Ordnance Survey (OS) of the Great Britain; the network they operate is called OS Net. To the extent the Team conducted our study, there is no CORS developed by private companies.

The total number of CORSs is 115. The coordinate system of CORS is compatible with ETRF89, while the country uses OSGB36, the U.K.'s original reference frame, as the map coordinate system. This means that inverse translation of coordinates is necessary for compatibility with maps. The OS provides the coordinate conversion software. According to HEXAGON Geosystems, the capability of reverse conversion to OSGB36 is embedded in the receiver (rover).

The applications of CORSs include agriculture, construction, surveying and mapping, and accurate asset management.

(Overview of CORSs in the U.K.)

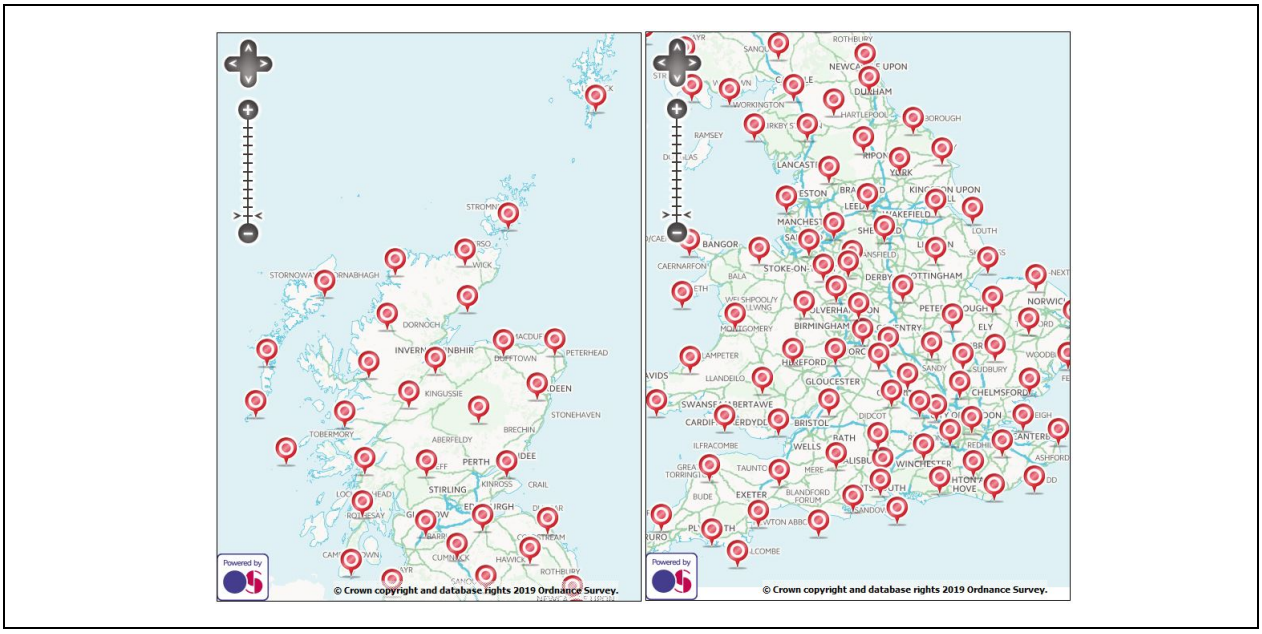


Fig. 3-8: OS Net of the U.K

Source: OS Website (https://www.ordnancesurvey.co.uk/gps/os-net-rinex-data/)

The majority of the data distribution service in the U.K. is undertaken by the private sector. The OS provides data for post-processing free of charge but do not distribute network RTK data. An enterprise partner provides the OS's CORS data as a paid service.

(6) CORS data distribution services in Malaysia (advanced example in Southeast Asia)

Malaysia boasts the most complete CORS network in the Southeast Asia. The CORS governing agency is the Department of Survey and Mapping Malaysia (Jabatan Ukur dan Pemetaan Malaysia: JUPEM).

The total number of CORSs in place is 78, which form a network called MyRTKnet. The CORS network as it is today was completed in 2008. 50 stations thereof are situated in Malay Peninsula and 28 in Sabah and Sarawak States.

The applications of CORSs include surveying and mapping, and general positioning services.

JUPEM being a national government agency provides both GNSS data for post processing and network RTK data. The data are subject to fees. The prices have lowered since the start of operation. (An unconfirmed report says that the prices have been lowered so as to boost the number of users.)

https://www.jupem.gov.my/v1/my/produk-perkhidmatan/real-time-kinematic/

(Overview of CORSs in Malaysia)

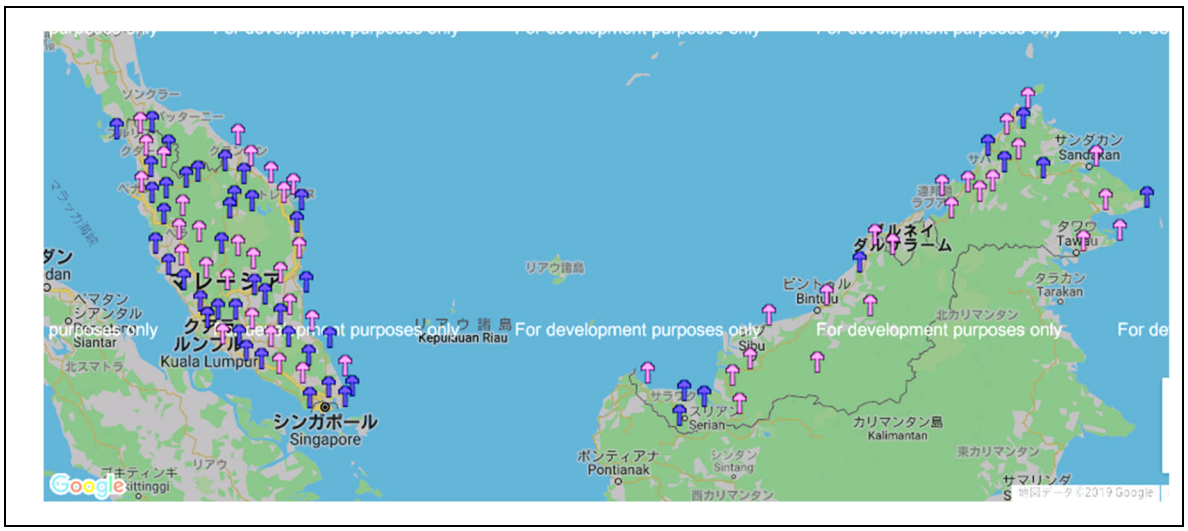


Fig. 3-9: MyRTKnet of Malaysia

Source: JUPEM Website (http://www.rtknet3.gov.my/SpiderWeb/frmIndex.aspx)

Regarding the distribution of network RTK data by the private sector, there seems to be no private company distributing the data to the extent the Team conducted our study.

3.2.2. Technical trends surrounding use of precise positioning services

"GNSS User Technology Report Issue 2" published in 2018 by the European GNSS Agency (EGSA) explains the recent trends of satellite positioning as follows.

More than 100 navigation satellites of various kinds including GPS, GLONASS, Galileo, and QZSS have been installed in recent years, and receivers compatible with these multi GNSS (multiple constellations) began to be widely used several years ago. And now, GNSS receivers are normally compatible with multiple constellations. The similar trend is observed among GNSS reception chipsets, which are nowadays mounted to smartphones and other products available in the general market, through these products were previously compatible with GPS only.

Precise positioning receivers have long been compatible with dual frequency signals. Inexpensive dual frequency reception chipsets were put on the general market in 2017, and smartphones compatible with dual frequency signals appeared on the market in the following year. All this has made it possible to perform more precise positioning with devices for general consumers than ever. As for Android terminals, Google LLC made GNSS raw measurements available to users of its Android operating system in 2016. Since then, developers have been taking advantage of these data to develop applications. Nowadays, chipsets enabling to receive precise augmentation signals (such as CLAS of QZSS) even with terminals for general consumers are available on the general market. Because these chipsets with high functions are easily available at low prices thanks to volume production, terminals for general consumers have been becoming high-precision, and now there is little difference with more professional receivers (such as positioning receivers and those for precision agriculture).

As for professional receivers, on the other hand, three-frequency (and even four-frequency) GNSS receivers have appeared on the market. In the realm of professional receivers, not only multi GNSS receivers and multi-frequency receivers, but also receivers using RTK, network RTK and other mature positioning technologies are commonly available. A new technology, precise point positioning (PPP), has already been introduced to seek higher precision, through the PPP method is still far from commercial use as it needs extra time to first fix (TTFF). However, solutions to multipath engineering problems have been developed, which is improving the reliability of positioning results. The evolution of these professional receivers helps improve the quality of GNSS receivers, including those for general consumers.

Other than the search for higher precision, the demand for safety and reliability of the service is also growing in order to adopt for autonomous driving of vehicles. To satisfy such demand, signals to receive need to be made available, continuous, complete and robust, and TTFF needs to be shortened. Research and engineering efforts have been made to deal with these challenges.

3.3. Demand for using precise positioning data in Thailand

3.3.1. Use of precise positioning data by government agencies and private sector

（1） Use of precise positioning data (CORS data) by government agencies of Thailand

This section overviews the use of precise positioning data by the members of Thailand-Japan Joint WG. Precise positioning data are chiefly used for two purposes in Thailand: practical purposes and as a subject of research and development.

(a) DOF

DOF has operated a vessel monitoring system (VMS) using geospatial and positioning information to monitor some 6,000 fishing vessels of 30 tons or more with GNSS[11] (https://vms.fisheries.go.th/signin.php). Vessels monitored are far from land, so they do not use CORS data now. However, they are interested in the use of precise positioning data to gain higher precision in defining fishery prohibited areas (three miles from the shore).

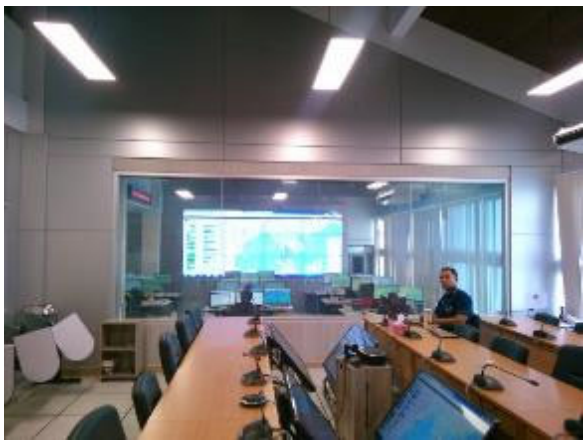


Photo 3-1: VMS operation room

(b) DOL

DOL is an agency that introduced the largest network of CORSs, enabling about 500 personnel to carry out RTK-based control point surveys for land boundary surveys and cadastral surveying each day.

[11] There are an estimated 20,000 vessels in entire Thailand.

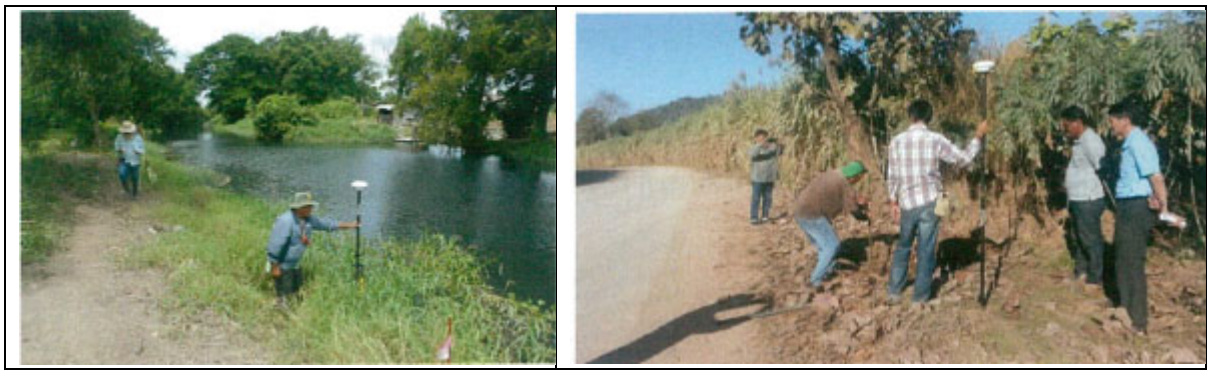


Photo 3-2: RTK-based surveying by DOL

Source: DOL (materials for the seminar in December 2017)

(c) DPT

DPT takes advantage of CORSs for aerial photogrammetry, large-scale geospatial information (1/1,000 or 1/4,000 topographic maps), on-site ground surveying and other purposes necessary for public works, spatial planning and urban planning, as well as road and other infrastructure projects both at national and regional levels. Specifically, DPT conducts RTK-based surveying in the process of control point surveys to create topographic maps, confirmation of land boundaries for urban development, and on-site surveying for road pavement alignment, which requires a centimeter-level precision. For road development, DPT is responsible for creating 1/1,000 situational maps of the roadsides. DPT also conducts road surveying using CORSs with its own MMS. DPT hopes to use CORSs to check maps created, and upgrade maps more efficiently when landscapes change with new houses and roads over years.

Photo 3-3: Creation and upgrade of 1/4,000 topographic maps by DPT

(d) GISTDA

GISTDA is responsible for research and development of GNNS satellites and CORSs as part of its activities for geospatial information and space technology development. GISTDA particularly focuses on GNSS-based autonomous operations of agricultural and construction machineries, autonomous control of drones,

infrastructure monitoring, and air traffic control. It undertakes projects in partnership with companies and universities at home and abroad under the slogan of the following value chain.

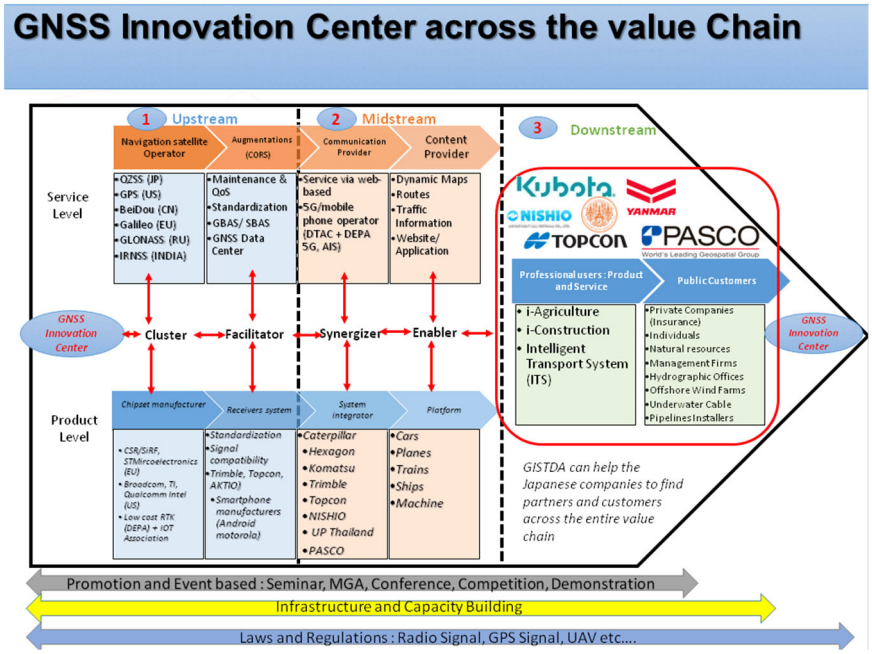


Fig. 3-10: GNSS innovation value chain

Source: Abstract from "Space Krenovation Park And EECi" materials prepared by GISTDA

GISTDA has launched a plan to build "Space Innopolis" within EECi[12] for GNSS technology development. Under the plan, "Space Innopolis" will have fields that enable to perform and verify ICT construction (i-Construction), smart agriculture, UAV delivery, and surveying in close-to-actual practice environments. It is still under planning and its actual date of completion is undetermined, but GISTDA is seeking to take advantage of i-Construction for the construction of the facilities.

[12] Research facilities specializing in innovation, located an hour from SKP

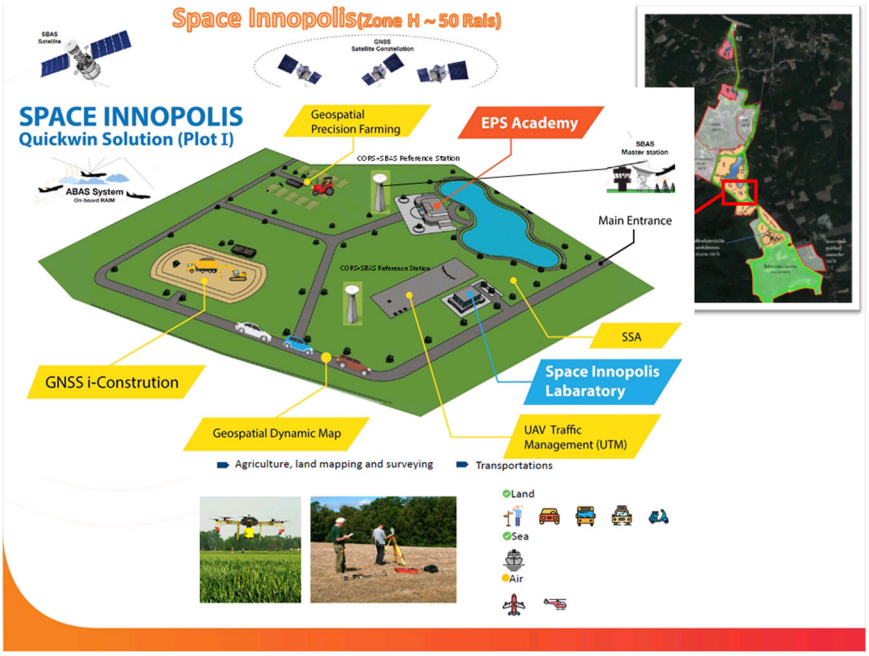


Fig. 3-11: GISTDA EECi

Source: Abstract from “Space Krenovation Park And EECi” materials prepared by GISTDA

(e) HII

HII studies possible use of CORSs as part of its research and development activities on information gathering and the gathering methods for water resources (including monitoring), emergency response, and disaster prevention and management. In line with this, HII participated in special experiments conducted in this Project, where HII used MMS and CORSs to create three-dimensional models of riverbanks and verify their precision. HII uses CORSs also for actual operations, such as when measuring the precise location when a water gauge is installed, measuring water levels of flooded areas during flooding disasters. HII hopes to apply CORSs to estimation of precipitable water vapor (PWV) and construction of models to assess water quantities.

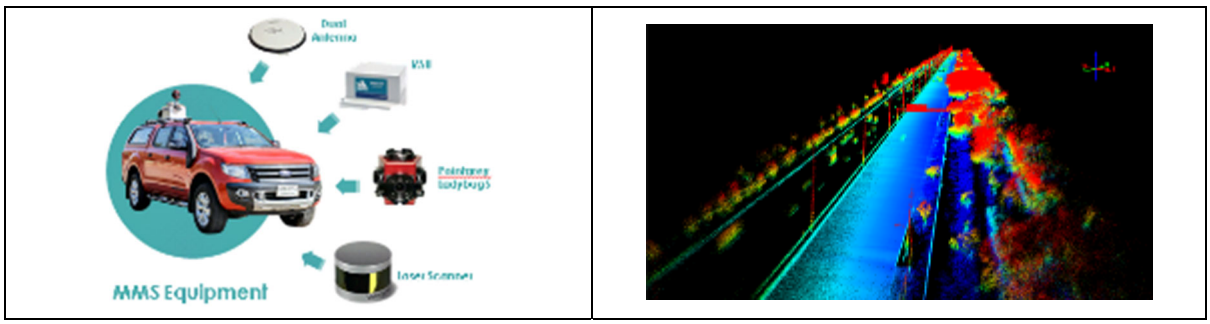


Fig. 3-12: HII’s MMS vehicle (left) and point group data measured with MMS (right)

Source: Abstract from the materials presented by HII at Thailand Japan Special Session (28th Aug.)

(f) RTSD

As Thailand's national organization responsible for surveying administration, RTSD takes advantage of CORSs to collect geospatial information for maintenance of the geodetic network and creation of 1/50,000 topographic maps. RTSD repeats observing the 8 existing stone marks of the reference network over 7 days per year; the 19 marks, the 8 marks of the reference network plus 11 marks, which form the primary network, over 7 days per year; and the 94 marks that form the secondary network, including those of the primary network, over 7 days every 2 to 3 years. They have no intention of replacing the current geodetic network with CORSs. The existing geodetic network and the CORS network presently installed will be coexisting.

(g) NIMT

NIMT, responsible for measurement standards in Thailand, takes advantage of CORSs to compare clocks for managing the standard time and monitor the standard time.

(2) Estimated applications and services fees when precise positioning data are made available in Thailand

(a) Estimated applications

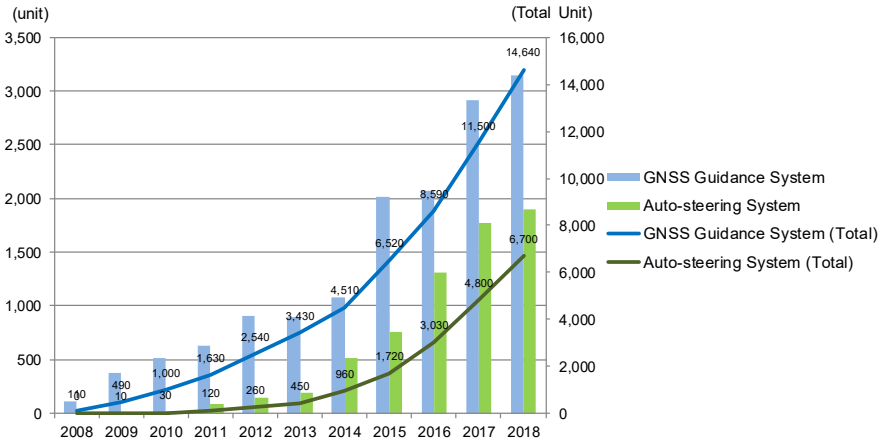
In Thailand, the precise positioning is recognized as one of the key technologies indispensable for making Thailand 4.0 a reality. Areas where the contributions of precise positioning data are expected particularly include surveying, agriculture (smart farming), construction (ICT construction), autonomous driving of vehicles, and disaster prevention and management, etc., in the order of priority.

For surveying, application of RTK or network RTK to surveying of control points, photo control points, and boundaries will make these operations more efficient. Moreover, if three-dimensional point group data obtained with a laser scanner on vehicles or UAV, and image data captured with cameras are analyzed with post-processed data, landforms and road objects can be identified speedily with high precision. In Thailand, DPT, HII and other agencies have already started to apply this technology to identify detailed landforms along roads and aged deterioration, and data distribution to the entire country will expand the use of precise positioning data.

For agriculture, in Japan, which faces a decline in agricultural population in the near future, GNSS guidance systems that support maneuvering of tractors, auto-steering systems, and robot tractors that can control steering without human intervention are beginning to be widely used (Fig. 3-13). In Thailand, no companies have started using the technology except Mitr Phol Group, Thailand's leading sugar producer, which has already adopted a GNSS guidance system[13]. But the increasing demands for robot tractors and other technologies are presumed because the country, like Japan, is aging and will soon face a decline in agricultural population.

[13] Based on the materials published by Mitr Phol Group at GEO SMART ASIA 2017

Precise positioning data is essential also for the pinpoint spraying system for agricultural chemicals with UAV, which Japan's Ministry of Agriculture, Forestry and Fisheries regards as a new agricultural technology (Fig. 3-14). When this technology is put to practical use and made widely available, it will be an application of precise positioning data also in Thailand.



(unit)

Categoly/ FY	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total Unit
GNSS Guidance System	110	380	510	630	910	890	1,080	2,010	2,070	2,910	3,140	14,460
Auto-steering System	0	10	20	90	140	190	510	760	1,310	1,770	1,900	6,700

* GNN guidance and auto-stering systems shipped as a set are counted in both categories. Figures are rounded off to the nearest 10.

Fig. 3-13: Shipments of auto-steering systems, etc. in Japan

Source: Edited by the Team from the materials (http://www.pref.hokkaido.lg.jp/ns/gjf/jisedai/GPS_GuidanceSystem.htm) of the Hokkaido Government, Agricultural Administration Department, Production Promotion Bureau, Technology Extension Division

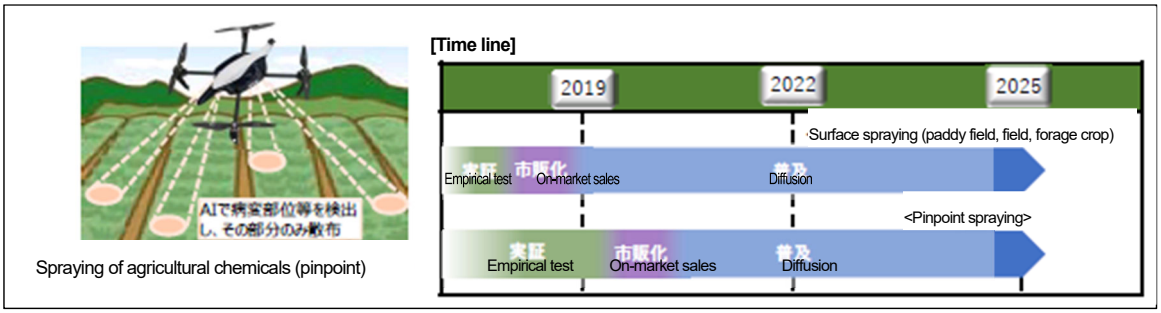


Fig. 3-14: Pinpoint spraying of agricultural chemicals with UAV

Source: Abstract from "Development of Smart Agriculture" (by Ministry of Agriculture, Forestry and Fisheries of Japan, July 2019)"

For construction, constructors are beginning to apply ICT to the process from research/current survey to designing, construction, inspection, and maintenance for higher productivity and quality control. In Japan, MLIT has been promoting "i-Construction" and encouraging constructors to use three-dimensional data for the above construction process since 2015, and the effects of these efforts have in fact been confirmed. These

efforts require high-precision three-dimensional measurement and real-time positioning. According to real-time data distributors in Japan, ICT construction (i-Construction) accounts for about a half of all the usage time of real-time data. In Thailand, precise positioning data is not yet utilized full-scale, but ICT construction or i-Construction will be widely used and become a major usage of precise positioning data in future because productivity and quality are key issues at construction sites in the country.

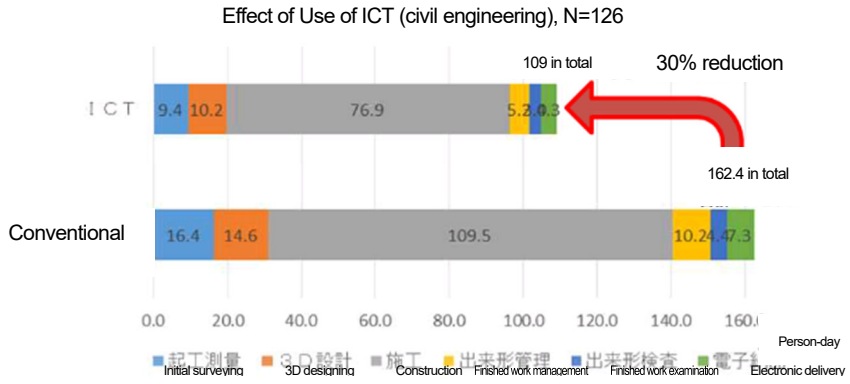


Fig. 3-15: Effects of ICT-based civil engineering in Japan (FY2018)

Source: Abstract from “Operational Situation of ICT-based Construction (FY2018)”, MLIT
(http://www.mlit.go.jp/common/001275855.pd)

(b) Estimated services fees

It is difficult to design fee system of the data distribution based on cost estimation, because details about personnel allocation, equipment and nature of services at NCDC are yet undetermined.

The agencies of the Thai government the Team interviewed expressed their views that precise positioning data should be provided free of charge at initial stages to boost the use of the data. As a matter of fact, HII, DOL and RTSD, the current distributors of the data, do not charge any fees. NCDC Management WG has also agreed that data will be distributed free of charge for the time being. On the other hand, the private companies, or users, the Team interviewed said that they would accept certain levels of service fees once precise positioning data become available in Thailand. Some Japanese companies said that they would use precise positioning data, if their prices are similar to data distribution service fees in Japan (21,000 yen/month of the license fee) or levels that reflect commodity prices in Thailand (3.3.2. (1)).

Thus, the Survey will simply estimate service fees by converting the service fees in Japan to the levels suitable in Thailand and examine how much the service fees estimated can make up for the cost of the data distribution services.

In Japan, the most inexpensive data distribution services are available at 21,000 yen per month (3.1.3. (4)). To convert these fees to the levels suitable in Thailand, we assume the Thailand/Japan ratio at 1:5.5 by

referring to the ratio of nominal GDP at 1:5.6 (6992USD: 39306USD) [14], the ratio of wages of general factory workers in manufacturing at 1:6.2 (413USD: 2578USD), and the ratio of wages of mid-level engineers in manufacturing at 1:4.8 (728USD: 3491USD)[15]. By dividing Japan's lowest fees of 21,000 yen at the ratio of 1:5.5, we obtain 3,800 yen per month. Converting it into Thai Baht, we obtain the monthly fee of 1,100 Baht (at the JICA rate of 3.47478 yen/Baht as of September 2019).

If the telecommunication charge at DOL (2.1. (2)) is simply allocated to 287 CORSs, it costs about 555,500 Baht/month, which is equivalent to fee revenue from about 505 users. However, it is necessary to increase the cable capacity if the number of users grows, which thus is likely to increase the telecommunication charges.

Moreover, an average of 41 GNSS receivers need to be replaced with new ones per year if they are replaced every seven years as in the case of GSI in Japan (3.1.1 (4)). Each receiver for CORSs costs about 20,000-30,000USD. Even if, however, the price is set at a lower level, for example, 10,000USD considering the price reduction due to competitive bidding and cost reductions, the replacement will cost 410,000USD or about 12,540,000 Baht per year (at the JICA rate of 30.58266 Baht/USD as of September 2019), which is equivalent to fee revenue from about 950 users.

The government, or a revolving fund or a public organization is expected to be responsible, so the personnel expenses are assumed to be borne by the national treasury. If wages of 10 mid-level engineers (23,842Baht/person per month)[16] are financed by fee revenue, it will be necessary to secure fees from 217 users. However, these wages are basic salaries, and the cost to be borne by the employer will be more if their social security and other expenses are considered.

What part of the entire costs the Thai side intends to make up for with fee revenue is a future task, but it is assumed, according to the estimation above, that they will be able to collect only part of the cost only if they have some hundreds or a thousand users.

3.3.2. Intents to utilize precise positioning data among Japanese firms operating or planning to operate in Thailand

The Team gathered information from Japanese companies doing business in Thailand or planning to do so on the demand for precise positioning data.

（1） Questionnaire survey

The Team sent questionnaire sheets via email to the two relevant organizations listed below.

[14] Quoted from the website of JETRO, "Country and Region Data Comparison"
[15] Quoted from the website of JETRO, "Investment Cost Comparison"
[16] Quoted from the website of JETRO, "Investment Cost Comparison"

Table 3-20: Target organizations of the questionnaire survey

Organization	Activities
Japan-Thailand Cooperative Council for G-Space Promotion	Organization led by the private sector to promote business development using precision positioning services in such fields as surveying, agricultural machinery and construction equipment
Space New Economy Creation Network (S-NET)	Support for activities of companies, individuals, organizations, etc. who are interested in creating new industries and services under the theme of “Space”

The Team received responses from 12 companies in the fields of surveying, construction, agriculture and others. They all take advantage of precise positioning data to offer their products and services in Japan. The table below presents their responses to the questionnaire survey.

Table 3-21: Outline of the responses to the questionnaire survey

Question	Response
Q1. For what kinds of tasks, or products or services do you plan to utilize precise positioning data in Thailand?	Surveying service, location-based information service, verification of the accuracy and stability of precise positioning data in low-latitude areas, autonomous driving of vehicles, ICT construction, autonomous operation of agricultural machinery, mapping
Q2. What level of accuracy do you expect?	• Millimeters (surveying) • Centimeters (ICT construction, autonomous operation of agricultural machinery, mapping) • Centimeters to 10 centimeters (autonomous driving of vehicles) • Decimeters (location-based information service)
Q3. Do you need precise positioning data to be available around the clock throughout the year?	• Daytime only (surveying, mapping) • 24/7 data availability would be safe. (ICT construction) • 24 hours a day during farming seasons (autonomous operation of agricultural machinery) • 24 hours 7 days a week (autonomous driving of vehicles)
Q4 To what extent do you allow monthly data fees to be?	• For non-real-time services, some 100 yen per hour of data or roughly 10-20,000 yen per month with unlimited download rights for the contracted data • For real-time services, a fixed rate of roughly 10-20,000 yen per month per account. • Any fees in a reasonable range are acceptable.

Question	Response
	• Same level as data distribution services in Japan or lower. But fees should be consistent with commodity prices in Thailand. • Because end users (of machinery) bear the fees, we expect the prices to be as low as possible. • Assumes that centimeter-level data are provided free of charge.

Respondent companies expressed their intentions to use precise positioning data in Thailand for surveying, i-Construction (the use of ICT-based construction machinery), autonomous operation of agricultural machinery, autonomous driving of vehicles, operation of drones, mapping, and others. The level of accuracy expected concentrated on the magnitude of centimeters. This is because the required accuracy of autonomous operation of farming or construction equipment is a few to several centimeters and also Japan's network RTK is provided with that range of accuracies. To the question on service hours, they typically replied that they basically used the data during the daytime but would be needing around-the-clock services once they start autonomous operation and location monitoring of agricultural machinery in the future. A general voice on the fees for using the data called for lower prices than Japan's distribution services In sum, the survey has confirmed that precise positioning data need to be desirably free of charge or provided at low prices for end users (users of construction and agricultural machineries), and that companies are willing to pay certain levels of fees when they use data for their tasks and business operations.

The Team also received the following views and opinions from the surveyed companies concerning the use of precise positioning data in Thailand.

- A certain mechanism needs to be put in place, which allows Japanese companies to bring observation data to Japan for processing and analysis. Otherwise, it would be difficult to prepare for technology development and practical implementation.
- We hope that an environment will be established, where precise positioning data on every part of Thailand is available.
- We would like to know as early as possible when precise positioning data in Thailand is made available, so that we can promptly plan business operations in the future.
- We hope that user-friendly infrastructure and non-infrastructure environments will be established.

As cited above, some expect that Japanese firms will be allowed to bring the data outside Thailand (to Japan) and that precise positioning data will become available in all parts of Thailand. Currently, DOL provides network RTK services which allow the precise positioning data to be received in all parts of Thailand; there may be, however, some areas where signals get partially weak. The development of the integrated CORS network is expected to solve this issue.

（2） Interview survey

On top of the above-reported questionnaire survey, the Team conducted interviews with the local corporations of Japanese firms which already operate in the country, to gather and consolidate the users' voice. The interviewees were selected from lists of firms included in JETRO's corporation surveys and partners of Pasco Corporation's local office. The table below is a list of companies the Team interviewed.

Table 3-22: List of interviewees

NO.	Company	Applications of GNSS
1	Vehicle equipment company (Thai)	Autonomous driving of small-sized electric vehicles
2	Road pavement company	GNSS-based machine control (Japan)
3	Agricultural machinery company	Unmanned agricultural machinery (the application in Thailand is still at an investigation stage.)
4	Construction equipment rental company	Machine control of construction equipment (no experience in Thailand).
5	Map producer and seller	GNSS-based driving investigation Correction of positions on satellite imagery
6	Construction company	Use of location-based information for maintenance of construction machinery
7	Construction company	Surveying and use of drones at construction sites (Japan)
8	Road construction company	Machine control at car testing center (proven)
9	Construction consulting firm	Surveying for road designs (other countries)

The above cited firms are already using GNSS in Japan mainly for construction projects and farming and construction equipment. The interviews with them highlighted that the use of precise positioning data is still at a preparatory stage in Thailand and it may take a little while to a stage where the data are actually leveraged.

According to the information the Team obtained in advance, an implementation of expensive equipment with a GNSS receiver for receiving precise positioning data is not cost-effective, as labor cost is very low in Thailand. The interview survey the Team conducted in this project saw similar responses; but at the same time, some expressed that the workforce of the country is aging, just like Japan, and is anticipated to decline in the construction work and farming sectors in the foreseeable future, which inevitably requires automation based on precise positioning data to prevent the nation's productivity from falling.

Moreover, a road construction company which has employed the unmanned machine control technology in Thailand said that they were willing to make active use of the technology, since it has been proven that unmanned machines can execute such works that usually require highly-skilled technicians. They shared that construction projects which employed machine control have proven to be good, and that the technology may become popular in the country once its benefits are recognized.

In the area of agricultural machinery, an interviewee explained that the above-described labor cost and the

small size of farm fields in the country pose obstacles to an implementation of the technology in question, and thus it is difficult to bring about immediate effects. Though Thailand 4.0 advocates an actualization of smart farming, including autonomous operation of agricultural machinery, the government currently has no concrete ideas on how to promote smart farming. An argument emphasized the importance of developing such a kind of policies that underpin the spread of the technology.

Many agreed that the use of precise positioning data is still too early in Thailand. However, the effects of the data are gradually recognized, and the data will potentially be used widely once laws are stipulated or the data demonstrates its effectiveness in actual large-scale projects. An in-vehicle device provider, which is already carrying out testing of smart EVs, stated that a wide-spread of precise positioning data needs a situation where the data are available nationwide.

3.3.3. Scientific research in relevant fields in Thailand

Universities such as Chulalongkorn University and the Asian Institute of Technology (AIT) are not the only research institutes in Thailand; the Geo-Informatics and Space Technology Development Agency (GISTDA) and Hydro Informatics Institute (HII) also perform scientific and technological research with regard to the use of precise positioning data. The following provides examples of research conducted in Thailand.

[1] A Taxi Zoning Analysis Using Large-Scale Probe Data: A Case Study for Metropolitan Bangkok (September 2016 to April 2017, AIT)

This case study was carried out as a part of an effort to develop a method to analyze the service zones of taxis using taxi probe data. The GPS log data[17] tracking 4,507 taxis between June to July 2015 were analyzed to identify the paths they took, locations they stayed at, and their working hours, which revealed characteristics of travel patterns made by the taxis. The analysis results were grouped depending on these characteristics to determine the taxi service zones. The series of analysis steps can be applied to the probe data of other taxis. Analysis on other time periods and places is also feasible.

[2] Measuring Connectivity between Thailand and Neighboring Countries with Probe Data(July 2018 to March 2019, Institute of Developing Economies)

The purpose of this study was to analyze the physical distribution between Thailand and its neighboring countries based on probe data of commercial vehicles. The probe data of commercial vehicles taken on 4th to 5th March 2018 and 12th to 13th September 201818 were examined to measure the connectivity in the country's international trade by identifying which points on the Thai borders with the neighboring nations

[17] Provided by TOYOTA TSUSHO NEXTY ELECTRONICS (THAILAND) CO., LTD.
[18] Provided by TOYOTA TSUSHO NEXTY ELECTRONICS (THAILAND) CO., LTD.

were crossed by the transporters and counting the total number of trucks passing through each of these points. The analysis results have proven to be effective as proxy data for the volume of trade with the neighboring countries. With the near real-time availability of the data in mind, this may be counted on as an alternative means to statistical data, which requires enormous amounts of time and cost to prepare.

[3] Identification and estimation health of coconut trees by using Unmanned Aerial Vehicles (UAV) data and machine learning method (September 2016 to April 2017, AIT)

This study was designed to map oil palm trees based on UAV imagery. Ko Pha Ngan, an island in the southern part of Thailand, was chosen as the site of interest. The team developed a method to extract individual oil palm trees from the UAV imagery that is accurately georeferenced using the GCPs collected through RTK positioning. The GCP-based accurate georeferencing resolves inter-image inconsistencies generated as a result of unstable attitudes of UAVs and hence makes it easy to process wide-area imagery. The Support Vector Machine-based detection rate of the canopy of oil palm trees reached an F1-measure of 64%. The next challenge to be tackled is how to resolve the deterioration of detection accuracy resulting from the health of the trees.

In addition, the Thai Traffic Foundation has conducted a comparative study between the data taken with ground-based traffic sensors and the probe data; it has found that the probe data excels more in both coverage and precision as a means to ascertain the traffic conditions.

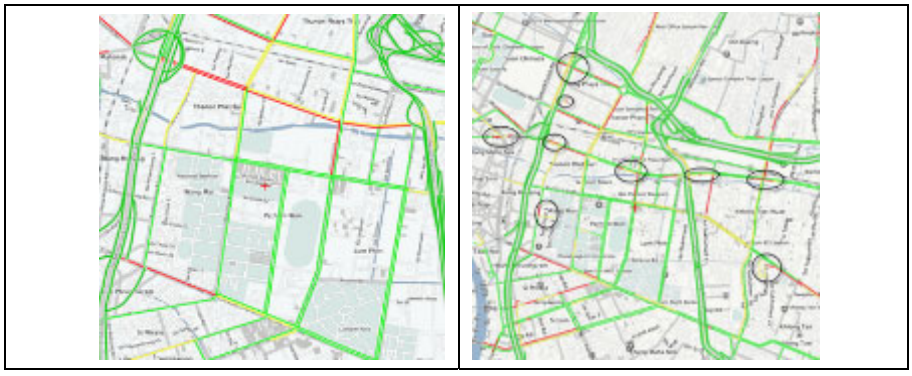


Fig. 3-16: Comparison between ground-based sensor data (left) and probe data (right)

出典：https://www.iticfoundation.org/probe-benefits

3.4.Constraints associated with the use of precise positioning services

3.4.1. Constraints associated with data distribution

（1） Legal systems associated with data distribution and collection of fees

In examining the structure and prices of data distribution after the NCDC is completed, it is most likely

useful to understand how maps are sold and fees are collected by RTSD in Thailand. The Team asked questions about the existing sales of maps in an interview with RTSD. In this subsection, the Team first addresses how maps are sold in Japan, and then what RTSD does to sell maps. The Team also interviewed GISTDA (public organization) and DOL in charge of fee collection from clients. Thus, the Team also addresses the possibilities for a public organization to collect fees and for government agencies to directly collect fees with taking example of DOL that collects handling charges and other fees.

(a) Status of map sales in Japan

Fig. 3-17 illustrates the mechanism of how Japan's domestic maps (issued by the GSI) are sold.

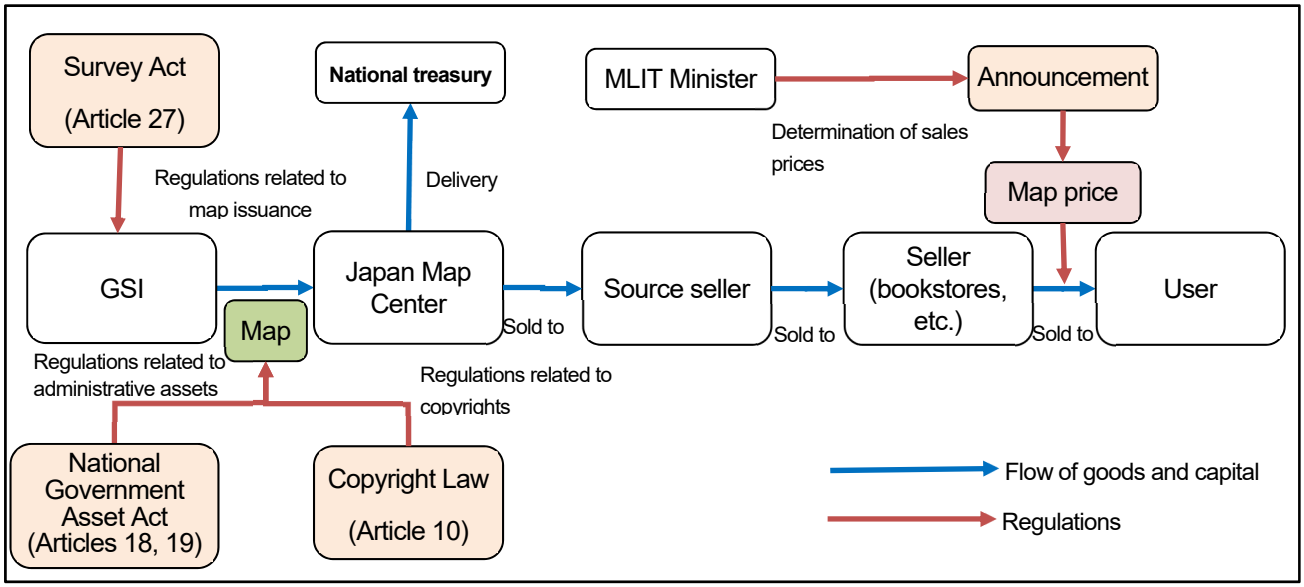


Fig. 3-17: Current relationship between the sale of maps and the legal framework in Japan

Source: The Team

In Japan, the MLIT is responsible for issuing maps according to Article27.2 of the Survey Act, as quoted below.

Table 3-23: Regulation concerning the publication of maps based on the Survey Act

Article 27.2 Of survey results of Basic Surveys, the Minister of Land, Infrastructure, Transport and Tourism shall publish maps and other results that should be made available for use by the general public, and he/she shall take measures to keep the information that constitutes such results by means of electromagnetic methods (methods that use electronic information processing systems or other methods that use information and communication technologies, hereinafter the same) stipulated in the Land, Infrastructure, Transport and Tourism Ministry Ordinance, whereby a number of unspecified people can obtain such information.

Source: Survey Act (Law No. 188 of 1949)

This provision requires the GSI to publicize maps to the general public; in the meantime, Article 10 of the Copyright Law and Articles 18 and 19 of the National Government Asset Act govern the sales of maps. The

Copyright Law protects the maps published by the GSI as its copyrighted works, and the copyrights thereof belong to the government as the maps being the government's assets.

Table 3-24: Regulation concerning maps based on the Copyright Law

Section 1 Works Article 10 (1) (Examples of works) The following gives an illustrative example of what is meant, on the whole, by the term "works" as it is used in this Act: (snip) (vi)maps and other diagrammatic works of an academic nature, such as plans, charts, and models (snip)

Source: Copyright Law (Law No. 48 of 6 May 1970)

In addition to the above, Article 18.6 of the National Government Asset Act, which permits profits from administrative properties, and Article 23, a provision concerning lease fees, on the basis of Article 19 applied mutatis mutandis allow the GSI to collect fees from map selling. The prices of maps are determined and announced by the Minister of MLIT. A part of the profits from map selling is deposited to the national treasury by the Japan Map Center (JMC).

Table 3-25: Regulation concerning the collection of fees from government assets based on the National Government Asset Act

Section 2 Government Assets Article 18 (Restrictions concerning disposal, etc.) Government assets may not be lent, exchanged, sold, transferred, entrusted or invested, or established a private right on. (snip) 18.6 A government asset may be used or make profits as long as such an act does not infringe its use or purpose. (snip) Article 19 The provisions of Articles 21 to 25 (excepting Articles 21 and 23 if the surface right or easement is to be established pursuant to the provision of Article 18.2.5 or 6, or Article 21.1.2 if the use or profit-making is permitted pursuant to the provision of Article 18.6) shall be applied mutatis mutandis to cases involving leasing according to the provisions of Articles 18.2.1 to 4; setting of the surface right according to Article 18.2.5 or of the easement according to Article 18.2.6; leasing pursuant to Article 18.3 (including cases where the same applies mutatis mutandis in Article 18.4); or the use of or profit-making from government assets according to permission on the basis of Article 18.6. Section 3 Ordinary Assets Article 23 (Lease fees) 1. Lease fees for ordinary assets shall be paid regularly on a yearly basis, provided that this provision does not prevent an advance payment worth several years. In the case of the preceding paragraph, if the borrower expresses a will to delegate the withdrawal of deposits or savings and the payment of lease fees with the money paid out to the financial institution at which the borrower has a deposit or savings account, the head of each ministry holding jurisdiction over the asset may approve such a request only when the payment is made for certain and at the same time approving the request is deemed to make more sense in terms of collecting lease fees.

Source: National Government Asset Act (Law No. 73 of 1948)

Nevertheless, CORS data are not acknowledged as "works" as they are simply data in nature, and hence not as government assets under the National Government Asset Act. With the absence of a legal basis for

collecting fees from the distribution of CORS data, the GSI, unlike the JMC, the paper map distributor, delegated the free distribution of the data to the JAS.

(b) Existing map sales model at RTSD

Fig. 3-18 illustrates the mechanism in which maps (published by RTSD) are sold in Thailand.

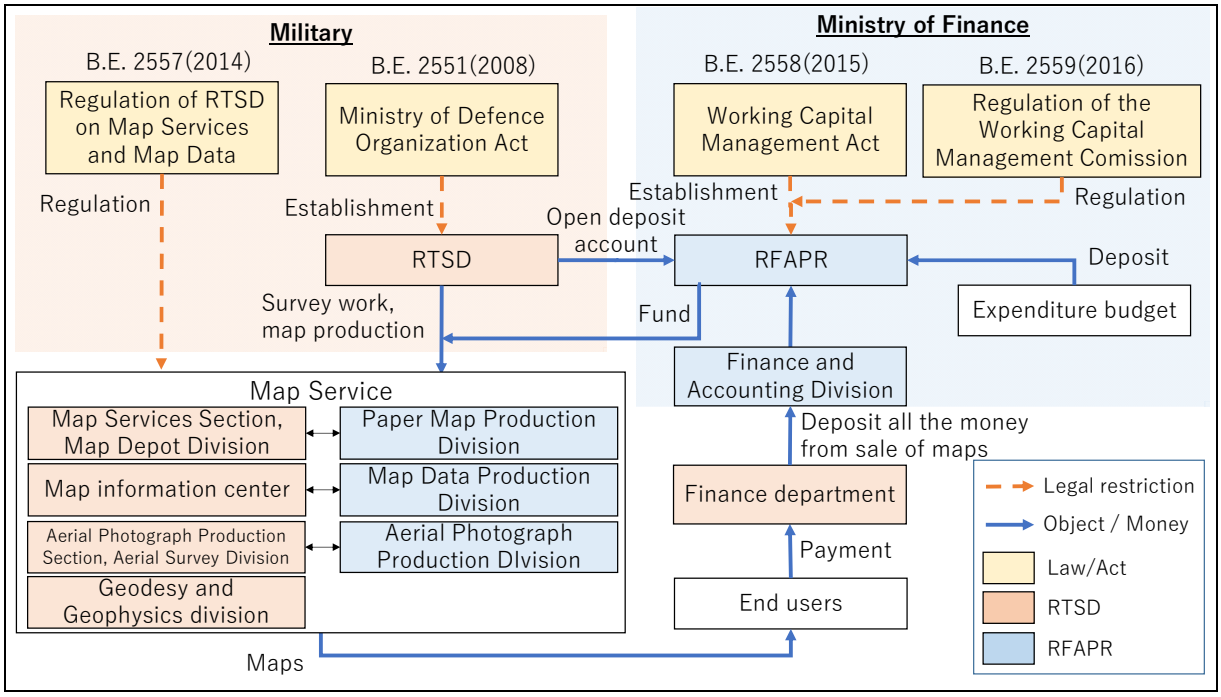


Fig. 3-18: Relationship between the map sales mechanism and applicable regulations in Thailand

Source: Created by the Team based on interviews with RTSD.

In Thailand, RTSD, under the supervision of the military, is not authorized to provide services directly to private-sector organizations. Thus, RTSD funded and founded a Revolving Fund Aerial Photograph Reproduction (RFAPR) under the Ministry of Finance, and sell maps through the fund. The RFAPR was originally established in 1992 as a revolving fund for developing aerial photography. It is now managed under the supervision of the Ministry of Finance in accordance with the Working Capital Management Act (B.E. 2558(2015)). Today, the Fund is in charge of all maps other than aerial photos as an organization completely independent of RTSD. The Regulation of the Working Capital Management Commission for Producing Aerial Photograph on Working Capital to Produce Aerial Photograph (B.E. 2559(2016)) (hereafter referred to as the "RFAPR Regulation") was developed on the basis of the Working Capital Management Act. It governs the capital management concerning the map sales by RFAPR. The Fund is designed to provide government bodies, state-owned enterprises, educational institutions and private companies with map services resulting from surveying and be managed with the compensations gained for the services provided. They cannot, however, earn profits from the services. An organizational chart of RFAPR is given in Fig. 3-19.

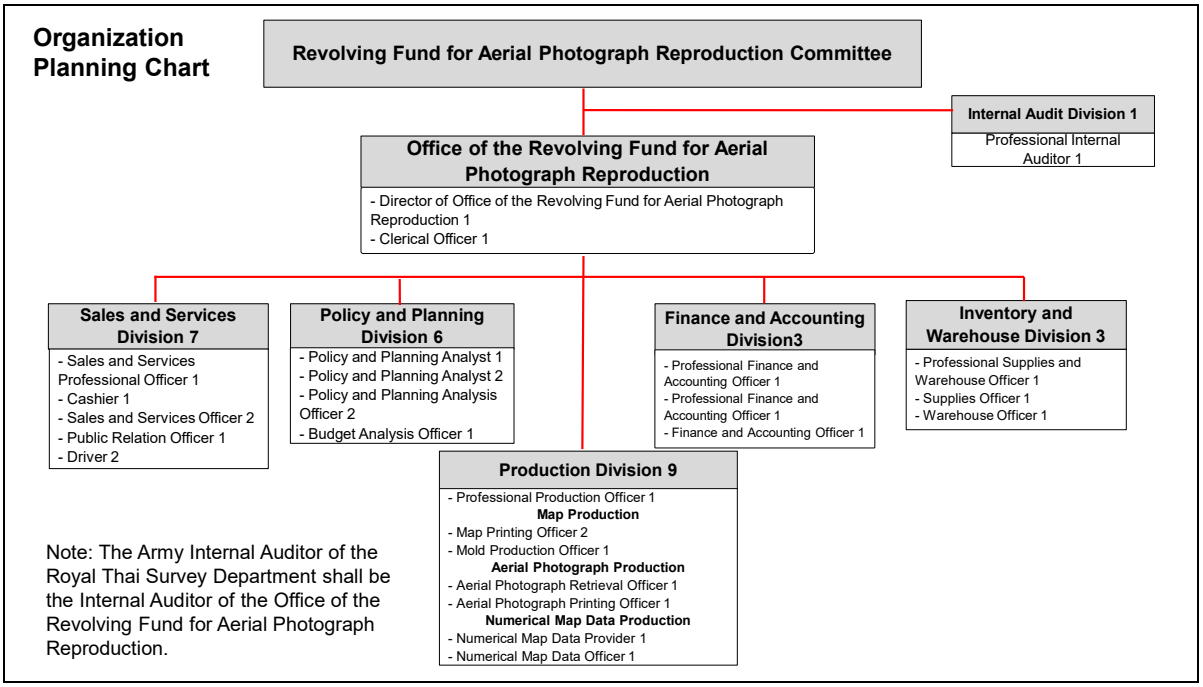


Fig. 3-19: Organizational chart of RFAPR

Source: RFAPR Website translated by the Team

The RFAPR is positioned as an entity independent of RTSD. The board of RFAPR is headed by the Director General of RTSD. Sections and divisions of RTSD, as shown in Table 3-26, provide the six different map services in the position as the Production Division of RFAPR.

Table 3-26: Types of map services and responsible organizations at RTSD

No	Type of maps	Organizations in charge
1	Paper map	Map Services Section, Map Depot Division
2	Digital map	Map information center
3	Control Point	Geodesy and Geophysics division
4	Aerial Photo	Aerial Photograph Production Section, Aerial Survey Division
5	Geographic data	Geography Division
6	Orthographic data	Mapping Division

Source: Created based on interviews with RTSD and control documents of RTSD.

The board of RFAPR consists of eight board members, as listed in the table below. By having members from outside RTSD, they seemingly intend to secure as much transparency as possible in the capital management in conjunction with map sales. The eligibility of board members is stipulated by Chapter 3 of the RFAPR Regulation.

Table 3-27: List of affiliations of the members of the RFAPR Board

No.	Affiliation
1	Chairman of the board, Director General of RTSD
2	Deputy Director General, RTSD
3	Representative of the Budget Bureau
4	Representative of the Ministry of Finance
5	Director of Legal
6	Director of Qualified Accounting
7	Director of Qualified Finance
8	Technical officer of RTSD

Source: from RFAPR Website (rfapr.com)(as of March 2019)

The map sales of RTSD is implemented on the basis of the Regulation of the Royal Thai Survey Department On Map Services and Map Data (B.E.2557(2014))(hereafter referred to as the RTSD Regulation). Article 6 thereof strictly prohibits selling any map that includes the vicinity of the national borders and of the Royal Palace and military facilities. It is only possible with special permits. Fig. 3-20 shows the mechanism of map selling and fee collection. The collection and administration of fees at RFAPR are dictated by the RFAPR Regulation.

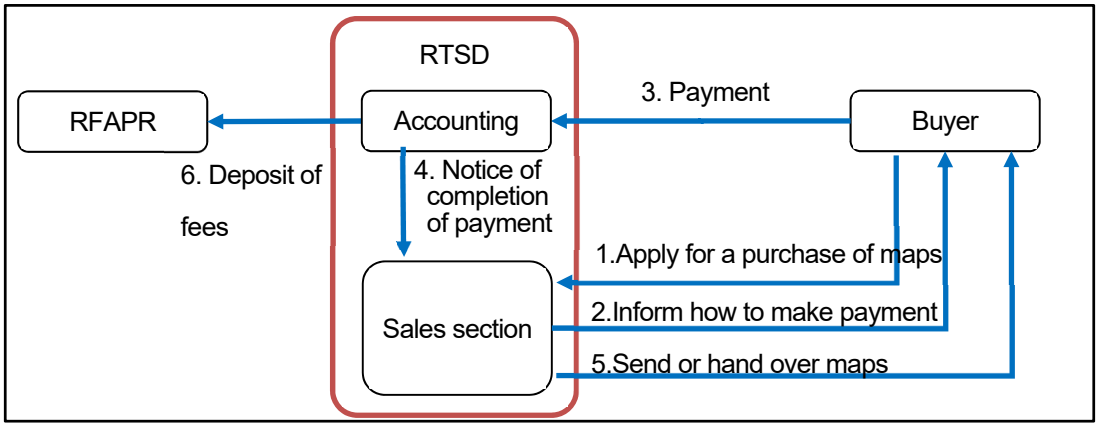


Fig. 3-20: Mechanism of map sales and collection of fees by RFAPR

Source: Created by the Team based on interviews with RTSD.

The map purchase and approval processes are dictated by Article 12 of the RTSD Regulation. Fig. 3-21 illustrates the purchase and approval processes.

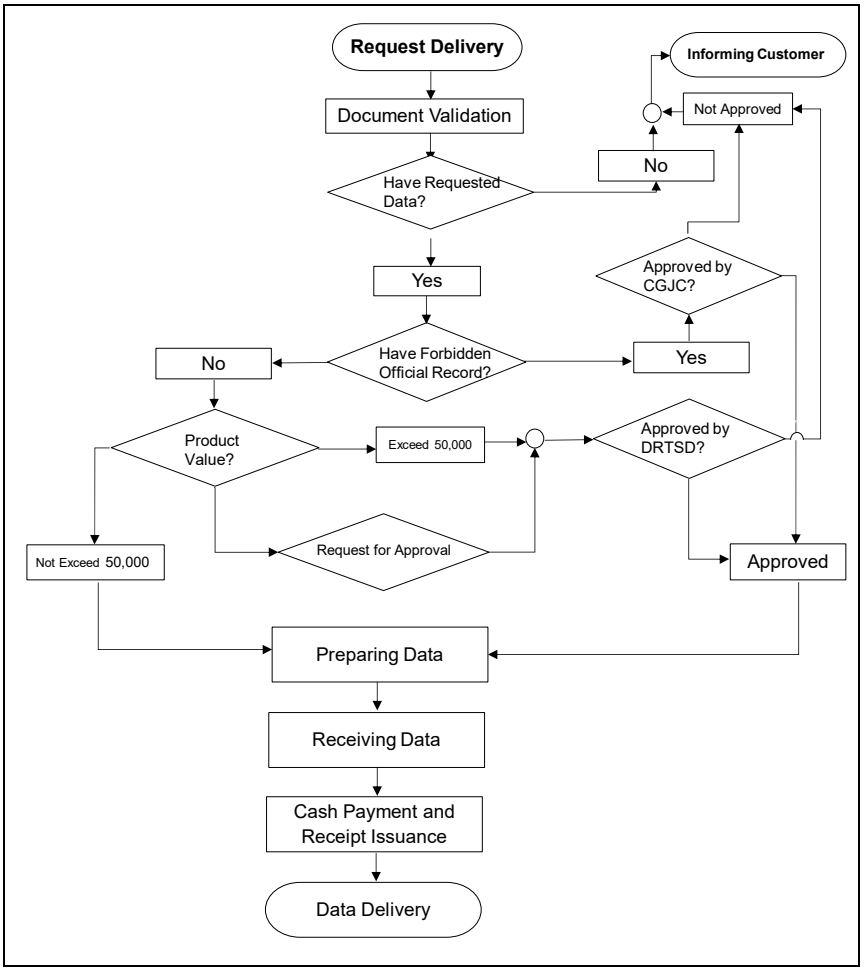


Fig. 3-21: Map provision process by RTSD's Map Information Center

Source: Diagram on RFAPR Website translated by the Team

To purchase a map, one has to fill in an application form specific to the section in charge of selling the kind of map he or she is buying. If the application is approved, the purchaser has to pay the bill in the specified way within one month from the approval. When making the payment, the purchaser has to show his or her ID card or passport as a Thai citizen. If the payment is not made, RTSD may cancel the order in question. According to Article 13 of the RTSD Regulation, the fee paid by the purchaser is first collected by the Financial Division of RTSD, and then the Division notifies the responsible section of the completion of the payment by the purchaser. The selling section checks the consistency between the name of the purchaser on the application form and the name in the payment information. Only then they will sell/send the map to the purchaser. In some cases, as a matter of fact, the names on the application form and the payment information do not match, hindering the process. According to Chapter 5 of the RFAPR Regulation, the proceeds from map selling will eventually be transferred from RTSD to RFAPR. Being a revolving fund established for the purpose of map sales, RFAPR cannot use these proceeds for other purposes than selling maps. This means that RTSD cannot directly use the money it received in return for maps sold instead of depositing it to RFAPR. The proceeds

from map selling must be transferred to RFAPR within three working days from the receipt of the money. This mechanism is designed perhaps to make it difficult to repurpose the money coming from civilians to military funds and also to ensure that the proceeds from map sales are spent for the sustainment of next services.

According to Chapter 6 of the RFAPR Regulation, on the other hand, if RTSD develops a budget for the next term and then and obtains approval of the board of RFAPR and Ministry of Finance within sixty days before the beginning of a fiscal year of every year, the fund can be allocated to an expansion or renewal of the existing series of maps available or to other map-related projects. The Director General of RTSD can spend the budget at his or her discretion within the scope of the next year's budget approved by the Ministry of Finance. According to Chapter 9 of the RFAPR Regulation, all records of transactions and other processes at RFAPR must be linked with the Government Fiscal Management Information System (GFMIS) of the Ministry of Finance; within 60 days of the start of the new fiscal year, the data of the previous year have to be audited by the Audit Council.

Fig. 3-22 below depicts the process of how map sales prices are determined: the Supreme Commander sets the sales prices of maps, RTSD notifies RFAPR of the determined prices, then with the final approval by RFAPR the prices are fixed (Article 8 of the RTSD Regulation). In fact, however, one step prior to the price setting by the Commander, the sections of RTSD responsible for map sales plan and report to the Commander revised map prices.

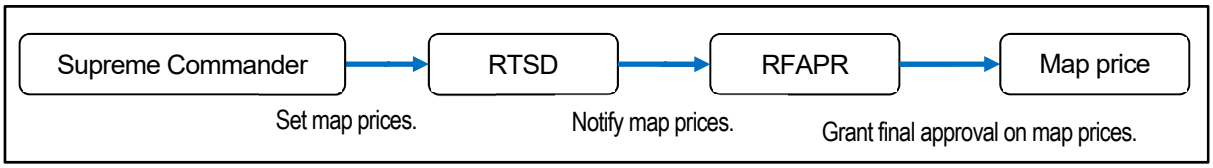


Fig. 3-22: Map price approval process at RTSD

Source: Created by the Team based on interviews with RTSD

The price setting of maps is two-fold: prices for government agencies and those for the private sector. The former is relatively lower, and certain maps are not sold to private-sector organizations. Additionally, maps may be provided free of charge to the Office of Prime Minister and agencies that carry out urgent missions, with approval of the Director General of RTSD, as far as a certain set of conditions (e.g., the value of one order does not exceed 20,000 Baht) are met (Article 10.1 of the RTSD Regulation.) Which band Thailand uses for 5G communications was undecided at the time of this investigation. Nevertheless, NBTC's Radio Wave Master Plan 2016-2020 indicates that the 30-57 GHz band is reserved for mobile services. It may likely be used for 5G communications in addition to the band currently in use (the demonstrative experiment uses the 26 GHz for the sake of the devices used, but the band to be used in actual operation is not yet known) . Table 3-28 provides a list of map product prices currently sold by the Map Information Center of RTSD as a

reference.

Table 3-28: List of sales prices of maps published by RTSD's Map Information Center

No.	Map product	Unit price	Price for the government (Baht)	Price for the private sector (Baht)
1	Map, scale 1:50,000, series L 7018 (series L 7018 S for the private sector)			
1.1	Raster Map, including data storage	Sheet	100	200
1.2	Vector Map, not including data storage			
	- All layers (14 layers)	Sheet	1,000	
	- All layers (13 layers)	Sheet		1,400
	- Separate layer sale	Layer	100	150
1.3	Digital Elevation Model : DEM	Sheet	2,500	3,000
1.4	Digital Terrain Elevation Model (DTED-II) *For military only	Sheet	10,000	
2	Map, scale 1:250,000, series 1501 G, A and other scale			
	- Raster Map, including data storage	Sheet	400	
	Map, scale 1:250,000, series 1501 S and other scale			
	- Raster Map, including data storage	Sheet		600
3	Digital Aerial Photo 9 X 9 inch	Photo	300	400
4	Digital Orthophoto 7.5 X 7.5 lipda	-	To be consulted	To be consulted
5	Digital Colour Orthophoto	km2	60	70
6	Digital Mosaic 15 X 15 lipda	-	To be consulted	To be consulted
7	Map, scale 1:20,000 Bangkok and suberb, series 9013 (series 9013 S for the private sector)			
	- Vector Map (total 20 sheets), 9 layers (year 1996)	Sheet	1,000	
	- Vector Map (total 20 sheets), 8 layers (year 1996)	Sheet		1,000
	Not sell separat layer			
8	Price for printing map on coated white paper 90 gram			
	- size A0 (width 84 cm X length 118.88 cm)	Sheet	950	1,090
	- size A1 (width 59 cm X length 84.1 cm)	Sheet	330	470
	- size A2 (width 42 cm X length 59.4 cm)	Sheet	190	330
	- size A3 (width 29.7 cm X length 42 cm)	Sheet	120	260

No.	Map product	Unit price	Price for the government (Baht)	Price for the private sector (Baht)
9	Price for printing map on coated white paper 120 gram			
	- size A0 (width 84 cm X length 118.88 cm)	Sheet	1,050	1,200
	- size A1 (width 59 cm X length 84.1 cm)	Sheet	400	540
	- size A2 (width 42 cm X length 59.4 cm)	Sheet	240	380
	- size A3 (width 29.7 cm X length 42 cm)	Sheet	150	300
	- size B0 (width 100 cm X length 141.4 cm)	Sheet	1,500	1,640
10	Price for printing map on coated paper (spacial water resistance) 180 gram			
	- size A0 (width 84 cm X length 118.88 cm)	Sheet	1,360	1,500
	- size A1 (width 59 cm X length 84.1 cm)	Sheet	610	760
	- size A2 (width 42 cm X length 59.4 cm)	Sheet	390	530
	- size A3 (width 29.7 cm X length 42 cm)	Sheet	260	410
11	Price for coating map with Glossy Laminate film 180 gram			
	- size A0 (width 84 cm X length 118.88 cm)	Sheet	190	330
	- size A1 (width 59 cm X length 84.1 cm)	Sheet	150	290
	- size A2 (width 42 cm X length 59.4 cm)	Sheet	110	260
	- size A3 (width 29.7 cm X length 42 cm)	Sheet	90	240
	- size B0 (width 100 cm X length 141.4 cm)	Sheet	220	370
12	Price for printing map by Oce printer, paper size A0, 120 gram	Sheet	1,020	1,220
13	Price for printing map by Oce printer, paper size A1, 120 gram	Sheet	510	610
14	Price for printing map by Oce printer, map paper, size A1, 120 gram	Sheet	540	650

Source: Created by the Team based on the document (price list approved as of March 2019) provided by RTSD.

Each section responsible for selling maps is entitled to make a deal at its own discretion when an estimated price of an order by a government or private entity does not exceed 50,000 Baht. When it does, they need to obtain approval of the Director General of RTSD (Article 10 of the RTSD Regulation).

Maps are sold in various ways as shown in Fig. 3-23 below: one can apply directly to the section in charge via the web (rfapr.com), email, postal mail, phone or the like, whereas some large bookstores in the countryside deal with a map product family for the private sector called S Series 1501 (No. 2 of Table 3-28).

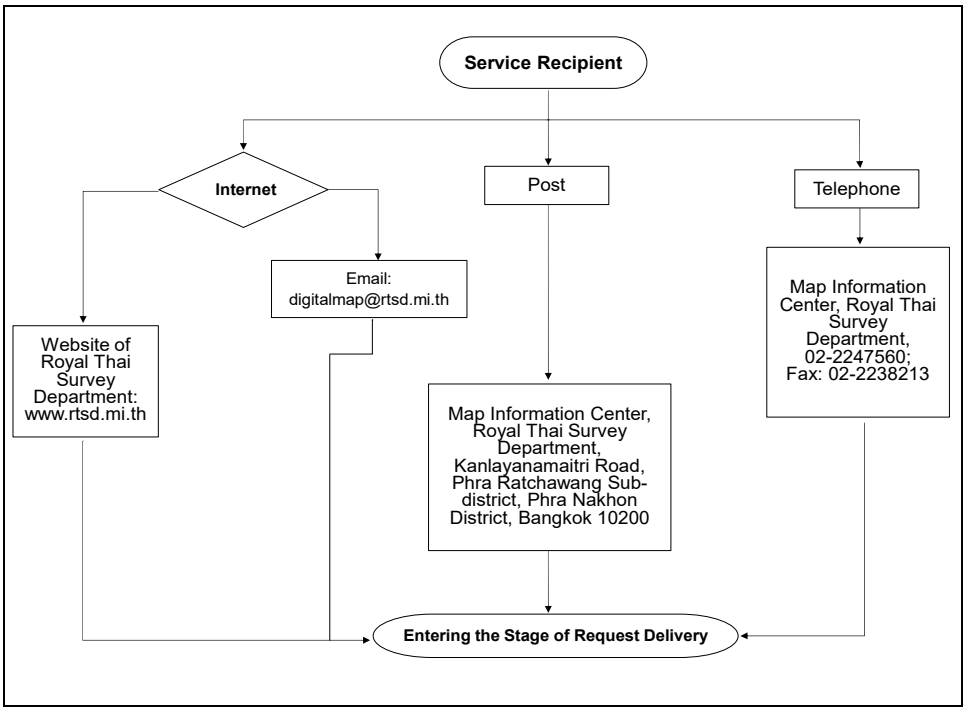


Fig. 3-23: Map sales channel of RTSD's Map Information Center

Source: Diagram on RFAPR Website translated by the Team

After the map sales process is completed at the map selling section, the purchaser can either visit the counter to receive the product or have it delivered by EMS. The EMS shipping costs are also prefixed, as shown in Table 3-29.

Table 3-29: List of EMS courier prices for maps sold by RTSD

Weight	Shipping cost (Baht)	Weight	Shipping cost (Baht)	Weight	Shipping cost (Baht)
– 20g	27	500g – 1000g	62	2500g – 3000g	122
20g – 100g	32	1000g - 1500g	77	3000g – 3500g	142
100g – 250g	37	1500g – 2000g	92	3500g – 4000g	162
250g – 500g	47	2000g – 2500g	107	4000g – 4500g	182

Source: Created by the Team based on RTSD map sales website (rfapr.com).

As Figure 3-24 illustrates, there are five options for the payment method: cash, money order, bank transfer, check, and credit card. A RTSD official commented that Thailand has no law controlling credit card and mobile payments. RTSD accepts credit cards, but users prefer cash payment and tend to avoid payments by card. Even so, RTSD has an intention to accept a variety of payment methods to improve the convenience for customers, so they are likely to start accepting mobile payment if they can secure budget for introduction and development of a mobile payment system.

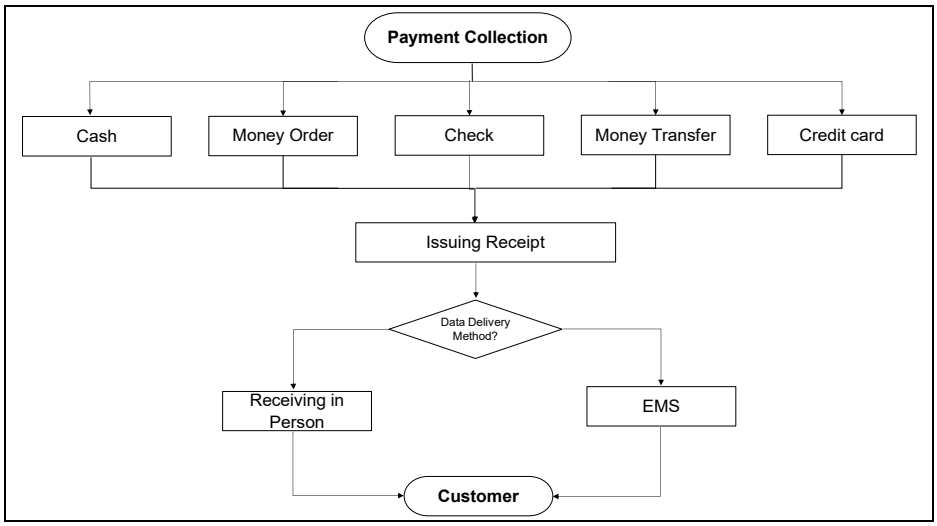


Fig. 3-24: Payment process at RTSD's Map Information Center

Source: Based on the Diagram on RFAPR Website, the information interviewed by the Team added

In the meantime, Article 29 of the RFAPR Regulation stipulates that the incomes earned as a result of disposing of, for example, superannuated equipment and deteriorated maps in the process of sales activity may be withdrawn from RFAPR's fund account and used. Such a transaction requires, however, the approval of the Director General of RTSD when the amount of money is up to 100,000 Baht, that of the Supreme Commander when up to 200,000 Baht, and that of the Ministry of Finance when exceeding 200,000 Baht.

The Team found out that another relevant law, Article 4 of the Copyright Act B.E.2537 (1994), acknowledges the maps sold by RTSD as copyrighted works. The Team asked if the provision in Article 7 of the Copyright Act, which says, "Articles and facts of current events that do not belong to the field of literary arts, academia or fine arts but have the nature as information only," applies to CORS data. The counterpart replied that they did not know at the point in time whether CORS data can be acknowledged as copyrighted works.

Table 3-30: Regulations of the Thai Copyright Act

Article 4 (6) Graphic works refer to maps, schemas, sketches, and tridimensional works related to geography, topography or science. Article 7 For the purpose of this Act, any works applicable to any of the followings are not considered as copyrighted works. Articles and facts of current events that do not belong to the field of literary arts, academia or fine arts but have the nature as information only.

Source: Copyright Act - B.E 2537(1994) translated by JETRO Thailand Office

The Team also asked if maps are considered as government assets, as in Japan, under a law equivalent to Japan's National Government Asset Act and if they have any regulations pertaining to the publication of maps, etc., under a law equivalent to Japan's Survey Act. The counterparts said that there were no such laws.

(c) Regulations to be applied when a public agency collects fees

Public organizations are established based on the Public Organization Act (B.E.2542 (1999)) in Thailand. GISTDA and HII are both such public organizations. A royal degree needs to be stipulated for every public agency. "Royal Decree Establishment of the Hydro and Agro Informatics Institute (Public Organization) B.E. 2551 (2008) is in effect for HII, and "Royal Decree Establishment of Geo-Informatics and Space Technology Development Agency (Public Organization)" "first version: B.E.2543 (2000) and second version: B.E. 2562 (2019)" are in effect for GISTDA. Based chiefly on the findings of the interview survey with GISTDA, this subsection outlines legal regulations to be applied when a public agency collects fees in exchange for their services to be provided.

Article 5 of the Public Organization Act, quoted below, states that public organizations "must not be those with main objectives in profit-seeking" through the services they provide.

Table 3-31: Regulation of Article 5 of the Public Organization Act

Section 5 The Government, when…or any other operation for public benefit, in any case they must not be those with main objectives in profit-seeking.

Source: Public Organization Act B.E.2542(1999)

Article 12 thereof also states that the revenues that public organizations make may include "fees, charges, reward, service charge or income from its operations" and "profits of money or income generated from its assets."

Table 3-32: Provision of Article 12 of the Public Organization Act

Chapter II FUND, INCOME AND ASSETS Section 12. Fund and assets for operation of public organization shall include: (1). money or assets being transferred to it; (2). money being paid for by the Government as initial fund; (3). general subsidy being allocated annually by the Government as deemed appropriate; (4). subsidy from the private sector or other agencies, including from foreign countries or international organizations, and money or assets being donated to it; (5). fees, charges, reward, service charge or income from its operation; (6). profits of money or income generated from assets of public organization.

Source: Public Organization Act B.E.2542(1999)

Article 13 thereof stipulates that "public organizations shall have the power to collect fees, charges, reward, or service charge in its operations, whereas Article 14 thereof defines that "all income of public organizations are not to be sent to the Ministry of Finance."

Table 3-33: Provisions of Articles 13 and 14 of the Public Organization Act

Section 13. Under its objectives, the public organization shall have the power to collect fees, charges, reward, or service charge in its operation as specified in the Royal Decree establishing it. Section 14. All income of public organization are not to be sent to the Ministry of Finance under the law on treasury reserves and the law on budget process.

Source : Public Organization Act B.E.2542(1999)

In view of the above-cited provisions of the Public Organization Act, Thailand's public organization may collect fees in direct return for the services it provides and manage the collected money as its own revenue. GISTDA sources say that it may make profits from fee collection, if not an excessively large amount. A public organization may use revenue from fee collection at its discretion within the scope specified by the relevant royal decree. For GISTDA, Section 7 of the relevant royal decree stipulates the scope of its services.

Table 3-34: Provisions concerning the scope of services of a public organization under the royal decree (GISTDA)

Section 7 The Agency shall have the objects as follows: (1). To develop space technology and geo-informatics applications, as borderless knowledge, to be beneficial to the general public; (2). To study and analyse the satellite data base and to serve as a centre for satellite based natural resources data; (3). To provide data services relating to space technology and geo-informatics and other relevant services; (4). To provide consultation and personnel development services in satellite remote sensing and geo-informatics; (5). To study, research, develop and to carry out other activities relating to, or incidental to, space technology, including to develop small satellites for natural resources survey; (6). To be the core organization responsible for setting up a common standard for remote sensing and geo-informatics systems.

Source: Royal Decree Establishment of Geo-Informatics and Space Technology Development Agency (Public Organization) B.E.2543 (2000)

Section 8 stipulated the power necessary for GISTDA to engage in activities set forth in Section 7. Section 8 stipulates, for example, that it is authorized to borrow money from financial institutions, collect fees, and participate in a joint venture with other organizations.

Table 3-35: Provisions concerning the power of the public organization to engage in its activities (GISTDA)

Section 8 In order to achieve the objects prescribed in Section 7, the Agency shall also have the power and duty to engage in the following activities; (1). To own, possess, or hold any property rights; (2). To create or enter into any jurist and relating to property; (3). To participate in a joint venture with other juristic person relating to the objects of the Agency; (4). To borrow money for the benefit of the operation under the objects; (5). To accept fees, dures, consideration or service fees in connection with its operation; (6). To arrange t have and provide grants in support of the operation of the Agency; (7). To coordinate and set up networks with national and international agencies or organisations on the exchange programme or technical assistance relating to the objects of the Agency; (8). To act as a secretarist of the commisiions having the authority dealing with space technology and geo-informatics; (9). To perform any act necessary for, or incidental to, the achievement of the objects of the Agency; To participate in a joint venture under (3) and to borrow money under (4) shall be in accordance with the criteria prescribed by the Council of Ministers.

Source: Royal Decree Establishment of Geo-Informatics and Space Technology Development Agency (Public Organization) B.E.2543 (2000)

In relation to Sections 7 and 8, the second version of the decree provides some amendments to allow GISTDA to hold the shares of and to partner with geo-informatic or space technology business of their juristic person. This implies that the royal decree can be revised if the necessity arises.

Table 3-36: Amendments under the second version of Royal Decree Establishment to provisions concerning the activities and power of the public organization (GISTDA)

Section 7 To add the following as (3/1) of Paragraph one of Section 8 of the Royal Decree on Establishment of Geo-Informatics and Space technology Development Agency (Public Organization) B.E. 2543 (2000). “(3/1) To hold the shares or to partner in geo-informatics or space technology business of the juristic person and the main objective of such shares holding or partnering shall not for the sake of profits.” Section 8 To cancel the provision in Paragraph two of Section 8 of the Royal Decree on Establishment of Geo-Informatics and Space technology Development Agency (Public Organization) B.E. 2543 (2000) and to be superseded by the following provision: “Join venture according to (3), shares holding or partnering according to (3/1) and loaning money according to (4) shall be in accordance with the principles stipulated by the Cabinet.”

Source: Royal Decree Establishment of Geo-Informatics and Space Technology Development Agency (Public Organization) B.E. 2562 (2019)

translated by the Team

Public organizations are required to supervise their business and operation with their respective Board of Directors. They need to obtain the approval from their Board when setting service fees. As for GISTDA, Section 19 of the relevant royal decree stipulates the role of the Board of Directors including the setting of service fees. The following table provides part of Article 19 related to service fees.

Table 3-37: Provision concerning fee collection under Section 19 of the Royal Decree on Establishment of GISTDA

Section 19. The Board has an authority to supervise the general business and the operations of the Agency to be in accordance with the designated objectives. Such authority shall govern: (omitted) (4) Giving consent for designation of fees, maintenance fees, compensation and service charges for the business operation of the Agency. (omitted)

Source: Royal Decree Establishment of Geo-Informatics and Space Technology Development Agency (Public Organization) B.E. 2562 (2019) translated by the Team

GISTDA sources also say that a public organization may provide services by using assets of other organization and share fee revenue with the organization if it concludes an individual MoU with the organization. There is also a possibility that a public organization launches a joint venture (JV) project with other organization to provide services. However, if the business scale of a JV project exceeds 1 million Baht, the project needs to be supervised by the Office of the National Economic and Social Development Board (NESDB).

With these factors taken into account, compared to revolving funds that are subject to the strict supervision of the Ministry of Finance, a public organization seems to relatively freely collect and use service fees, though it takes time and effort to have an individual decree enacted.

(d) Regulations to be applied when a governmental organization directly collect fees

The Team interviewed DOL concerning the case where a governmental organization directly collects service fees. This subjection outlines possible restrictions if DOL collects service fees.

DOL collects fees, charges, and taxes in relation to land registration under Thai Land law. They accept cash, check, and credit card etc. However, all the fee revenue needs to be sent to the national treasury, so DOL cannot use fee revenue for the provision of its services. DOL distributes CORS data to the private sector experimentally free of charge. When the Team asked a DOL official if DOL intends to start charging users for the data in the future, it replied that it had no intension to do so. A possible reason is that there is no guarantee that DOL will gain more budget even if the relevant laws are revised or a mechanism of fee collection is established. It is likely that other governmental organizations would face the same difficulty as

DOL, so it will be reasonable, like RTSD, to indirectly collect fees via a revolving fund or other method when a governmental organization wishes to collect its own service fees.

(e) Legal constraints associated with the distribution of data in Thailand

With respect to the distribution of RTK services in Thailand, it was approved that RTSD would manage the NCDC when NCDC Management WG held a meeting in July 2019. While RTSD operates and manages the NCDC, NCDC Management WG affiliated to the GNSS Subcommittee of the National Geo-Informatics Board will directly supervise the NCDC, which will thus directly report on its activities to NCDC Management WG.

The NCDC will distribute data to users free of charge for the coming six months and obtain the approval for fee data distribution services every six months thereafter. RTSD has an intention that the NCDC will be allowed to collect fees directly from the private sector when the number of users increases and any private businesses also start data distribution services.

If the NCDC is authorized to collect fees of any kind from the private sector in the future, the map sales mechanism of RTSD described earlier may serve as a model because RTSD will manage the NCDC.

In the light of the existing map sales model, it is not easy for RTSD (NCDC) to collect fees and directly interact with customers. Accordingly, they would likely have to set up an organization, such as a revolving fund under the Ministry of Finance, similar to RFAPR, in accordance with the Working Capital Management Act, as an agency to collect fees and perform actual work associated with the distribution of RTK services on behalf of the Department. In this case, a regulation governing the management of the revolving fund will be needed just like the RFAPR Regulation. At the same time, the RTSD Regulation should perhaps be revised within the Department where the actual work is expected to be carried out. Incidentally, the RTSD was established based on the Ministry of Defense Organization Act, B.E. 2551(2008), which does not, however, contain any provision directly applicable to the tasks of RTSD.

Other than the use of a revolving fund, another possible option is to designate the NCDC as a public organization to allow it to manage services. In the case of GISTDA, it takes time and effort to have an individual royal decree stimulated in accordance with the Public Organization Act, but GISTDA is not required to send collected fees to the Ministry of Finance, which is a great advantage. Moreover, unlike a revolving fund, it is possible to make profits, if not excessively. So long as the decree is stimulated appropriately, a public organization can use its revenue relatively freely at its own discretion and flexibly share it with other organizations if it concludes a MoU with them. It is possible to establish a new public organization responsible for data distribution, take advantage of an existing public organization, or launch a joint venture with multiple other organizations for data distribution business.

A revolving fund is effective because the NCDC will be able to utilize its revenue for maintenance of its data distribution services so long as it is managed in compliance with the Working Capital Management Law

that prevents profits of the distribution services from being easily repurposed to other objectives. On the other hand, a public organization has an advantage in that it is not required to send the revenue from the distribution services to the national treasury and can manage its operations relatively freely at its own discretion. As for disadvantages, with a revolving fund, the managing agency is required to send its revenue to the national treasury, whereas a relevant royal decree is needed to designate the managing agency as a public organization. Either way, both options seem effective as they allow the governmental agency to directly collect fees from users.

(f) Summary of laws and regulations investigated in the aspect of data distribution and fee collection

Table 3-38 below summarizes the findings of the Team on the laws concerning collecting fees and developing services associated with data distribution and map sales described in this section.

Table 3-38: List of laws and regulations studied in relation to data distribution and fee collection

No.	Name of law in English	Enacted in		Language			Outline
		B.E.	A.D.	Thai	En	Jp	
1	Ministry of Defense Organization Act	2551	2008	A	C	—	This law provides the basis for the establishment of RTSD. It does not define specific tasks of the Department.
2	Working Capital Management Act	2558	2015	A	C	—	This law provides the basis for establishing a revolving fund under the jurisdiction of the Ministry of Finance.
3	Regulation of the Working Capital Management Commission for Producing Aerial Photograph on Working Capital to Produce Aerial Photograph	2559	2016	A	C	—	This regulation stipulates how RFARP, in particular, must be managed and operated.
4	Regulation of the Royal Thai Survey Department On Map Services and Map Data	2557	2014	A	C	—	This regulation (manual) governs the management of map services within RTSD.
5	Electronic Transaction Act	2544	2001	A	B	B	This law regulates electronic transactions. But it does not regulate means of payment settlements by governmental organizations.
6	Copyright Act	2537	1994	A	B	B	This law protects the maps and map data published by RTSD. It is uncertain if the law also protects RTK data.
7	Public Organization Act	2542	1999	A	B	—	This law provides the basis for establishing a public organization. It also defines service fees.
8	Royal Decree Establishment of the Hydro Informatics Institute (Public Organization)	2562	2019	A	B	—	This law provides the basis specifically for HII, among other public organizations.
9	Royal Decree Establishment of Geo-Informatics and Space Technology Development Agency (Public Organization)	2543	2000	A	B	—	This law provides the basis specifically for GISTDA, among other public organizations.
10		2562	2019	A	C	—	The second version amended in May 2019.

(Legend for the Language column: “A” represents the official document; “B” indicates unofficial translations (of which the Japanese versions were translated by JETRO Thailand Office; “C” refers to translations by the Team; and “—” means no translation.)

Source: Created based on the studies conducted by the Team.

(2) Spectrum allocation and applicable laws

(a) Networks used for receiving and sending CORS data

The distribution of CORS data uses networks for two purposes: one is to transmit the data acquired by CORSs from the stations to the data centers; and the other is to deliver the data to end users (Fig. 3-25).

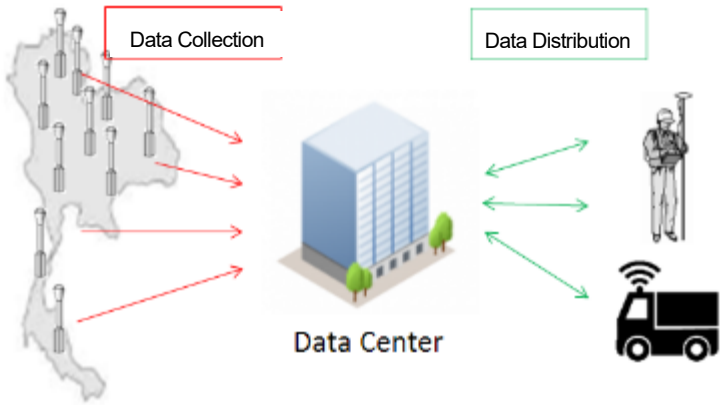


Fig. 3-25: Network used for receiving and sending CORS data

Regarding the data transfer from the stations to the data centers, the Team investigated how the data are transmitted from the stations to the data centers of relevant organizations, what kind of network is used for the data transfer, and whether there is any backup system in place. As for the data delivery to end users, the Team investigated the policies associated with data distribution, specifically whether they would also take care of devices without connection to the internet and what kind of network is used for the data delivery.

(b) Data collection

Table 3-39 lists the networks used by the individual organizations for receiving CORS data. Basically, they use two different networks for fault tolerance.

Table 3-39: Means of data collection

Organization	Data collection network	
	Main	Main
DOL	Optical fiber (CAT)	3G/4G Network
DPT	Optical fiber (ToT)	3G/4G Network
GISTDA	Optical fiber (contractor unknown)	None
HII	Optical fiber (GIN)	None
RTSD	Optical fiber (ToT)	3G/4G Network

The Government Information Network (GIN) refers to the network of the central government, which the Digital Government Development Agency (DGA) is seeking to connect all governmental agencies on a single network to enable them to offer a range of public services efficiently, stably, and continuously.

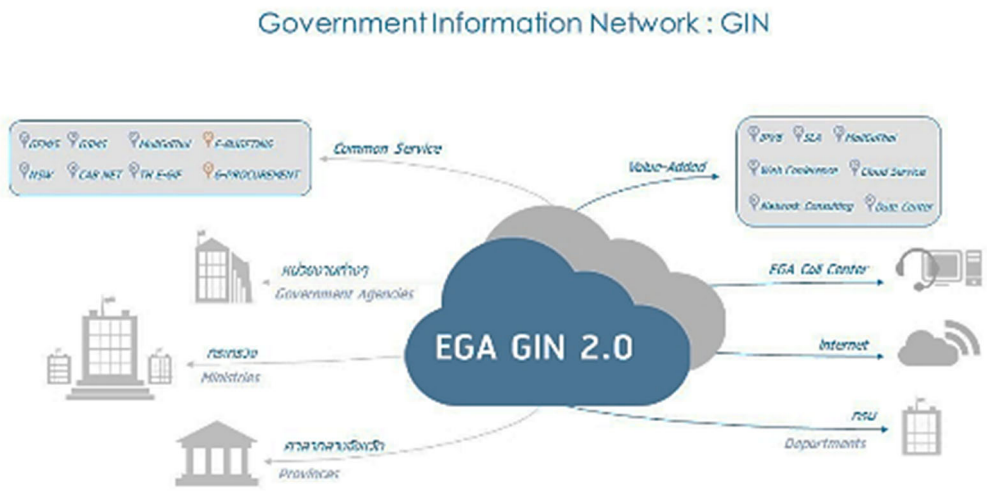


Fig. 3-26: GIN initiative

Source: the website of DGA (https://www.dga.or.th/en/profile/904/)

The use of the GIN network for data collection from CORSs will reduce the cost of telecommunications, which will reduce the overall operating cost and secure high-level telecommunication security. So far, however, only HII takes advantage of the GIN network. Other organizations are slow in adopting the network apparently because it is difficult to obtain the use permit and because it takes time to make decisions.

(c) Data distribution

RTSD plans to distribute data with most current technologies. Thus, they plan to support data distribution through 3G/4G/5G mobile networks only, and will not consider data distribution to devices that are not connected to the Internet (mainly traditional RTK devices), which typically communicate via modem-based Peer 2 Peer connection or radio waves.

(d) Spectrum used by mobile network operators

The Mobile Network Operators (MNOs) in Thailand are composed of three private companies (AIS, DTAC, TrueMove) and two state-owned corporations[19] (ToT, CAT Telecom). The five use the 3G/4G spectrums respectively as shown in Table 3-40 (as of March 2019).

[19] All shares are owned by the Ministry of Finance.

Table 3-40: Spectrum used by mobile network operators in Thailand

-	AIS	DTAC	TrueMove	ToT	CAT Telecom
4G LTE	2100MHz (Band 1) 1800MHz (Band 3) 900MHz (Band 8)	2300MHz (Band40) 2100MHz (Band 1) 1800MHz (Band 3) 900MHz (Band 8)	2100MHz (Band 1) 1800MHz (Band 3) 900MHz (Band 8)	2300MHz (Band 40) 2100MHz (Band 1)	2100MHz (Band 1) 1800MHz (Band 3)
3G W-CDMA	2100MHz (Band 1)	2100MHz (Band 1) 850MHz (Band 5)	2100MHz (Band 1) 850MHz (Band 5)	2100MHz (Band 1) 1900MHz (Band 2)	850MHz (Band5)

Source: The Team

The two state-run corporations shifted its operations from direct services to consumers to wholesale of circuits to operators in accordance with a change in national policy. However, they kept the consumer services as well. In October 2015, ToT Corporation was granted permission for providing LTE (4G)-based services by the National Broadcasting and Telecommunications Commission (NBTC). ToT today provides not only direct services to consumers but circuits to MNOs and Mobile Virtual Network Operators (MVNOs).

CAT Telecom provides 3G services using 850MHz (Band 5) and 4G services using 2,100MHz (Band 1) and 1,800MHz (Band 3) as consumer-oriented services.

Japan once faced a challenge in which the L1 band, the GNSS reception band of CORSs, was interfered by the LTE 1,500MHz band. However, mobile network operators do not use 1,500MHz band.in Thailand. Thus, there will be no problem of interference with LTE in Thailand.

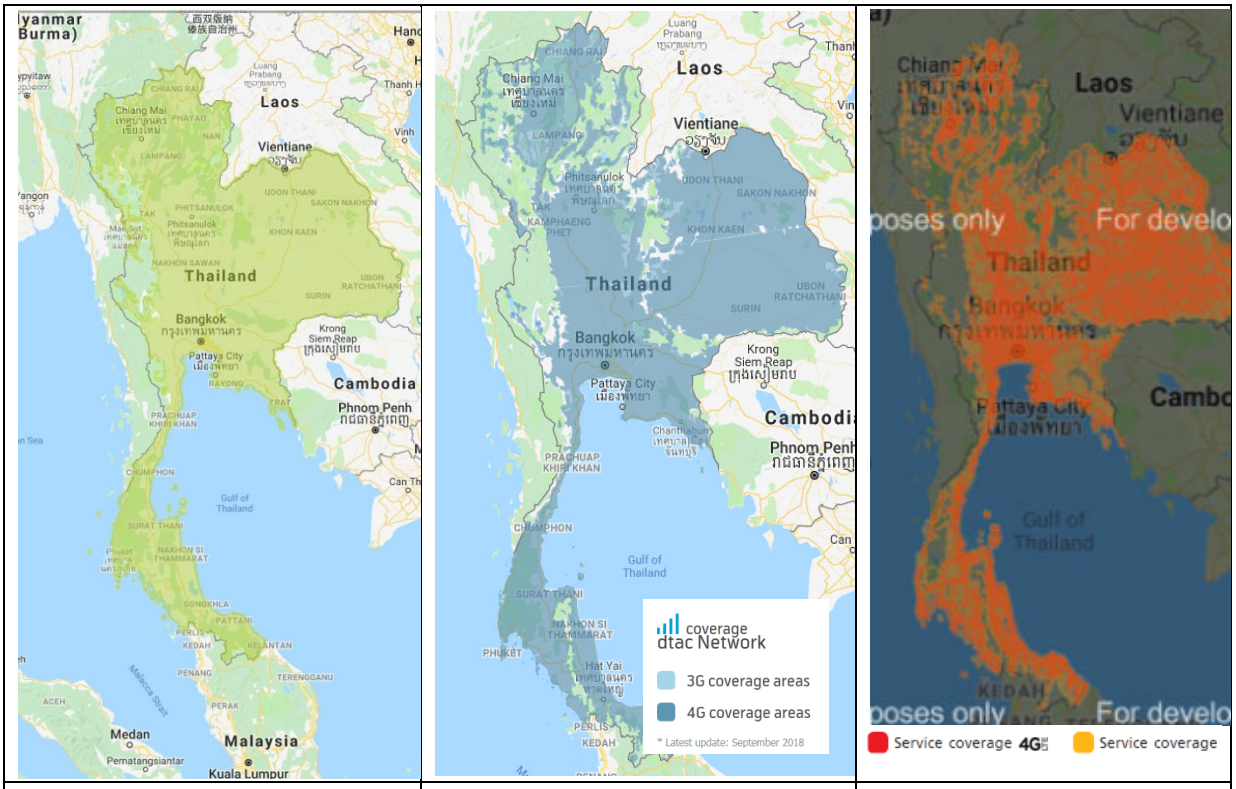
(e) Trends among MVNOs

According to the Global ICT Report compiled by Japan's Ministry of Internal Affairs and Communications (last updated in Japan fiscal year 2017 http://www.soumu.go.jp/g-ict/country/thailand/detail.html#law), the number of MVNOs, known as low-cost SIM providers in Japan, registered to NBTC was 44 in Thailand (as of March 2017), nine of which have begun their operations. These MVNOs, in fact, provide communication services using the lines provided by the MNOs, namely, AIS, DTAC, TrueMove, ToT and CAT Telecom; they cannot use any other lines, i.e., spectra, than those provided by the five companies[20]. For this, the trend among MVNOs is not considered in this Survey.

(f) Coverage by each MNO

Fig. 3-27 shows the current coverages by the MNOs (except ToT and CAT Telecom, whose coverages were not found in this investigation). When considering the distribution of CORS data via mobile network, the service coverage of the MNOs may give an idea about how far the distribution services can reach.

[20] MVNOs are defined as "telecommunication operators who use mobile communication services provided by or are connected with an MNO/MNOs to provide mobile communication services without owning or operating their own wireless stations (base stations) in connection with the mobile communication services they provide."



AIS (as of March 2019)	DTAC (as of November 2018)	True Move (as of March 2019)

Fig. 3-27: Coverage of the MNOs

Source: The operators' Websites

(g) Development of a fiber optics network

Fiber optics networks in Thailand are operated chiefly by ToT and Fiber One. FiberOne covers Bangkok and its peripheral areas, whereas ToT provides nationwide support. ToT does not publicize its fiber optics service coverage map but if one goes to the following URL and enters his or her residential address, he or she will know if their service is available in his or her local town (Fig. 3-28).

https://www.tot.co.th/en/fiber2u/register#checklocation

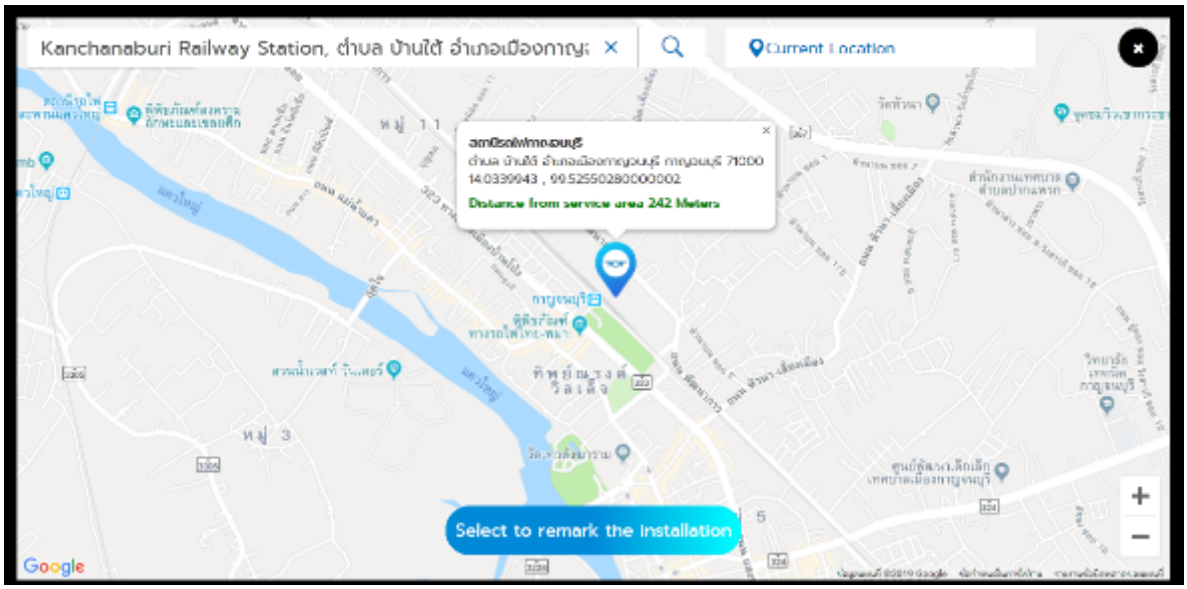


Fig. 3-28: Service Area Check (ToT Corporation)

Providers that support optical fiber networks include ToT, CAT Telecom, AIS, True and 3BB. Each provider supports a maximum download speed of 1,000 Mbps, except CAT Telecom providing 200Mbps. The upload speed widely varies between 100 Mbps and 500 Mbps as the maximum speed depending on the subscription options (Table 3-41).

In data communication with CORSs, the upload speed is more important than the download speed.

Table 3-41: Maximum speeds of optical fibers operated by the MNOs

Provider	Download (Mbps)	Upload (Mbps)
ToT	1,000	100
CAT Telecom	200	200
AIS	1,000	300
True	1,000	500
3BB	1,000	500

Optical fiber cables for consumer use are laid in terminal connecting sections for each provider (thus, the installation cost is incurred). If users wish to change the provider, cables need to be physically replaced with those for a new provider, which incurs the cost. (For private sector use, these charges are included in monthly charge and less visible for users.) While the cable installation cost is embedded in monthly cable charges for consumer use, it is not certain how the cost is handled for a special case such as wiring to CORSs (particularly those in remote areas).

(h) Trends surrounding the fifth generation (5G)

The government of Thailand plans to commercialize 5G communications in 2020. Currently, the EEC and other parties concerned are performing a demonstrative experiment. The planned spectra to be used for 5G communication are largely divided into two bands (Table 3-42): one is so-called sub-6GHz, specifically 450 to 6,000 MHz defined by the 3GPP (Third Generation Partnership Project), and the other is a millimeter waveband of 24,250 to 52,600MHz as defined by the same group.

Which band Thailand uses for 5G communications was undecided at the time of this investigation. Nevertheless, NBTC's Radio Wave Master Plan 2016-2020 indicates that the 30-57 GHz band is reserved for mobile services. It may likely be used for 5G communications in addition to the band currently in use (the demonstrative experiment uses the 26 GHz for the sake of the devices used, but the band to be used in actual operation is not yet known) .

Table 3-42: Bands used for 5G and their user countries

	Sub-6GHz bands 600(n71)/700(n28)MHz, 2.5(n41)/3.5(n78)/4.5(n79)GHz, etc.	Millimeter waveband 28(n257)/39(n260)GHz, etc.
Standalone	U.S., China	-
Non-standalone	U.S., ROK, Japan, Europe	U.S., ROK, Japan

Source: Anritsu Website (https://www.anritsu.com/ja-JP/test-measurement/technologies/5g-everything-connected/5g-world-freq) (as of September 2018)

3.4.2. Constraints concerning social experiments (including EEC exceptions)

Based on the findings from Section 3.3.2 Intents to Utilize precise positioning Data Among Japanese Firms Operating or Planning to Operate in Thailand, the Team investigated licenses and constraints that may be associated with social experiments on and/or future implementation in society of surveying, i-Construction (use of ICT-based construction machine), autonomous operation of agricultural machinery, autonomous driving of vehicles and operations of drones and MMSs.

(1) Examination of Japanese laws

The Team first looked into Japanese laws. The table below lists the laws and regulations concerning the abovementioned technologies of interest.

Table 3-43: Japanese laws examined

Technologies	Applicable laws	Details of the law
Surveying	Survey Act	The law is aimed at ensuring accurate and smooth execution of surveying.
i-Construction	Enforcement policy on the full use of ICT	The policy is aimed at promoting the use of ICT in public works.
	Standards for supervision of civil engineering works (draft)(standards and standard values for as-built control)	The standards ensure that a civil engineering project must be implemented in accordance with the term, performance, and quality designated in the contract documents. (ICT-based construction is supported.)
	Procedure for calculating the quantity of civil engineering works (draft)(including a draft procedure for calculating how much civil engineering work has been completed based on construction record data.)	This procedure simplifies the method of calculating how much work has been done in a progress-payment project, by compiling simple and convenient methods of calculating the progress of civil engineering works based on record data of ICT-based construction machine.
	Procedure for as-built control using UAV-based aerial photogrammetry (for civil engineering works)(draft) and procedure for supervision and inspection (for civil engineering works)	This procedure is aimed at ensuring that UAV-borne-photogrammetry-based as-built measurement and control are carried out efficiently and accurately.
	Procedure for as-built control using laser scanners (for civil engineering works)(draft) and procedure for supervision and inspection (for civil engineering works)(draft)	This procedure is aimed at ensuring that terrestrial laser scanner (TLS)-based as-built measurement and control are carried out efficiently and accurately.
Autonomous operation of agricultural machinery	Road Trucking Vehicle Act	This law is aimed at promoting the public welfare by regulating road trucking vehicles through authentication of ownerships, assurance of safety, and improvement of technologies for pollution prevention and vehicle repair,

Technologies	Applicable laws	Details of the law
		and also by contributing to the sound growth of the automobile repair industry.
	Road Traffic Act	This law is aimed at assuring safe and uninterrupted road traffic by preventing and removing all possible dangers and obstacles on roads.
	Guidelines for assuring the safety in Autonomous operation of agricultural machinery	The guidelines provide a set of principles concerning risk assessments and other safety measures and also guidance on roles and responsibilities among stakeholders, with an aim at assuring the safety of wheeled agricultural machinery with robotics (sensors, intelligence and control, and drive-train) for autonomous driving.
Autonomous driving of vehicles	Road Trucking Vehicle Act	Same as the Road Trucking Vehicle Act in the “Autonomous operation of agricultural machinery” above.
	Road Traffic Act	Same as the Road Traffic Act in the “Autonomous operation of agricultural machinery” above.
Drone	Survey Act	Same as the Survey Act in the “Surveying” above.
	Civil Aeronautics Act	This law is aimed at assuring the safety in transport, enhancing the convenience on the user side, developing aviation and promoting the public welfare.
	Assessment procedure for approval of licensing the flight of UAVs	This procedure defines the requirements for applying for licenses in relation to the flight of UAVs and assessment standards for granting permissions.
	Act on Prohibition of Flight of Small-sized Aircrafts, etc.	This law prohibits the flight of small-sized UAVs and other vehicles above important national facilities, such as the Diet Buildings and the Prime Minister’s Office, foreign delegations and nuclear energy-related facilities as well as their peripheral areas.
	Radio Act	This law is aimed at promoting the public welfare by securing the fair and efficient use of radio waves.
	Guidelines for handling footages and other contents from drones on the internet	These guidelines sort out ways of thinking about rendering footages and other contents from drones viewable on the internet and points out considerations to

Technologies	Applicable laws	Details of the law
		be taken by people in so doing.
MMS	Survey Act	Ditto
	Road Traffic Act	This law is aimed at assuring safe and uninterrupted road traffic by preventing and removing all possible dangers and obstacles on roads.

In Japan, new technologies are put into appropriate use by developing standards and procedures promoting or regulating new technologies or industries as they arise, in addition to the traditional laws, such as the Survey Act and Radio Act.

(2) Examination of Thai laws

The Team studied Thai laws and regulations in the context of the above Japanese laws.

Table 3-44: Thai laws examined

Japanese law	Corresponding Thai laws		
	Name	Content	Enacted in
Survey Act	SURVEY ACT	This law aims to protect domestic safety, providing commissioning standards, and rules for management of commissioned survey, and publication and storage of survey results, when creation of cadastral maps and surveying works are commissioned to survey companies.	2014
Road Traffic Act	ROAD TRAFFIC ACT	Just like the Japanese equivalent, this law defines the categories of automobiles and traffic rules and controls driving licenses.	1979
Civil Aeronautics Law	Aviation Law	This law controls driving licenses and handling of aircraft and defines rules regarding management, charges, and other details.	2019
Assessment procedure for approval of licensing the flight of UAVs	On rules to apply for permission and conditions to control and launch unmanned aircraft in the category of remotely piloted aircraft	These rules provide for applications for licenses and regulations concerning the flight of drones. They also describe limitations by weight and by geography (airports and public facilities, for example).	2015

Japanese law	Corresponding Thai laws		
	Name	Content	Enacted in
Japan does not have any requirement for registration of radio devices for drones.	Subject of Radio Communications Registration Using for Unmanned Aerial Vehicle that controlled flight from outside	This rule requires the registration of radio devices used for drones.	2017
Radio Act	Subject of Rules and Condition to Approve of Using Frequency Wave for Unmanned Aerial Vehicle that using in general.	This rule provides for applications for licenses and regulations and conditions concerning the use of radio waves and frequencies for UAVs.	2018
Radio Act	RADIO COMMNICATION ACT	This law regulates the registration of radio devices and licensing of radio waves as well as associated penalties.	1955

The Survey Act was studied by JETRO upon the request of the Team. The Survey Act provides provisions on safety protection of information about surveying, but does not regulate survey methods, qualification of surveyors, and other matters, which are regulated by different laws. RTSD explains that, if any party wishes to bring aerial photographs, point group data, and similar materials out of Thailand, they need to be accompanied by officials of RTSD, and process such data under their supervision.

The Road Traffic Acts of the two countries do not have a big difference, meaning that an MMS can also operate on public roads just like common cars, as long as the vehicle is compliant with the requirements, in Thailand. Unmanned driving, on the other hand, is not easy on public roads in the country, as no applicable law has been developed yet.

With respect to drones, a new regulation has come out and they need to be operated in accordance with the provisions thereof. Drones themselves and pilots are required to register to the Civil Aviation Authority, which can be done on line (in English). Anyone, including foreigners, can register as long as they have a residential address in Thailand. On top of this, however, one must obtain permissions of landowners and submit an application to the local police within the scope of shooting; an actual shooting project would thus be quite difficult without the cooperation of local staff and enterprises in the country.

There is no applicable law in relation to the use of ICT-based construction machine. This implies that the equipment can be utilized in the same way as conventional equipment at construction sites, but one must

consult with relevant ministries and agencies with regard to the use of it in other areas.

The autonomous operation of agricultural machinery likewise does not have any governing laws. The use of it on farmland with a permission of the landowner should be no problem but the use of it in other ways requires consulting with relevant ministries and agencies.

(3) Compliance with preferential deregulation measures in the EEC

The EEC stands for Eastern Economic Corridor, extending over Chachoengsao, Chonburi and Rayong Provinces. The government enforced the Special Law on the EEC in 2018, which allows foreign-funded companies and foreigners investing in the Industrial Promotional Zones inside the EEC to receive tax merits and immunity from existing laws concerning land ownership and others. This is perceived as to bring advantages to foreigners performing economic activities within the EEC.

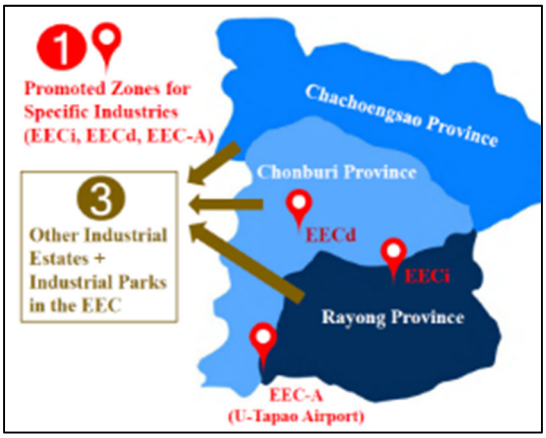


Fig. 3-29: 3 EEC Provinces and 3 Industrial Promotional Zones

Source: Board of Investment of Thailand

The Team examined a possibility of conducting an advanced social experiment in this zone taking advantage of some deregulations.

The Special Law on the EEC does not provide for specific deregulations but states what kind of benefits the law brings about. The Team expected at the beginning of the Survey that the Special Law on the EEC provides for details of deregulations, but found later that the law provides no such details. JETRO Bangkok Office explained that the Team has to first contact the EEC Office and explain how the Team wants to benefit from an Industrial Promotional Zone of the EEC, so that they will contact ministries and agencies involved for confirmation and possible implementation of such deregulation measures. In other words, the deregulation backed by the Law is not predefined.

The Team asked the Office if autonomous driving or free flight of drones can be executed in the EEC of Innovation (EECi), and found that the Office is entitled to set rules to be followed within the EEC but cannot

do so on its own and need to coordinate with relevant government bodies.

The EEC does not just grant foreigners tax merits but privileges in terms of work permits and land acquisitions. Through our investigations, building a foothold in any of the Industrial Promotional Zones certainly gives advantage when starting a new business. On the other hand, performing an advanced social experiment expecting to benefit from deregulations would require coordination with responsible government bodies and the EEC Office, which will take much time in practice.

4. Consideration of utilization and distribution of precise positioning data

4.1. Prospective use of precise positioning data in Thailand

4.1.1. Use of precise positioning data by precision level

The following table shows the uses of precise positioning data by precision level, identified from the results of a hearing survey with government agencies, private companies, etc. in Thailand. With regard to the bus operation management (※1) mentioned in the table, on 27th February 2019, Ministry of Transport, Thailand, announced a plan to replace all old route buses in Bangkok with new ones equipped with GPS and monitoring cameras within two years. With regard to the motorcycle taxi dispatching (※2), on 28th February 2019, the Economic Research Institute of University of the Thai Chamber of Commerce released results of a research on 1,243 motorcycle taxi drivers in Bangkok and surrounding provinces, where drivers who used a taxi distribution application increased their monthly income by 1,741.95 baht on average. It seems that utilization of positioning data is receiving attention as a solution to road congestion in Bangkok, where road congestion is a serious social issue.

Table 4-1: Uses by precision level

Precision Level (Error Range)	Use
1cm or less	Monitoring of crustal deformation and landslides
1cm - 10cm	Surveying (ground survey, laser surveying, MMS, etc.), smart agriculture (precision agriculture, autonomous operation of agricultural machinery, etc.), ICT construction/i-Construction (3D surveying, construction machine control, etc.), autonomous driving of vehicles
10cm - 1m	Maps for autonomous driving (dynamic map)
Over 1m - several meters	Satellite-based Augmentation System (SBAS), sea survey, monitoring of vessels, bus operation management※1, motorcycle taxi dispatching※2

Of the use listed above, surveying, smart agriculture, ICT construction, and autonomous driving at the precision level of 1-10cm are considered to be the future use of CORS data towards Thailand4.0 (Fig. 4-1) and the fields of innovative GNSS technology (Fig. 4-2), so the precise positioning data seems to be more utilized in the future. Most prospective users of the NCDC to be established in Thailand would use precise positioning data for these purposes, so that the user environment and the contents of data need to be designed while takin into account these purposes.

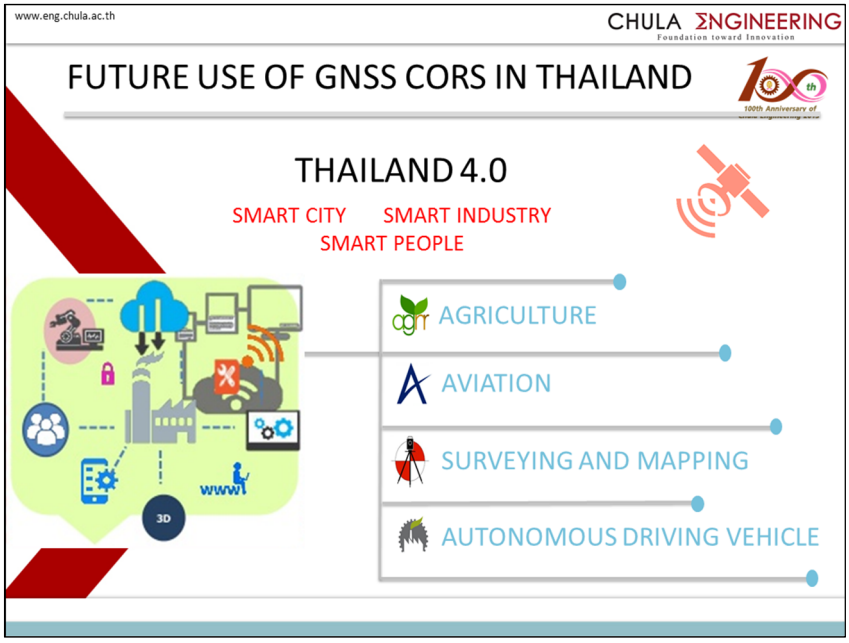


Fig. 4-1: Thailand4.0 and use of CORS

Source: Quoted from seminar materials of Prof. Chalermchon Satirapod at "Thailand japan Special Session (28th Aug)"

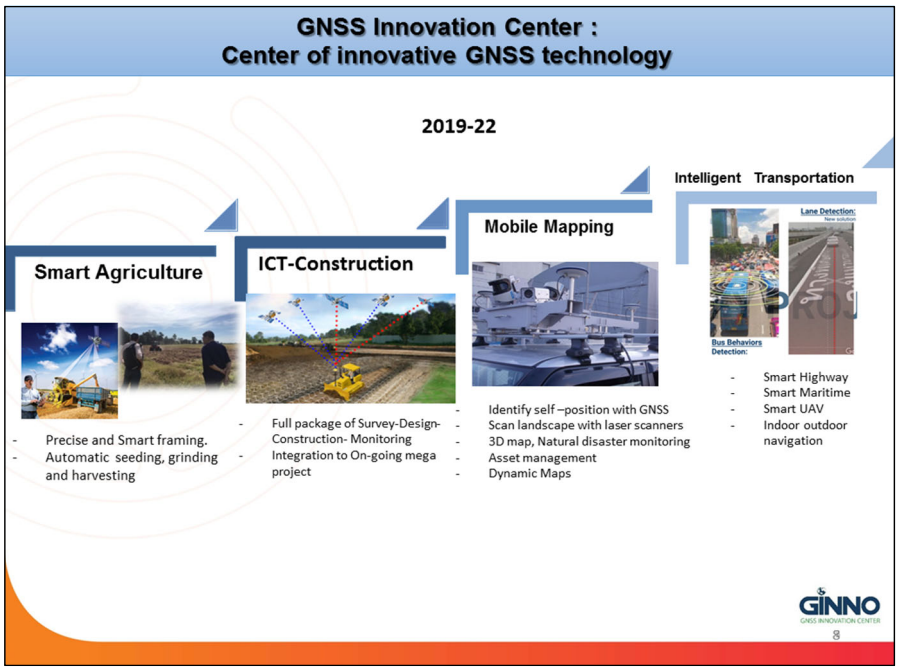


Fig. 4-2: GISTDA's focused Innovative fields of GNSS technology

Source: Quoted from "Space Krenovation Park And EECi"" materials prepared by GISTDA

4.1.2. Environment and contents necessary for use of precise positioning data

The following subsections summaries the user environment and contents of data necessary for the above-mentioned prospective use of precise positioning data at the precision level of 1-10cm.

（1） Necessary environment

As stated in the first part of Chapter 2, almost the whole country of Thailand are covered with circles of 35km radius centered on CORSs, so no additional CORS is considered to be required for most of prospective users. These existing CORSs require no improvements because they have no serious problem with providing data to be described below (except replacement or other improvements due to breakdown caused by natural disaster or aged deterioration in future). However, in case using certain inexpensive models of receivers which are incompatible with the network RTK, reference stations for single-station RTK would need to be installed, if necessary as in the case of Japan, near construction sites and farms (desirably within 10km radius). As for autonomous driving of vehicles, it is necessary to consider the environment that can support related users in line with prospects of research and development in future.

（2） Contents of data required

RTCM already adopted by Thailand's government agencies and Ntrip[21] are recommendable data format and communication method, respectively. As for time slots, it seems enough to provide data in the daytime only for certain purposes such as surveying, but data needs at all times for agriculture, construction and other purposes. Moreover, if users for autonomous driving of vehicles and other uses are taken into account, data needs to be distributed seamlessly 24hours a day and 7 days a week even during maintenance. All this has to be borne in mind for the operation and maintenance of NCDC.

Table 4-2: Data formats and communication methods adopted by government agencies in Thailand

Category	DOL	DPT	GISTDA	HII
Real-time data	RTCM	RTCM 3	RTCM 2, 3	RTCM 2, 3
Post-processed data	RINEX at interval of 15 secs	RINEX at interval of 5 secs	RINEX 2.0,3.0 at interval of 5 secs	RINEX 2 at interval of 1 sec
Communication method	Ntrip	Ntrip	Ntrip	Ntrip

Source: Prepared by the Team based on interview survey

[21] Networked Transport of RTCM via Internet Protocol. Communication tool designed specifically for RTCM to enable base stations (data centers), mobile stations, etc. to exchange correction and GNSS data via Internet.

4.1.3. Activities to promote the use of precise positioning data

To promote the use of precise positioning data in Thailand, it is necessary to enhance the recognition of NCDC and data to be distributed, and offer user support. The following table lists proposed activities that can be considered.

Table 4-3: Proposed activities to promote the use of precise positioning data

Higher recognition/user acquisition	• A website launch and sending out of information • Seminars and learning sessions for individual industries and uses • Demonstration and hands-on events • Compilation and dissemination of successful case studies through presentations at events, the website and various other opportunities
User support	• Startup training • Installation of a call center for users • On-site and online support for users • A website launch and sending out of information for users • Learning sessions on latest technologies

Some of these activities can be performed by NCDC alone, while others need collaboration with private companies or should be performed on the initiative of private companies.

Meanwhile, as for the operations of Japanese companies in Thailand, the Japan-Thailand Cooperative Council for G-Space Promotion, which has been offering cooperation and collaboration in this Survey, has been planning to participate in relevant events and perform experimental projects. (The Space Edge Lab that serves as a secretariat of the Council has concluded MOU with GISTDA.) It will be effective and desirable to work with the Council when performing activities, in which Japanese companies participate during the next coming technical cooperation project.

4.2. Precise positioning data provision system

4.2.1. Fee setting and collection methods for data provision to the private sector

According to RTSD establishing NCDC, the following two scenarios are expected for fee setting.

1) Data provided without charge both to government and private organizations
2) Data provided without charge to government organizations and with charge to private organizations

However, NCDC Management WG decided at its meeting in July 2019 that NCDC would distribute precise positioning data in principle free of charge for the initial six months and review the fee system every six months thereafter. Thus, the possibility of charging private companies for data remains. The following table provides possible schemes by prospective fee collection agency.

Table 4-4: Possible fee collection scheme for NCDC

Implementing agency	Revolving fund	Public agency	Government agency
Example	RFAPR(RTSD)	GISTDA	DOL
Supervising organization	Ministry of Finance	Board of Directors	Superior government organization
Fee setting method	After a decision made by the manager at a rank equivalent to Supreme Commander, the final approval needs to be obtained from the Board of Directors of the revolving fund or other organization that supervise the operation of NCDC.	Relevant provisions on the services need to be set forth under the relevant royal decree, and the approval from the Board of Directors is required for the fee setting.	Relevant provisions need to be set forth in the law related to the agency concerned.
Fee collection method	Cash, post office, bill, bank transfer, credit card, etc. No particular legal restriction.	No particular restriction. Fee collection can be performed relatively freely at the discretion of RTSD.	Cash, bill, credit card, etc. No particular legal restriction.

Source: Prepared by the Team based on interview survey

Judging from the case of DOL, the Team considers that there will be little advantage of direct fee collection by a government agency. Thus, it is necessary to establish a revolving fund, public agency or an organization of other form to collect fees. As RTSD uses a revolving fund for its map sales and thus has a know-how of establishing a revolving fund, it is possible to establish a fund for NCDC to collect data distribution fees. However, RTSD personnel are doubtful of this idea, explaining that RTSD would have to send fee revenue to the national treasury under a RTSD revolving fund scheme. Thus, there is a possibility to designate NCDC as a public agency in future and build a fee collection scheme with NCDC as the implementing agency.

On the other hand, as estimated in 3.3.1.（2） (b), if the price of the Japanese distribution service is converted to a level suitable in Thailand, the monthly fee comes to about 1,100 baht per user. Based on this estimate, it is assumed that partial costs can be recovered only when there are several hundreds to thousands of users.

4.2.2. Distribution of collected fee income

The following table summarizes how to distribute and use fee income in the cases where fees are collected by a

revolving fund, public agency, and government agency as discussed in the previous section.

Table 4-5: Possible advantages and disadvantages of fee income distribution by each fee collection agency

Implementing agency	Revolving fund	Public agency	Government agency
Example	RFAPR	GISTDA	DOL
Process of approving use of fee income	The responsible agency plans the budget for the fund and obtain the approval of the Board of Directors each fiscal year. The responsible agency can distribute fee income among multiple agencies if they agree in advance on the budget plan.	The responsible agency can use fee income freely at its discretion within the range stipulated under the relevant royal decree. The responsible agency can distribute fee income with other agencies if it concludes MoU with individual agencies.	The responsible agency is not authorized to use fee income, once fees collected are sent to the national treasury.
Advantages	The responsible agency can use fee income sent to the national treasury within the range approved in advance. It is possible to appoint an existing government agency to establish a revolving fund.	There is no need to send fee income to the national treasury. The responsible agency can make profits if not excessively.	There is no particular advantage.
Disadvantages	Collected fees are needed to be sent to the national treasury first. Fees collected are strictly supervised by the Ministry of Finance, and distribution and use of fee income are subject to the approval of the Board of Directors of the fund. Unless the approval is obtained, the responsible government agency cannot use fee income freely.	It is necessary to have a new royal order stipulated and establish a new public agency. If an existing public agency is designated as the responsible agency, it is still necessary to have the relevant royal decree amended. It may be necessary to transfer necessary personnel from other agencies.	Fees collected need to be sent to the national treasury. The responsible government agency is not allowed to use fee income for its own operations.

Source: Prepared by the Team based on interview survey

As discussed in the previous section, the possibility is remote that a government agency would directly collect

and distribute fee income, while it is possible, as in the case of the map sales, to take advantage of a revolving fund or public agency. Under a revolving fund, collected fees are needed to be sent to the national treasury first, and the use is strictly supervised by the Ministry of Finance, so the use of fee income is not flexibly reviewed unless the relevant document specifying the use is amended. Fee income, however, can be used without fail for purposes specified in advance. On the other hand, a public agency is not required to send fee income to the national treasury but allowed to use it flexibly within the scope of its operations set forth in the relevant royal decree. Even so, it takes time to have such a royal decree stipulated. It will be necessary to carefully examine these advantages and disadvantages of the possible means of fee collection and distribution to decide on the best way for NCDC to collect fees from the public sector in the future.

5. Consideration of the CORS data distribution system and the system configuration

5.1. Consideration of the CORS system appropriate for the expected future uses

5.1.1. Overall structure of the data distribution system and the CORS system

（1） Data distribution system

According to the information collected by the Team, the Thai side was initially considering a data distribution system as shown in Figure 5-1. The distribution system will be implemented under the responsibility of RTSD according to the decision by NGB.

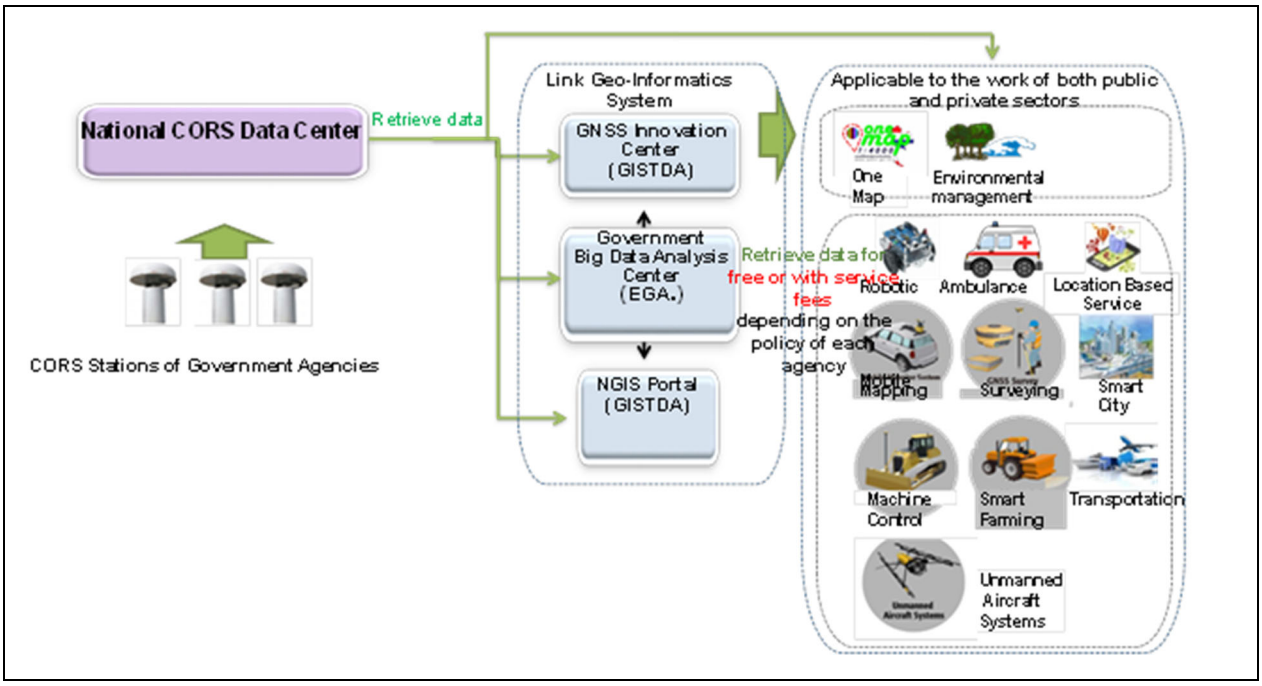


Fig. 5-1: Data distribution system initially being considered in Thailand

Source: Material provided by RTSD (March 2019) and modified by the Team

As discussed in 4.2.1, NCDC Management WG decided at the meeting on 18th July 2019 that data would be distributed free of charge to government agencies, as well as to private companies for the first six months, after that fee collection will be reconsidered and decided every six months. In this report, the Team considers a distribution system for the private sector, which can also be used for government agencies except fee collection.

Based on the examples in Japan, the data distribution system could be as shown in Fig.5-2.

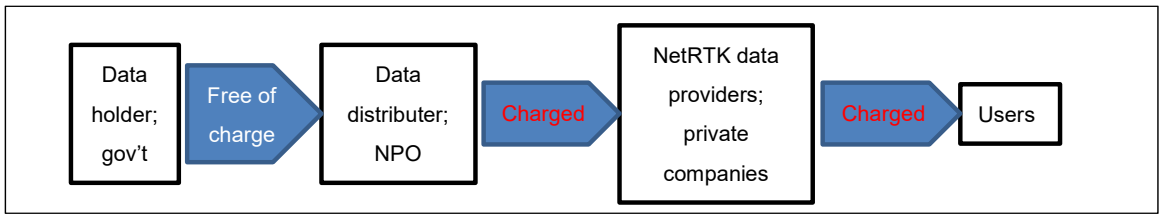


Fig.5-2: Data distribution system – Scenario A

This system is modeled after the Japanese distribution service described in 3.1. In this system, 1) data will be provided free of charge from the government agencies who will collect and own data to Data distributer (an NPO) who will distributes data; 2) the Data distributor will collect data distribution fees from and distribute data to private companies providing positioning services such as provision of correction data; and 3) the private companies will provide correction data, etc. with charge to users, and the fee will be determined through market competition among the companies.

As discussed earlier in 3.2.1, network RTK data distribution services are provided by private companies in many European countries and the United States as well as in Japan.

On the other hand, GNSS is not used much in Thailand and, according to the result of this survey with private companies, not many companies want to actively use GNSS data (3.3.2). In the survey on distribution services in neighboring Malaysia, no private distribution services were found, either (3.2.1 (6)). Therefore, it is unlikely that any companies will participate in the distribution service for a while. Also considering that the government itself has conducted experiments of a distribution service in DOL and HII, it is believed that the project will be carried out quickly if the government, a revolving fund, or some other public agency provides the distribution service. Based on the RTSD map sales system, studied in 3.4.1, the Team has come up with a similar system as shown in Fig. 5-3.

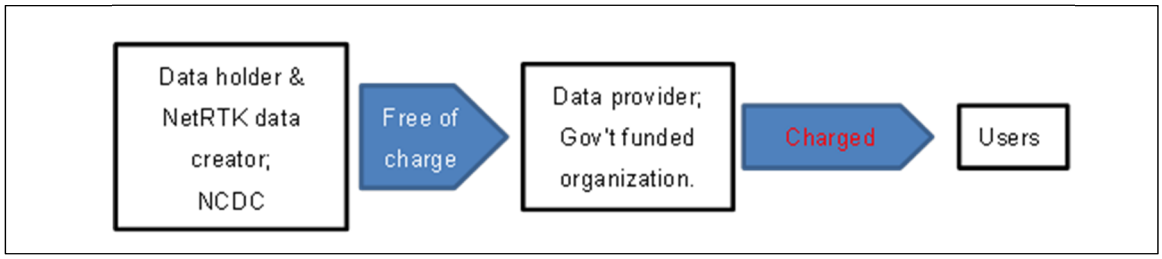


Fig. 5-3: Data distribution system – Scenario B

In this scenario, an organization corresponding to RFAPR, who sells RTSD maps, will distribute data and collect fees. NCDC, which is a government organization, will collect data and create correction data, and then another organization such as a revolving fund will receive data from NCDC free of charge and distribute it to users with charge. The fee collection method and distribution of collected fees will vary depending on who will operate and manage NCDC. In addition, a public organization that seems more flexible about fee

collection and utilization than a revolving fund could be established for data distribution (4.2.2). The Team can also think about a slightly different version of this scenario where NCDC will not create correction data but another government funded organization will develop and distribute correction data. Table 5-1 shows the pros and cons of these two scenarios.

Table 5-1: Comparison of distribution systems

	Scenario A	Scenario B
Pros	With multiple data distributors, there will be market competition for prices and technologies and improvements can be expected. The system can quickly respond to sudden increase of users in the middle of a fiscal year.	Long-term business continuity can be expected because the government can be directly involved in distribution. The government can take measures to encourage utilization (such as free service provision for a certain period of time) till users increase
Cons	There is a concern about distributors' business continuity. Participation of many companies in the distribution business cannot be expected because it is unlikely that there will be many users in the initial stage.	There will probably be no competition in prices or technologies because there will be only one distributor. It will be difficult to quickly respond to sudden increase of users.

Considering the pros and cons of the two scenarios, the Team can think about Scenario C (Fig. 5-4), which is a combination of Scenario B and Scenario A. In this scenario, Scenario B will be followed in the beginning of the distribution service, and, when the number of users becomes large enough for private companies to participate, Scenario A (distribution by private companies) will also be introduced. Eventually the system will be completely shifted to Scenario A when private companies can generate profit. As increase of users will be a key factor, data could be distributed free of charge in the beginning of the service to encourage utilization.

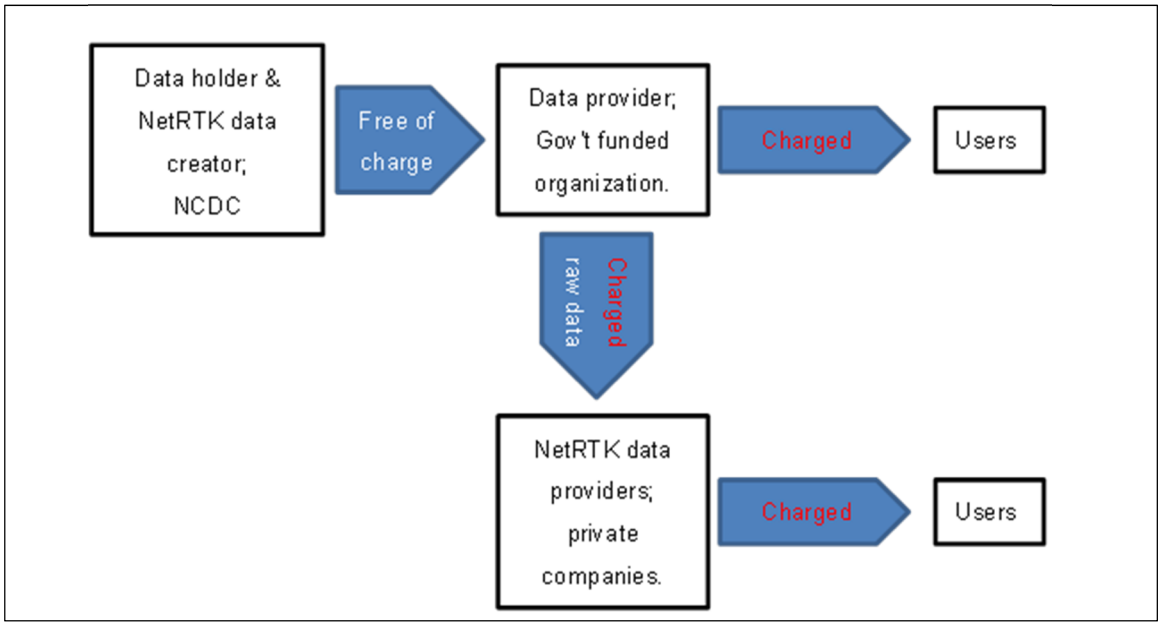


Fig. 5-4: Data distribution system – Scenario C

The Team presented these scenarios at the meeting of the Thailand-Japan Joint WG held on 24th May where it was decided that NCDC Management WG would continue deliberating on the data distribution system based on Scenario B.

(2) Overall structure of the CORS system

At the same Thailand-Japan Joint WG meeting, the Team presented two scenarios for data collection. One of the scenarios, which is the initially considered by the Thai side, keeps the functions of the existing data centers that each of the five agencies collect their own CORS data and the data will be sent to NCDC from each agency for centralized management (Fig. 5-5 Scenario A).

Another possible scenario for data collection is to connect CORSs owned by individual agencies directly to NCDC and allow agencies to receive data from NCDC if they need to have their own data center (Fig. 5-6 Scenario B). Table 5-2 shows the pros and cons of these two scenarios.

Table 5-2: Comparison of data collection systems

	Scenario A	Scenario B
Pros	Existing data center functions can be maintained. CORSs can be used according to the needs of each agency. NCDC can be established quickly.	Data delay will rarely occur because data will be communicated directly from CORSs. Operation commands can be sent directly from NCDC to each CORS.
Cons	Data communication can easily be delayed because communication will be performed through each data center. Because operation commands cannot be sent directly from NCDC to each CORS, it will require additional work to request each agency to do so.	It will take time to modify network connection to maintain existing data center functions. It will take time for WG to coordinate for the use of CORSs according to the needs of each agency.

Based on the presented scenarios, the Thai side began to deliberate on the most appropriate scenarios in NCDC Management WG meetings. At the first meeting on 18th July, it was decided to conduct data streaming tests between the data centers of DOL and RTSD and evaluate the results thereof and then expand the tests to include other agencies' data centers to determine the most appropriate scenarios based on the results. Following this decision, the streaming tests between DOL and RTSD began in August, and the results are currently being evaluated.

Concurrently with the above, the Team presented more detailed data collection scenarios to the relevant agencies to support their deliberation process. These scenarios include new proposals to use GNSS receivers with a multiple I/O port configuration function. Details of the each scenario presented by the Team will be discussed in 5.1.4.

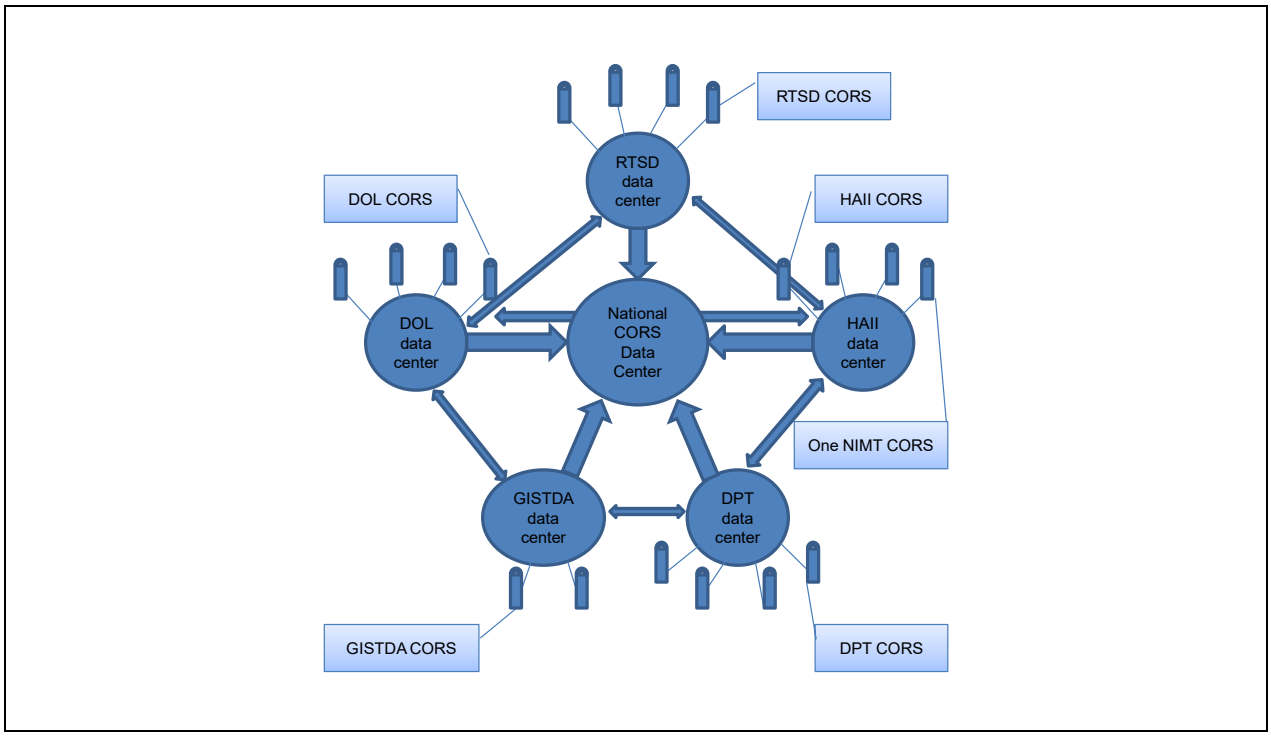


Fig. 5-5: Data Collection System– Scenario A

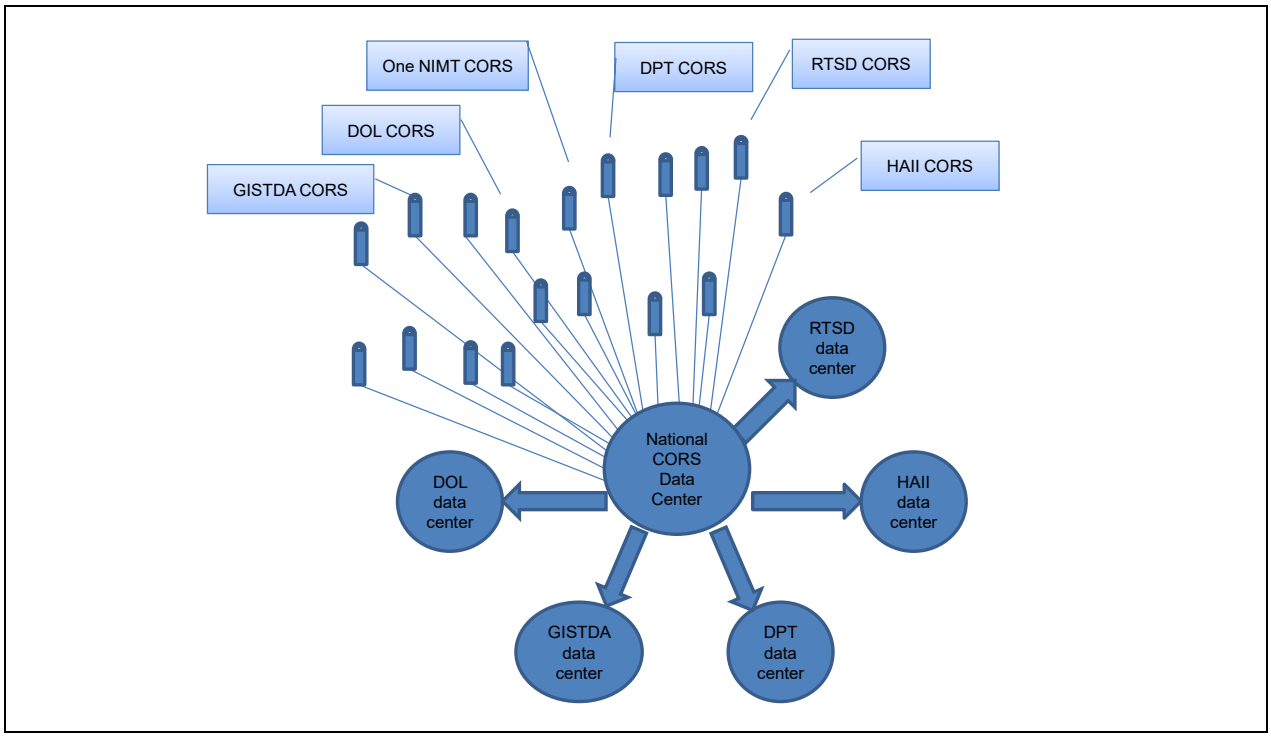


Fig. 5-6: Data Collection System – Scenario B

5.1.2. CORS establishment plan

Thai government agencies have established a total of 240 CORSs in the country. Combined with 47 CORSs to be established by DOL in the future, the CORS network will cover 287 stations in total.

When CORS data is released and utilized in Thailand, the inter-station distance of CORSs will largely affect the horizontal position precision of the survey result obtained through the use of network RTK, which will be the major use for the private sector. Manufacturers and Japanese data distributors have published technical data concerning the station-to-station CORS distance that is considered practical in network RTK. Although the contents of such publications vary somewhat, the data indicate that the required inter-station distance should be 70km or less when the required horizontal precision level is about a centimeter[22]. Moreover, as Fig. 2-2 shows, the standard deviation (STD) of horizontal component of network RTK is 13mm and that of vertical 25mm when distance between CORSs is 70km, meaning that 3 σ (3 times of STD) being equivalent to 99.7% reliability is 39mm (horizontal) and 75mm (vertical). This leads us to conclude the present deployment of CORSs is almost satisfactory.

5.1.3. Specifications of CORS equipment

While the current CORS coverage is satisfying the required inter-station distance for the most part, the Team, in anticipation of a need for additional CORSs in the future, deliberated on the appropriate standard CORS specifications that will satisfy the requirements for the CORS system configuration and achieve the purposes of establishing a CORS system. Consideration was given not only to the specifications of individual devices but also to other matters including installation method/place, measures to protect natural environment and safety measures.

When specifications of GNSS receivers and GNSS antennas are considered, special attention should be paid to whether the specifications satisfy the needs of future CORS data utilization in Thailand and to QZSS-signal reception. In anticipation of additional Quasi-Zenith satellite deployment, consideration will be given to specifications of equipment that can receive an enough number of signals.

Moreover, consideration will also have to be given to equipment specifications that can minimize the maintenance cost so that CORS equipment can be operated in an efficient manner for a long time.

From the above-described viewpoints, consideration was given to the following matters concerning CORS standard specifications.

[22] The distance recommended by Trimble is 50km while that supposed by Topcon is 70 km.

Table 5-3: Consideration matters of standard CORS specifications

Equipment/item	Matters to consider for specifications
GNSS receiver	Types of satellites whose signals can be received, good records of use as CORS in Japan and Thailand, observation sampling rate, number and types of receivable signals, number of receiving channels, positioning performance of equipment, water/dust-proof performance, communication interface, data storage capacity, data recording method, output data format, battery performance, remote controllability
GNSS antenna	Antenna type, types of satellites whose signals can be received, antenna phase characteristics, water/dust-proof performance, measures against interfering radio waves
Tower	Height, material, securing method, wind resisting performance
Radome	Form, material
Data communication device	Communication method, communication speed, stability, good records of use in Japan and Thailand
Power supply regulator	Number of output lines, remote controllability, security measures
Storage box (if installed outdoor)	Internal dimensions, temperature control function, water/dust-proof performance, security measures
Installation method/place	Installation criteria for rooftop/wall surface/ground installation, overhead visibility criteria, presence of interfering radio waves, whether CORS can be permanently installed or not
Measures to protect natural environment	Measures against high/low temperature, rain, strong wind, dust, flood and lightening
Safety measures	Measures against vandalism, theft and destruction, information security measures

Source: Results of study by the Team

The results of deliberating the standard specifications based on the above are attached to the end of this report. It should be noted that product names are provided for reference as samples of equipment models that satisfy the standard specifications.

5.1.4. Possible scenarios to integrate CORS observation data into NCDC

NCDC Implementation WG (WG Chairperson: RTSD Director), under GNSS Subcommittee, is responsible for developing the data center plan whereas NCDC Management WG (WG Chairperson: RTSD Director) is in charge of implementing the plan. As of December 2019, FY 2020's budget for the establishment of NCDC has not been approved yet. Therefore, detailed specifications of NCDC equipment have not been planned or determined. Details have not been finalized, either, for each agency's CORSs that will provide observation data to NCDC, and feasibility of data provision will finally be determined according to each agency's policy.

The NCDC Management WG has been having concrete discussions for the establishment of NCDC since July 2019. This section examines possible scenarios to integrate each agency's CORS observation data into NCDC.

(1) Preconditions for integrating observation data into NCDC

There are several possible ways to integrate each agency's CORS observation data into NCDC, which will be examined based on the preconditions listed below.

- NCDC must be established as soon as possible.
- DOL and RTSD have signed a long-term O&M contract.
- R&D institutions of HII and GISTDA want to maintain their data centers.
- DOL, DPT, and RTSD who use CORS networks for their work cannot shutdown the existing CORS networks unless NCDC's operation is stabilized.

Base on the above preconditions, possible integration scenarios will be examined. Cloud servers may be applicable for NCDC servers for all of the ideas described below. However, possibilities of troubles specific to cloud services need to be bear in mind when considering using cloud servers.

(2) Initial idea of the Thai Government

In the initial idea proposed by the Thai Government, CORS real-time data will be sent and integrated via each agency's data center (central station) into NCDC. This method has already been adopted by the agencies, which are now exchanging data streams among themselves. The agencies are also planning to provide their own RTK services. In addition, a backup center for NCDC is being planned in another location to enforce redundancy.

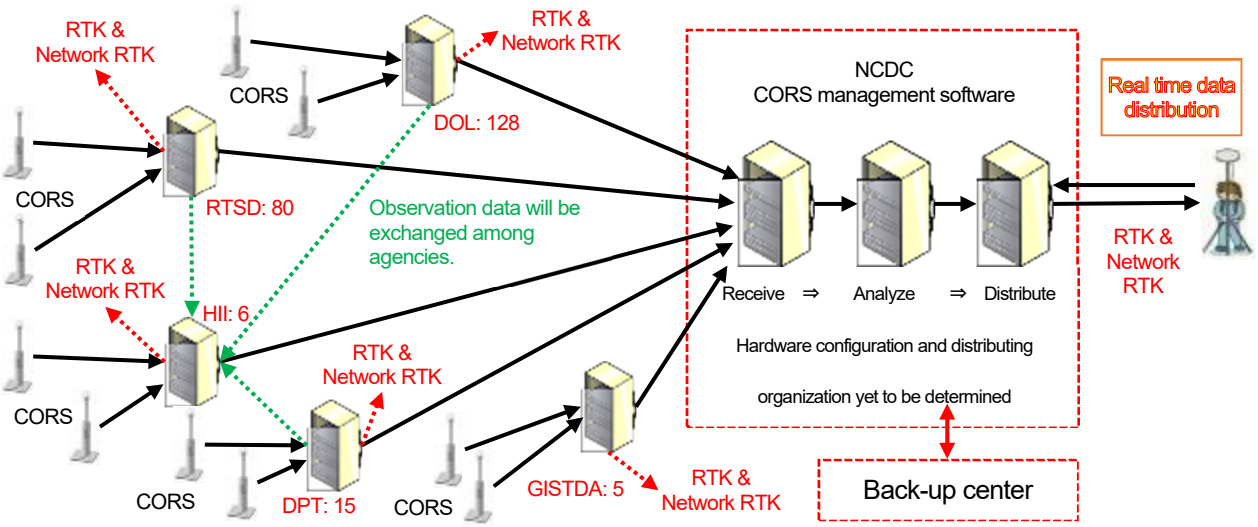


Fig 5-7: Thai Government's initial idea for integrating CORS data into NCDC

Source: Interview results edited by the Team

The table below outlines the result of evaluating the above data integration approach, which is expected to facilitate the establishment of NCDC because no major considerations need to be taken in the O&M plan of each agency. On the down side, O&M of NCDC will likely face some difficulties in the future.

Table 5-4: Evaluation of the Thai Government's initial idea

Pros	Cons
• Requires no major modification in each agency's CORS system. • Can be quickly implemented without giving much consideration to each agency's O&M contract. • Each agency can retain its own data center.	• If trouble occurs at the agency level, real-time data will not be sent to NCDC. • Increased data traffic, etc. may cause a delay in real-time data transmission. • There are still some concerns about data quality (due to different geodetic reference systems and coordinates). • No cost reduction can be expected. • Operational responsibilities to deal with problems are unclear. • Each agency will need higher-performance IT devices than their current ones. • NCDC cannot directly operate and monitor the CORSs.

Source: Based on the results of surveys conducted by the Team

(3) Scenario A proposed by the Team

Scenario A is similar to the streaming method between Japan's GEONET and the Japan Association of Surveyors (JAS). Observation data of all CORSs will be sent to the real-time server, which will be a part of NCDC. Real-time data (raw data) will be distributed via the real-time server to the data center of each agency. In this setup, NCDC and the agencies' data centers will be placed in an equal position.

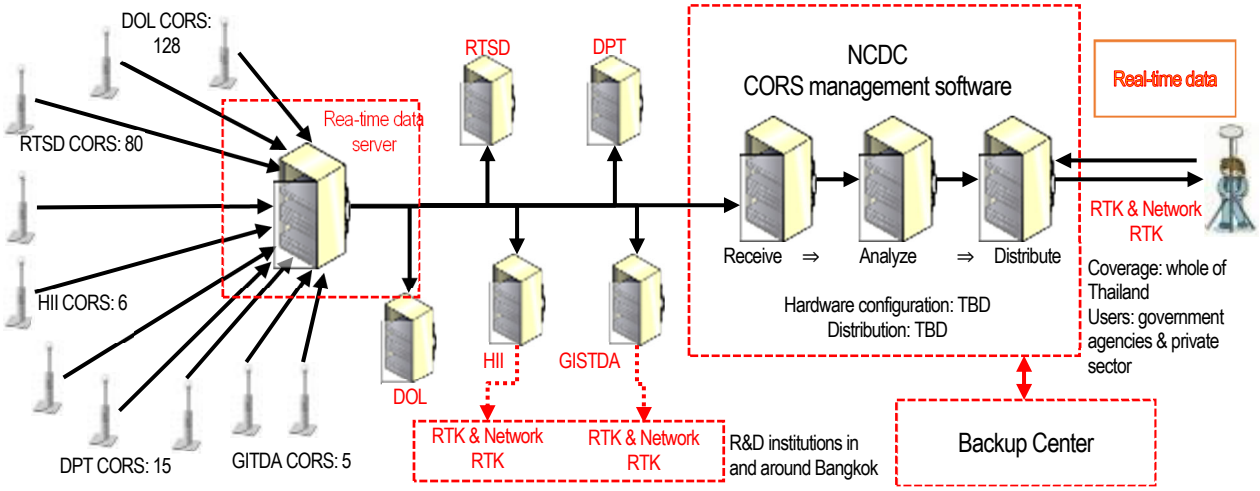


Fig. 5-8: Data integration method proposed by the Team – Scenario A

Source: survey results edited by the Team

It is desirable to shut down the agencies' data centers, except those with special purposes, one by one upon expiration of their respective O&M contracts.

The evaluation result of Scenario A is outlined in the table below. This method requires consideration for the O&M plan of each agency, which prevents quick establishment of NCDC. On the positive side, because

of the proven track record of a similar approach in Japan, it is expected to bring stability in the operation and maintenance of NCDC.

Table 5-5: Evaluation of Scenario A proposed by the Team

Pros	Cons
• Can reduce traffic of real-time data. • Low probability of delay in real-time data transmission. • All CORSs can be monitored centrally.	• Cannot be implemented until the O&M contract expires. • Real-time data server requires a high level of redundancy. • Needs to develop monitoring software.

Source: Based on the results of surveys conducted by the Team

（4） Scenario B proposed by the Team

Scenario B is an idea focusing on CORSs. Real-time data of each CORS will be transmitted simultaneously to NCDC and their respective agencies' data centers. In this setup, |GNSS receivers of CORSs will need a multiple I/O port configuration function. In addition, data transmission among the agencies may need to be restricted to reduce the traffic.

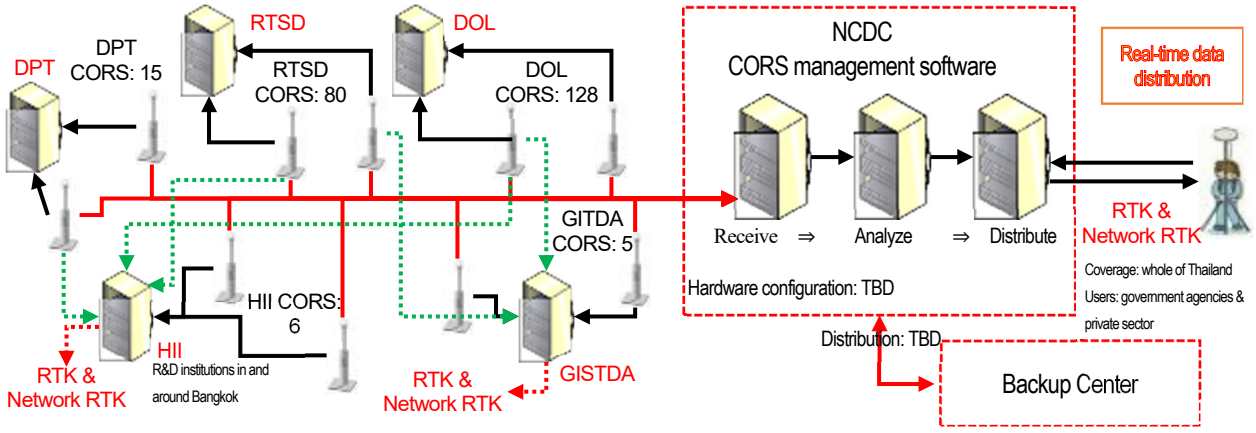


Fig. 5-9: Data integration method proposed by the Team – Scenario B

Source: Based on the results of surveys conducted by the Team

It is desirable to shut down the agencies' data centers, except those with special purposes, as well as simultaneous transmissions one by one upon the expiration of their respective O&M contracts.

The evaluation result of Scenario B is outlined in the table below. This method does not need to give much consideration to the O&M plan of each agency and allows quick establishment of NCDC. Stable operation and maintenance of NCDC can also be expected in future.

Table 5-6: Evaluation of Scenario B proposed by the Team

Pros	Cons
• Requires no major change in each agency's system. • Does not require higher-performance equipment for the agencies' data centers. • Can be implemented quickly without giving consideration to O&M contract. • R&D institutions can retain their data centers.	• GNSS receivers will need simultaneous transmission capabilities. • Real-time data traffic may increase. • Cost reduction cannot be expected. • NCDC cannot directly operate and monitor CORSs.

Source: Based on the results of surveys conducted by the Team

(5) Scenario C proposed by the Team

While similar to Scenario A, Scenario C gives precedence to NCDC over the agencies' data centers. In Scenario A, real-time data will be sent simultaneously to NCDC and the agencies' data centers whereas in Scenario C, observation data of all CORSs will be sent directly to NCDC. Real-time data (raw data) will be transmitted from NDCD to the each agency's data center.

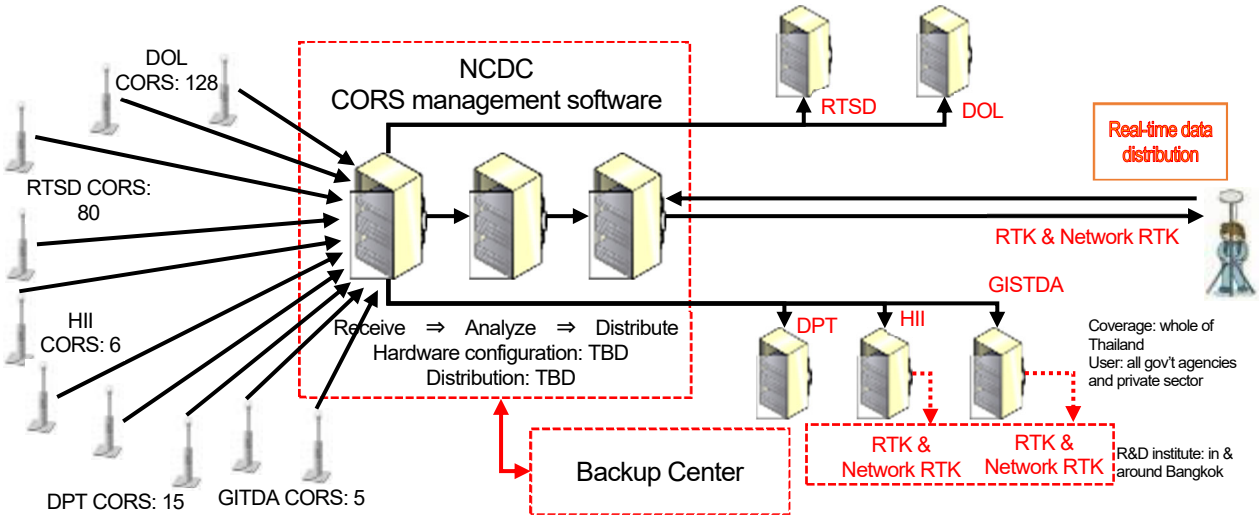


Fig. 5-10: Data integration method proposed by the Team – Scenario C

Source: Based on the results of surveys conducted by the Team

The evaluation result of Scenario C is outlined in the table below. This method requires consideration for the O&M plan of each agency, which prevents quick establishment of NCDC. On the positive side, it is expected to bring stability in the operation and maintenance of NCDC because of direct connection between the agencies' CORSs and NCDC.

Table 5-7: Evaluation of Scenario C proposed by the Team

Pros	Cons
• Enables the most stable and quick transmission from CORSs to NCDC. • Low probability of delay in real-time data transmission. • All CORSs can be monitored centrally.	• Cannot be implemented until the expiration of O&M contract. • Needs to develop monitoring software.

Source: Based on the results of surveys conducted by the Team

(6) A new idea proposed by the Thai Government

This idea was proposed by some Thai Government officials during the course of discussion with The Team. It adds a real-time data server to The Team's Scenario B and restricts simultaneous transmissions to and from CORSs to reduce the load on the GNSS receivers. It also takes into account the future configuration of NCDC.

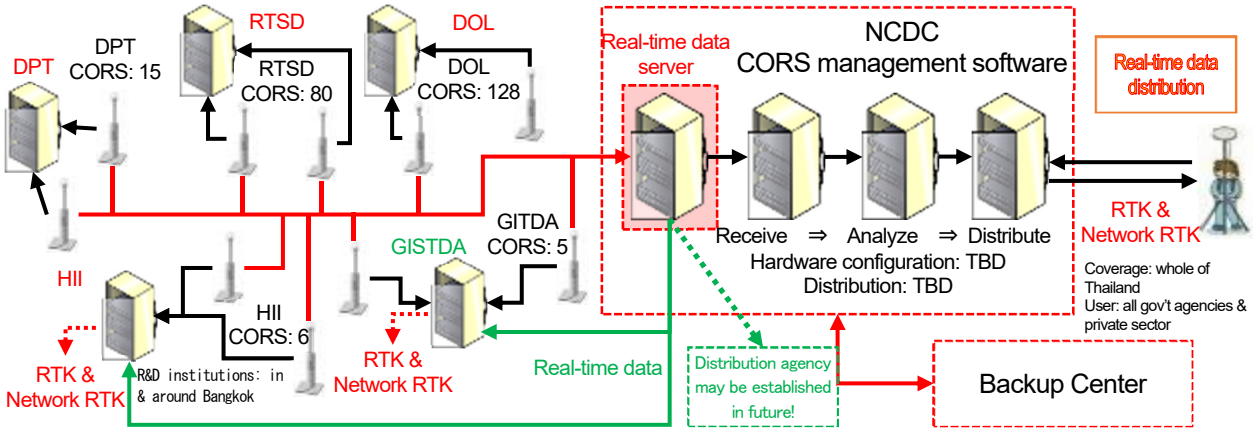


Fig. 5-11: New idea proposed by the Thai Government

Source: Drafted by the Team based on the results of discussion

The evaluation result of the newly-proposed method is outlined in the table below. This method does not need to give much consideration to the O&M plan of each agency and allows quick establishment of NCDC. In addition, it is expected to gradually bring stability in the O&M of NCDC as well as cost reduction in future.

Table 5-8: Evaluation of the new idea proposed by the Thai Government

Pros	Cons
• Requires no major change in each agency's system. • Can be implemented quickly without regard to the O&M contract. • NCDC can be built gradually. • R&D institutions can retain their data centers.	• GNSS receivers need to have multiple I/O ports. • Traffic of real-time data may increase. • Initially, NCDC cannot directly operate and monitor CORSs. • Need to develop monitoring software.

Source: Based on the results of surveys conducted by the Team

At present, none of the above scenarios and ideas have been finalized. The Thai Government plans to test various approaches to select the best one.

5.1.5. Specifications of equipment of the National CORS Data Center

This section outlines the points to be noted in the deliberation of the equipment configuration, etc. of the National CORS Data Center, which need to be considered in determining the equipment specifications.

（1） Ensuring of redundancy at the Data Center

An appropriate level of redundancy to ensure stable operation and service quality of NCDC needs to be determined while keeping in mind that excessive redundancy will create cost-related problems. The Thai Government should make a decision based on past experience in operating the CORS networks. How to manage risks should be clearly defined, as the existing O&M contracts do not set out specific measures or procedures for dealing with failures except requiring the service providers to restore services within a few days.

In determining an appropriate level of redundancy, it is important to consider the points listed below to avoid over-specification. In Japan, some commercial distributors are adopting a dual data center configuration (two locations) while many data centers are using a dual server configuration. GSI has a dual server configuration and has established a data backup center in a remote location. Although establishment of a backup center is also being considered for NCDC, adoption of a costly dual data center configuration should be examined carefully while taking into account the risk of earthquake, storm, flood, and other natural disasters, as well as twice the cost for CORS software if dual servers are to be installed.

Table 5-9: Points to consider in planning data center redundancy

Level	Redundancy options	Description (provisional)	Remarks
1	Dual data center	Local: Bangkok Remote: outside Bangkok Service continuity or backup only	To be investigated
2	Dual equipment (server, etc.)	Primary and secondary servers Hot standby or cold standby	To be investigated
3	Duplication of communication lines with CORSs	Main line: cable Sub line: wireless mobile network (3G/4G), etc.	Implemented
3	Duplication of CORS power supply	Main: grid power Sub: battery, etc.	Implemented
4	GNSS receivers with data storage capability	GNSS receiver data storage capacity (2 or more days)	Implemented

Note: Level 3 and 4 redundancies are must and have been implemented by the Thai Government.

Source: Based on the results of surveys conducted by the Team

Remote access from data centers to CORSs should also be secured though it is not a redundancy option. Remote access will enable quick restoration of CORS, etc. and is expected to reduce operational cost.

(2) Data center equipment configuration

An appropriate data-center equipment configuration needs to be determined from other perspectives aside from redundancy especially for the server equipment, a central unit of the data center performing the functions listed below, because the physical server configuration varies depending on what software is used and/or how the server is operated.

Real-time data will be captured 24/7, amounting to an enormous volume, which, however, do not need to be stored continuously. In Japan, all 30-second RINEX data (for post processing) have been stored since the observation began. However, such data can be stored in external media instead of the server hard drive so that the hard drive will not need an excessive storage capacity. Moreover, the number of users in the beginning will likely be small. Thus, the server specifications should not be excessive but should desirably be just enough for the first five years, at the end of which the server is expected to be renewed.

Table 5-10: Points to consider when determining server specifications

<table>
<tr><th>Server function</th><th>Points to consider</th><th>Remarks</th></tr>
<tr><td>Reception</td><td>Determine the number of physical servers appropriate for the number of CORSs (GSI has 1 physical server for every 200 or so stations).
Select an appropriate CPU occupancy rate for 24/7 operation.</td><td>Independent physical server</td></tr>
<tr><td>Application</td><td rowspan="2">Determine the specifications and number of physical servers appropriate for the operating conditions.</td><td rowspan="4">Determine the physical server configuration according to the software and analysis type.</td></tr>
<tr><td>Analysis</td></tr>
<tr><td>Database</td><td>Determine an appropriate real-time storage period (a few to several months).
Determine appropriate specifications and storage period of RINEX data.</td></tr>
<tr><td>RTK distribution</td><td>Determine the number of physical servers according to the number of RTK service users.</td></tr>
<tr><td>RINEX provision</td><td>Select appropriate protection measures against access from external networks.</td><td>Independent physical server</td></tr>
<tr><td>Backup</td><td>Determine appropriate specifications according to those of the database server.</td><td>Independent physical server</td></tr>
</table>

Source: Based on the results of surveys conducted by the Team

In addition to the above, an appropriate configuration of a load balancer, switches, etc. should be determined according to the level of redundancy and data processing volume of each server. Setting up a DMZ (DeMilitarized Zone) with a server should also be considered by studying the access points of external users who will be downloading RINEX data, etc.

(3) CORS management software

It is highly likely that NCDC will use a software package developed by a survey equipment manufacturer. Software license fees of world-class survey equipment manufacturers generally consist of a base fee and a variable fee depending on the number of stationary stations (CORSs) and/or mobile stations (RTK service users). Accordingly, the number of licenses should preferably be determined to satisfy a minimum requirement to reduce cost. While the license fee calculation methods vary from manufacturer to manufacturer, major software companies in EU and USA use virtually the same formula.

Table 5-11: Use status of CORS management software by Agencies

No. of licenses	DOL	DPT	GISTDA	HII	RTSD
Software	CHCNAV CPS	Leica SPIDER	Geo++ GNSMART	Geo++ GNSMART	Leica SPIDER
Stationary station	Unlimited	15	Unlimited	40	250
Mobile station	Unlimited	Unlimited	No setting	No setting	Unlimited
Current no. of users	Approx. 3,000	Approx. 300	Several	Several	Approx. 260

Source: Based on the results of surveys conducted by the Team

Required software functions are outlined in the table below. As CORS systems in Thailand are configured with devices made by different manufacturers and receive signals from multiple satellite systems, biases among different manufacturers and satellite systems need to be calibrated. It is especially important that the CORS system is compatible with not only GPS and GLONASS but also other satellite systems.

Table 5-12: Required functions of CORS management software

Item	Main functions
GNSS observation data	Collection/storage of observation data, communication supervision, format conversion, editing, etc.
Observation data analysis	Daily CORS coordinates calculation, displacement monitoring, etc.
RTK service	Generation/distribution of RTK correction data, etc.

Item	Main functions
RINEX service	RINEX data download service, observation data acquisition status, etc.
Monitoring	Management of CORS information, monitoring, remote maintenance, monitoring of observation data quality, etc.
User management	User registration, password management, access control, charging fees, etc.
Other	Backup, remote control of devices made by multiple manufacturers, etc.

Source: Based on the results of surveys conducted by the Team

Although a software package of GNSS equipment manufacturers usually contains most of the above functions, there may be a need to develop additional software or run separate software manually depending on the required specifications.

At present, the following points should be considered when developing additional software.

Table 5-13: Points to consider when developing additional software

Item to be developed	Points to consider
Real-time data server	Whether or not to install a real-time data server
User management	When the specifications of the software package cannot provide required functions.
CORS routine analysis (daily coordinates calculation)	When using Bernese GNSS Software.
RINEX service	When giving priority to user convenience and security.

Source: Based on the results of surveys conducted by the Team

For NCDC, use of the software developed by RTSD, especially the note-worthy coordinate calculation software based on Bernese should also be considered.

（4） Data format

In operating NCDC, attention needs to be paid to the format of data to be exchanged between CORS and data centers, as well as corrected RTK data and data for post processing.

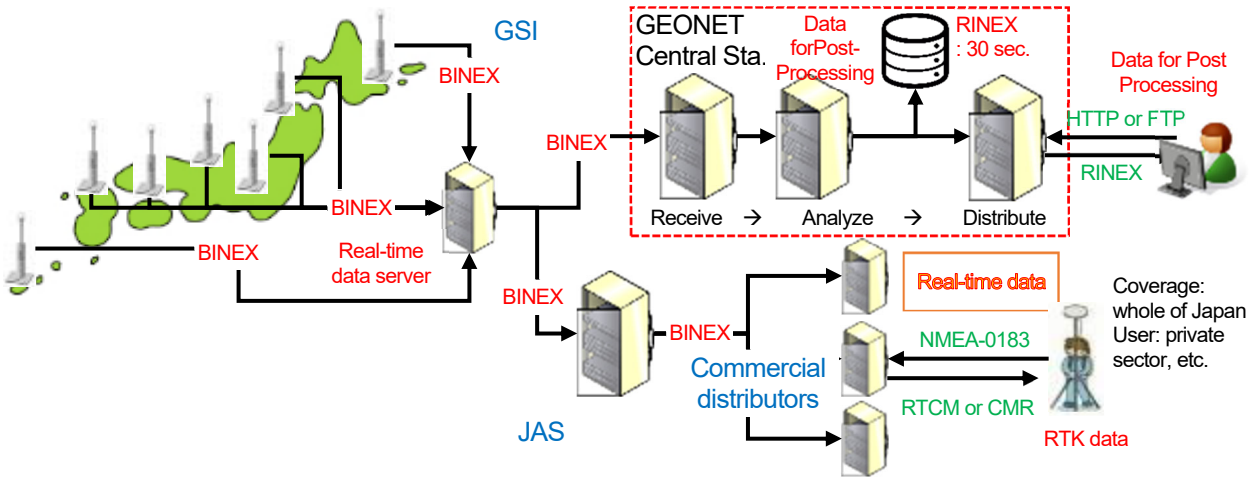


Fig. 5-12: Data format used in GEONET

Source: GSI, JAS, etc.

(a) Data exchanged between CORSs and data center

Data observed by each CORS will be sent from its GNSS receiver to NCDC. The data can be sent in a format unique to the GNSS receiver developed by the manufacturer. However, considering the use of GNSS receivers by different manufacturers as well as data processing and equipment renewal, etc. in the future, it is desirable to adopt an internationally standardized format. The Thai government agencies are already using international standard formats, which they will likely continue using.

A conceivable standard protocol may be BINEX developed by University NAVSTAR Consortium (UNAVCO), etc. or RTCM 3.2 MSM recommended by the Radio Technical Commission for Maritime Services (RTCM). Japanese GEONET adopted BINEX because of its superior carrier phase performance at that time and has since been using BINEX. Today, RTCM format is more popular than BINEX despite the bigger data size.

(b) RTK correction data, etc.

Use of an internationally accepted standard, instead of unique formats developed by GNSS equipment manufacturers, is also recommended for RTK correction data. Generally, the RTCM format is used.

Table 5-14: RTCM format

Version	Release	Description	Constellations
RTCM 2.3	Aug. 2001	A format recommended by RTCM for DGNSS services, used widely around the world.	GPS, GPS+GLONASS
RTCM 3.0	2004	More efficient alternatives to RTCM 2.3 (data	GPS, GPS+GLONASS

Version	Release	Description	Constellations
RTCM 3.1	2006	compression, etc.)	
RTCM 3.2	Feb. 2013	Offers more accurate positioning, supports multiple GNSS constellations	GPS, GLONASS, Galileo, QZSS, BeiDou, SBAS

Source: RTCM, etc.

The CMR format developed by Trimble of the United States is another de-facto standard used by many GNSS equipment manufacturers. It should be noted, however, that CMRx, which supports multiple GNSS constellations, has yet to be released to the public.

Table 5-15: CMR format by Trimble

Format	Release	Description	Remarks
CMR	1992	Developed for early GPS-RTK format	
CMR+	1997	An expanded version of CMR (for GPS, GLONASS)	Released in 2005, supports GLONASS
CMRx	2009	Supports all GNSS systems	For use by Trimble only, not released to the public.

Source: Trimble

NMEA-0183 developed by National Marine Electronics Association (NMEA) is the most commonly used protocol in communication between mobile stations and data centers (to report the positions of mobile stations).

In addition, Ntrip (Networked Transport of RTCM via Internet Protocol) is recommended for distributing correction data. Ntrip is a protocol for streaming correction data and GNSS data between data centers and mobile stations over the Internet in accordance with the specification published by RTCM.

(c) Data format for post processing

RINEX (Receiver Independent Exchange Format) is an international standard data format for post processing. RINEX was developed by the Astronomical Institute of the University of Bern in Switzerland and is now jointly managed by the International GNSS service (IGS) and RTCM Special Committee 104 (RTCM-SC104). RINX 3.04, the latest version, was released in November 2018.

5.2. Consideration of the O&M system for the CORS system

5.2.1. O&M of CORSs

Consideration will be given to the CORS O&M plan for the O&M of the entire CORS system. In Thailand, multiple government agencies have established their CORS systems. Their O&M are currently planned and

implemented according to each agency's policy. However, for the integration of data centers and efficiency improvement of the operation and management of the entire CORS system, the integration of O&M work should be considered. While integration of such work will help reduce costs by economy of scale, it may take longer to conclude an agreement because it requires coordination of all relevant agencies. Coordination will also be required about burden allocation by each agency and about the agencies' O&M policies that are different because their major uses are different. More specifically, there is a difference in required recovery time between the agencies whose major use is distribution of high-precision real-time correction data to private companies and the agencies who use the service for long-term research.

Below listed are the pros and cons of integration of operation and management.

Table 5-16: Pros and cons of integration of CORS O&M

Pros	・ Labor cost for O&M can be reduced. ・ Communication cost and electricity cost can be reduced by economy of scale. ・ Maintenance cost can be reduced by economy of scale if maintenance is outsourced. ・ Procurement cost for consumables can be reduced. ・ O&M know-how can be easily accumulated.
Cons	・ It takes time to make arrangements and reach agreement about cost and workload allocation among the agencies. ・ It takes time to coordinate O&M policies among agencies.

Source: Results of hearing survey by the Team

Points to consider in planning CORS O&M are listed in the table below, which was compiled after investigating the O&M services provided in Japan and interviewing the personnel of the Thai government agencies. Special attention was paid to identifying issues with CORS O&M faced by the Thai government agencies and incorporating measures against these issues into the plan. Planning is also required as to how to carrying out O&M for the existing equipment, including how to secure the funding needed therefor, after expiration of maintenance contracts with private contractors, by which the existing equipment is currently covered. Moreover, even with proper maintenance, equipment will need to be renewed in 7 to 10 years. Renewing the equipment all at once would not be practical. Planning is needed also for selecting the CORS sites to be renewed each year, as well as securing budget for the renewal.

Table 5-17: Matters to consider concerning the CORS O&M plan

Category	Matters to consider
Manpower/structure	Response at normal time/time of failure, weekday/holiday, during day/night Communication/chain of command at the time of failure Clarification of roles and responsibilities
Maintenance cost	Labor cost Communication cost, Electricity cost, Consumables cost Periodic inspection cost Failure response cost
Funds	Yearly budget and budget securing method
Frequency of maintenance	Levels of frequency determined by degree of importance Levels of frequency determined by natural conditions, etc. Consideration of remote maintenance items
Failure response	Setting of degrees of urgency, Setting of recovery targets
Outsourcing	Consideration of outsourcing for each implementation item Consideration of security
Equipment replacement at the end of life	Setting of standard life for each equipment Failure cause investigation Consideration of equipment renewal cost and funding
Securing overhead visibility (tree trimming)	Setting of overhead visibility criteria Identification of risks for each CORS and consideration of measures Consideration of remote surveillance methods, such as installation of overhead surveillance cameras
Maintenance of structures	Monitoring of degradation of structures due to aging and vegetation growth Estimation of maintenance cost
Relocation of CORSs	Identification and consideration of risks for each CORS Various actions for relocation (procedures for permission, coordinate calculation, publication, operation)
Response to inquiries	Response to inquiries about CORSs Response to inquiries from maintenance company Development of a response manual

Source: Results of study by the Team

5.2.2. O&M of the national CORS Data Center

NCDC Management WG, under GNSS Subcommittee, assumes a role in establishing and implementing a plan for the O&M of NCDC. However, NCDC has not been established yet and the details are also yet to be determined.

（1） O&M status of each agency

This section sorts out the current O&M status of each agency in preparation for determining an appropriate O&M structure for NCDC.

DPT and RTSD have signed a multi-year blanket contract that covers the operation of the data center,

periodic inspections of CORS, response to trouble, software maintenance, consumable supplies, telecommunication and electricity charges, and repair parts, etc. Stable and smooth operation is also required under the contract, and replacement of equipment with different specifications from the original ones may be necessary. In contrast, DOL is the main administrator of its CORS system and has signed a blanket O&M contract with an outside vendor that takes care of all aspects of O&M except for the operation of its data center, which is carried out primarily by DOL on a 24/7 basis. In case of trouble, DOL can ask for support from the manufacturer's agent.

R&D institutions such as GISTD and HII are carrying out O&M on their own for the most part without concluding a blanket contract. They have minor agreements that cover the maintenance of software and GNSS equipment.

Table 5-18: O&M status of each agency's CORS system

Item	DOL	DPT	RTSD	GISTDA	HII
Purpose	Surveying / geospatial services			R&D on the use of CORS	
Coverage	Whole of Thailand			In and around Bangkok	
No. of CORSs	134	15	80	2	6
Administrator	DOL	Manufacturer's agent		GISTDA	HII
O&M	DOL+ agent	Blanket contract with agent		GISTDA	HII+ agent
Contract period	7 years	1 year	5 years	3 years (Software only)	5 years

Source: survey results edited by the Team

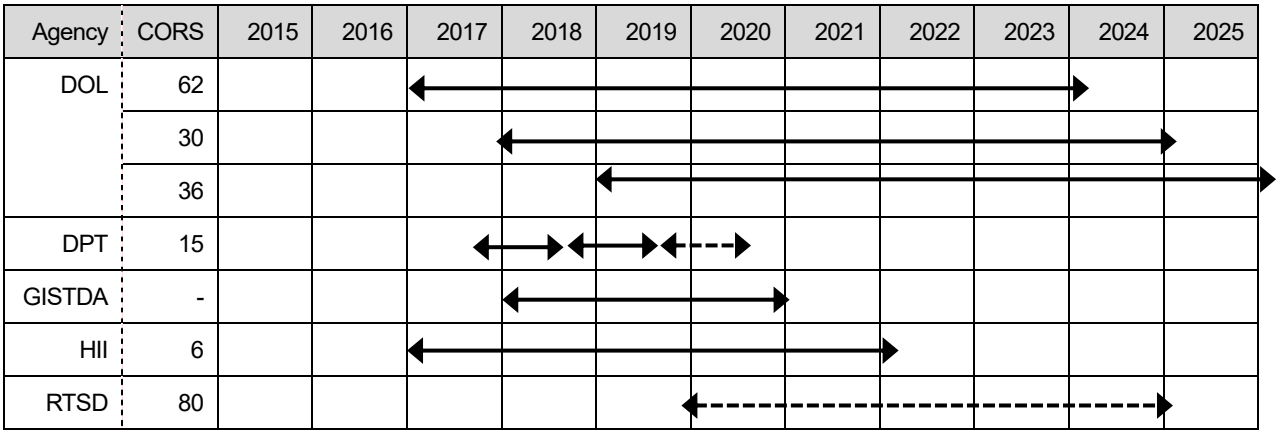


Fig. 5-13: O&M contract of each agency's CORS system

Source: survey results edited by the Team

（2） Position of NCDC and personnel assignment

By resolution at the National Geo-Informatics Board (NGB) meeting in May 2018, RTSD was entrusted to establish NDCD as a new project for FY2019 (October 2018 – September 2019) and has requested FY2020 budget allocation from the state to procure the NCDC equipment. The request was being reviewed by the Government Procurement Board under the Ministry of Digital Economy and Society as of December 2019. NCDC will be situated within RTSD's areal photogrammetry area (on Lat Phrao Street in the Bangkok Metropolitan Area).

While NCDC Management WG comprised of multiple government agencies, etc. is responsible for O&M of NCDC, the above indicates that RTSD has a greater responsibility for implementation. However, which organization NDCD will belong to has yet to be determined. The Thai Government needs to examine if NCDC, as a physical organization, can be placed under the jurisdiction of a meeting body such as NGB and GNSS Subcommittee.

The next first step toward establishing a concrete O&M structure for NCDC will be to determine NCDC's organizational position and assignment of government personnel.

（3） O&M personnel structure

In planning O&M for NCDC, its personnel structure needs to be determined first. The key is how to utilize external human resources from the private sector in addition to Thai government personnel in carrying out O&M.

The chart below shows how the Japanese GEONET central station, which operates 24/7, is employing external personnel. Detailed terms and conditions of personnel outsourcing are not set out in contracts. The contractors are assigning personnel at their own discretion in accordance with the essential provisions of the contracts. Usually, three or so persons are working during the day on weekdays.

External personnel	Sun	Mon	Tue	Wed	Thu	Fri	Sat	Remarks
Managers		← - -	- -	- -	- -	- - →		Part-time, standby for phone calls
Software		← - -	- -	- -	- -	- - →		
Security		←	—	—	—	→		Full-time, standby for phone calls
Engineers	←	—	—	—	—	—	→	3 shifts with 4 engineers, at least 1 engineer in every shift.

Fig. 5-14: Personnel deployment at GEONET central station

Source: GSI

GEONET outsources mostly ICT system engineers, who need to have some knowledge of surveying and

GNSS, as they are entrusted to provide analysis services as well. The degree of such knowledge required of external engineers will depend on the type of services commissioned by NCDC.

Table 5-19: Roles and duties of personnel outsourced by GEONET

External personnel	Main roles and duties
Software	• Maintain the O&M system to ensure proper operation of software. • In case of software/hardware failure, identify the cause and restore normalcy. • Gather information related to hardware support. • Gather and report information provided by IGS and other GNSS-related agencies.
Security	• Maintain information security of GEONET central station, etc. • Collect HTTP, FTP, and other logs; user statistics; monitor web pages. • Create network diagrams and other documents; manage IP addresses and account information. • Gather information and make proposals regarding licensing and security.
Engineers	• Download observation data. • Monitor data collection, respond to trouble and restore CORS. • Monitor the operation of hardware and software. • Convert and distribute observation data. • Support restoration of failed CORS.

Source: GSI

At GEONET, RTK services are provided by private companies, which should be taken into account in drafting a personnel plan for NCDC. Especially, user support services may need extra staff depending on the expected number of users.

(4) O&M management system

If NCDC's operation is to be outsourced, a system to manage outsourced services needs to be considered as well. It is especially important to clearly define the division of responsibilities between the internal and external personnel, as well as the chain of command in daily operations and in case of failure.

At GSI, the Geodetic Observation Center has the overall responsibility for O&M work of GEONET, of which operation of GEONET is taken charge by the CORS Division.

Table: 5-20: Organizational structure of GSI Geodetic Observation Center (as of January 2019)

Title/Division	No. of persons	Roles, duties, etc.
Director General	1	Oversees the entire operations of the Center.
Satellite Geodesy Div.	12	General affairs, planning, budgeting, technical development/maintenance.
CORS Div.	16	Operates/sophisticates GEONET.
Crustal Movement Monitoring Div.	10	Monitors crustal movement, provide data.

Source: GSI

Responsibilities of the CORS Division staff are outlined in the table below. It should be noted that their primary responsibility for O&M is decision-making on such matters as relocation of CORS and renewal of equipment, and actual work is carried out by outside vendors.

Table 5-21: Roles of CORS Division Staff

Operations	Main roles
Daily operations	• Check to see if all servers, etc. operate properly. • Check to see if all CORSs operate properly. • Share all failure information. • Request to post notices of suspended observation, etc. on the Web site • Request to reanalyze routine analysis. • Share and request to register/delete information about installed/removed observation stations. • Coordinate on-site and data-center operations.
O&M	• Calculate CORS survey results and phase characteristic models. • Suspend CORS survey results (decision making). • Relocate CORS (decision making). • Repair/renew CORS equipment (decision making). • Conduct on-site inspection of CORS. • Cut/trim trees around CORS (decision making). • Coordinate routine analysis; in case of failed analysis, identify the cause and solve the problem. • Adapt to new technologies and specifications. • Respond to inquiries.

Note: crustal movement monitoring and semi-dynamic corrections are carried out by other Divisions.

Source: GSI

（5） Services to be provided by NCDC

Services to be provided by NCDC to other government agencies and private companies will include distribution of RTK correction data and downloading of RINEX data (for post processing). Disclosing the operational status of each CORS should also be considered as part of user services.

Table 5-22: Matters to consider in determining the CORS service content

Services	Matters to consider
RTK	• Service level and content (including service hours, etc.) • User support (user registration, password management, response to inquiries, etc.)
RINEX	• Data specifications (format, data acquisition interval, combination of satellites, time, etc.) • User support (user registration, password management, response to inquiries, etc.)
Other	• Disclosure of CORS properties (station name, receiver/antenna name, location, coordinates, etc.) • Disclosure of operational status of CORS (in operation, suspended, scheduled for suspension, decommissioned, etc.) • Observation data acquisition status of CORS (disclosure of missing data)

Source: survey results edited by the Team

（6） Development of an O&M plan

To operate and maintain NCDC properly, an adequate O&M plan should be prepared by incorporating the above matters, as well as such essential items as security measures, periodic inspections, response to trouble, and equipment renewal plan. It is especially important to consider adding extra security. Moreover, preparation of standard operating procedures, manuals, and report/record forms should also be considered.

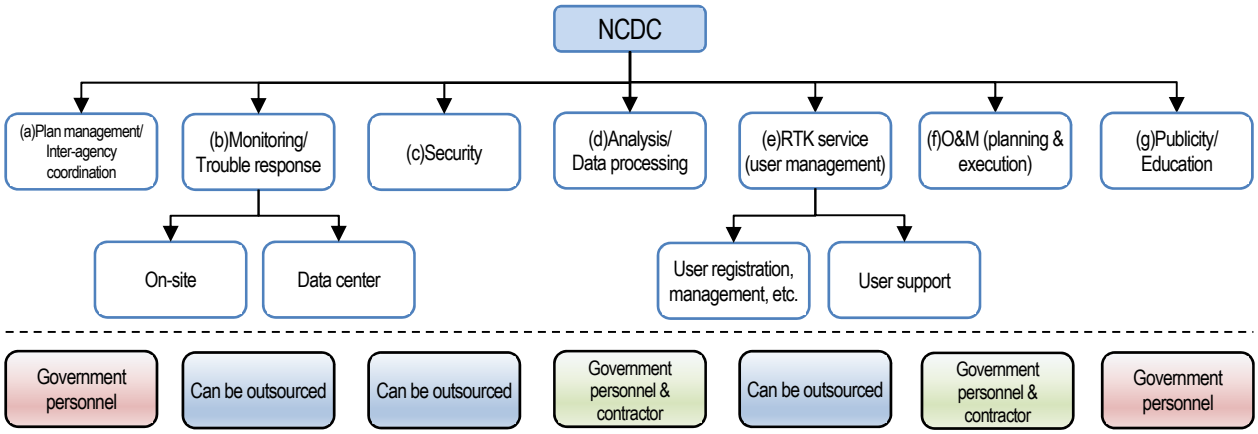
（7） Monitoring and restoration of CORS

After the establishment of NCDC, the existing CORSs will likely continue to be managed by their respective government agencies for a while because of the current O&M contracts still in effect. In this case, it will be necessary to coordinate with each government agency as to how to monitor and maintain their respective CORSs, report trouble, restore to the normalcy, etc.

5.2.3. Roles and functions required of NCDC

Based on the above points, roles and functions NCDC is expected to perform, as well as assignment of

government personnel and external contractors, are being considered. Outsourcing is especially recommended for ICT-related services. O&M work of CORS is included in NCDC's roles and functions on the assumption that it will be taken over by NCDC in future.



Note: The above functions and roles are merely suggestions made by the Team and need further refinement. In case of outsourcing, a chain of command among the government personnel and external contractors needs to be established.

Fig. 5-15: Roles and functions required of NCDC

Source: survey results edited by the Team

Generally, services involving decision-making should preferably not be outsourced. Accordingly, it would be difficult to outsource services related to plan management, O&M, and publicity/education. It is recommended that outsourcing should be limited to daily routine work.

Functions and attention points of each role are described below, and current situation of each agency's O&M is summarized in Table 5-23.

(a) Plan management / Inter-agency coordination

This function manages overall planning of NCDC, including budget planning and execution. It also serves as a liaison with GNSS Subcommittee and other government agencies and acts as an international contact point for matters related to IGS projects, etc. in Thailand.

(b) Monitoring / Trouble response

This function monitors the operational status of CORSs and data center on a daily basis. Trouble at CORS will be attended to in collaboration with on-site staff. Whether or not a 24/7 workforce is required needs to be determined. While this function is relatively easy to outsource, a chain of command and the roles of external contractors need to be clearly defined.

(c) Security

This function is responsible for implementing daily security measures on software and hardware as well as for establishing a structure to prevent illegal access to NCDC. Outsourcing security is also relatively easy. See the details in the section about outsourcing (security) of GEONET.

In addition, an overall security policy of NCDC needs to be established and enforced, which should be done by government personnel.

(d) Analysis/Data processing

This function analyzes and processes data received daily by CORSs, which can be outsourced as well. However, government personnel should make the final decision on the results of data analysis and carry out advanced analysis by themselves.

(e) RTK service (user management)

This function provides network RTK and other services to government agencies and private companies, which would include monitoring of service provision, user registration, user support, and trouble response. It also needs to make an announcement when CORS is to be shut down for maintenance, etc. In addition, an emergency contact system needs to be developed to maintain communication with external organizations in case of power outage and/or telecommunications failure.

(f) O&M (planning and execution)

This function prepares annual plans for CORSs and NCDC and procures/renews equipment periodically according to the equipment renewal plan. It also evaluates new technologies and considers adoption thereof, as well as relocation of existing CORS and establishment of new CORS, as necessity arises.

(g) Publicity/Education

This function conducts publicity and educational activities regarding NCDC and CORS to disseminate CORS-related technologies in the private sector, etc. It also considers participation in and organizing of workshops and seminars. Outsourcing this function is not recommended, as it also needs to serve as a help desk to respond to inquiries from the public.

Table 5-23: Current situation of O&M of each agency

NCDC Function	DOL	DPT	RTSD	GISTDA	HII
(a)Plan management / Inter-agency coordination	DOL	DPT	RTSD	GISTDA	HII
(b)Monitoring / Trouble response	DOL	Contractor	Contractor	GISTDA	HII
(c)Security	DOL	Contractor	Contractor	GISTDA	HII
(d)Analysis/Data processing	Contractor (when implemented)	DPT	Contractor (plan)	GISTDA	HII
(e)RTK service (user management)	DOL	Contractor	Contractor	GISTDA	HII
(f)O&M (planning and execution)	DOL & Contractor	Planning: DPT Execution: Contractor	Planning: RTSD Execution: Contractor	GISTDA	HII& Contractor
(g)Publicity/Education	DOL	N/A	TBD	GISTDA	HII

Source: survey results edited by the Team

5.2.4. CORS O&M Plan

Following is an O&M plan proposed by the Team considering the current status and issues at the present time.

（1） Objectives

1) Integrate and centrally manage the operation and maintenance of all CORSs (supposedly 287 stations) owned by the agencies by around 2025 (in 5 years).
2) Renew the equipment every 7 years or so.

（2） Challenges

1) Unified execution for O&M of all CORSs is difficult because O&M is planned and executed by each agency according to its own policy.
2) Overall optimization for O&M of all CORSs is difficult because budgets and organizations for O&M are allocated to and managed by each agency.

(3) Required activities

(a) For objective 1)

- Form a consensus among the relevant agencies on integrating budget allocation and execution for O&M of all CORSs into NCDC.
- Based on the consensus, NCDC will centrally manage O&M of all CORSs, including budget allocation and execution. All services under incumbent O&M contracts between the agencies and their respective external contractors will be integrated upon their expiration.
- Data transmission method from each agency's CORSs to NCDC will be determined based on the result of data streaming tests currently underway.
- Telecommunication lines will be replaced with those compatible with the above transmission method. An appropriate selection should be made to reduce cost by concluding a bulk contract at the time of integration.
- Prepare an O&M manual for routine maintenance of CORS equipment and sites, based on which to carry out periodic maintenance activities.
- Collect information about and learn new technologies and adopt them as necessary.

(b) For objective 2)

- Renew instruments (receivers and antennas) successively as they reach a point where they have been in operation for over 7 years.
- To level out expenditures over time, such expensive items as CORS receivers and antennas should be renewed at a rate of about 41 units per year. If more units need to be renewed, choose items according to the degree of aging and deterioration.
- Try to collect information about and learn new technologies, and incorporate the knowledge in equipment renewal as needed.

(4) Necessary expenses

- According to DOL's current contract, 6,666,000 baht per year will be needed for telecommunication lines (refer to 3.3.1. (2) (b)).
- For equipment renewal, 25,000,000 – 38,000,000 baht is estimated to incur to renew 41 receivers (20,000 – 30,000USD per receiver). However, the expenses will likely decrease over time, as the price of receiver is expected to go down in future.
- The cost of renewing 41 antennas is estimated at 12,500,000 – 19,000,000 baht (10,000 – 15,000USD per antenna). Price reduction cannot be expected because CORSs use highly-specialized products called choke ring antennas. However, the renewal interval of seven years may be extended, considering the fact

that the renewal interval of antennas is longer than that of receivers in GSI's O&M.

- Additional expenses will incur for outsourcing periodic CORS equipment/site maintenance as well as repair services in case of failure or breakage.
- Other expenses will include those for renewing as necessary telecommunications and power-supply equipment, batteries, cables, pillars, equipment storage, etc.
- It is assumed that funds for these expenses (44,000,000 – 64,000,000 baht per year or more) will be provided by the state government, as data will initially be distributed free of charge. In future, the expenses may be partially covered by fees collected from data users, for which, however, 1,000 or so users will be needed (see 3.3.1.(2)(b)).

(5) Departments in charge

- Of the internal departments of NCDC proposed by the Team, "Plan management /Inter-agency coordination", "Monitoring /Trouble response," and "O&M (planning and execution)" will take charge of these activities according to their respective roles and functions.

5.2.5. Data Center O&M Plan

Following is an O&M plan proposed by the Team considering the current status and issues at the present time.

(1) Objectives

1) Present a service-level agreement (SLA) (e.g. 99% operation rate) for at least the same number (approx. 3,000) of DOL data users and maintain that level.
2) Expand the user base and increase the number of users (set a numerical target for 2025 around 1 year after the start of service).
3) Renew the equipment every 7 years or so.

(2) Challenges

1) Position coordinates of CORS are not referred to the unified geodetic reference.
2) Position coordinates of geospatial information must be referred to or transformable to the same geodetic reference for CORS to promote the utilization of CORS. However, the current situation is not.
3) NCDC will face difficulties to take prompt actions when it finds changes in the position of CORS and/or abnormal behaviors in CORS data under the current situation where O&M of CORSs is not integrated into NCDC.
4) NCDC will also face difficulties to define the quality requirements of data appropriate for presenting the

SLA under the current situation where O&M of CORSs is not integrated into NCDC.

5) Securing personnel in NCDC engaging in daily information security measures and tools for information security are required.
6) Securing personnel and improving the quantity and performance of equipment in NCDC are required corresponding to the increasing number of users.
7) Building the organizational structure is required, where new technologies on GNSS are studied and learned so that the research results are incorporated in works in NCDC as well as transferred to private sectors.

(3) Required activities

(a) For objective 1)

- Recalculate the coordinates of CORS based on the (newly) unified geodetic reference.
- Ensure that the CORSs are operated and maintained as planned while establishing unified geodetic reference for CORS and other geospatial information and developing/providing tools needed to transform position coordinates.
- Carry out data analysis on a routine basis to maintain, and update as necessary, the coordinates of each CORS and if any abnormality is found, identify the cause and make necessary corrections promptly. In addition, develop tools for these activities.
- Define the quality requirements of real-time data appropriate for the SLA and provide data that meet the requirements by monitoring the data on a daily basis and developing necessary tools.
- Ensure that security measures are implemented on a daily basis, including software update and communication traffic monitoring, to protect information assets and user information by blocking illegal access and developing necessary tools.
- Respond to inquiries from users on a daily basis and provide information to users promptly in case of abnormality or failure.
- Try to collect information about and learn new technologies, and incorporate the knowledge in developing tools and improving systems.

(b) For objective 2)

- Prepare and provide users' manuals for the users in the surveying and other sectors.
- Expand the user base beyond the surveying sector through publicity and educational activities.
- Relax the requirements for users to allow foreign individuals and companies to use the services.

(c) For objective 3)

- Renew devices (servers and discs) successively as they reach a point where they have been in operation for over 7 years.
- Increase the quantity and upgrade the performance of equipment according to the increasing number of users.

(4) Necessary expenses

- Expenses for telecommunications lines are included in CORS-related expenses.
- Brand-new equipment will be procured for the data center, which means renewal expense will not incur initially for several years.
- Additional expenses will incur for outsourcing periodic hardware/software maintenance services, repair services in case of failure or breakage, and development of various tools.
- The amount of necessary expenses will likely be smaller than that for CORS, but will require expenditure from the state government as part of its annual operating budget.

(5) Departments in charge

- The seven departments of NDCD proposed by the Team will take charge of the activities according to their respective roles and functions.

5.3. Consideration of the human resource development plan required for the operation of the CORS system

5.3.1. Development of human resources required for the operation CORSs

Normal operation of CORSs requires accurate daily O&M as well as appropriate emergency responses to failures. A hearing survey was conducted about the concrete contents and details of the actions currently taken and issues related to Thai government agencies' CORS operation, and the areas where capacity development is required will be identified from the above-mentioned two viewpoints.

Table 5-24: Capacities required for the operation of CORSs

Areas of focus	Contents
Facility maintenance	On-site inspection ・Understand the check points. ・Learn how to do simple maintenance work that does not require specialized services. Remote monitoring ・Check surveillance camera and sensor information.
Skills and technologies	Become proficient at operating new/existing equipment and software. Investigate/evaluate new technologies.
GNSS data monitoring	Monitor GNSS signal reception ・Reception of radio waves ・Intensity of radio wave reception ・Noise ・Delay, etc. Monitor GNSS signal reception quality ・Missing data ・Validity of data content
Communication data monitoring	Monitoring of data sent from CORS ・Reception ・Signal intensity ・Noise ・Communication speed ・Delay ・Packet loss ・Retries ・Detection of illegal access
Troubleshooting and restoration	Speculate where the failure occurred. ・On the CORS side or data-center side? Identify the cause. ・External factors (weather, accident, etc.) or internal (see below)? Make a decision as to how to restore. ・Is the failure temporary or requires equipment replacement, etc.? Identify internal factors. ・Operational error or human error? ・Is it related to equipment, such as antenna, receiver, and computer? ・Is it related to software? Restoration ・Determine whether or not it can be solved internally. ・Notify relevant agencies and users. ・Protocol for temporary system shutdown ・Restoration work

Source: result of deliberation by the Team

These are the capacities required of personnel whose role is Monitoring/Trouble response and O&M (planning and execution) covered in the NCDC system proposal made by the Team in 5.2.3.

5.3.2. Development of human resources required for the operation of the NCDC

According to the results of the interviews with the government agencies, there is only a small need for technology transfer for daily activities for data center operation, including IT technologies and failure response. Agencies outsourcing data center operation and agencies operating their own data center have different needs and measures for human resource development. However, they all have common needs for advancement of analysis, etc. and improvement of service provision. It is also confirmed that there are needs for research on the utilization and development of precise positioning data.

Moreover, it is also confirmed that many employees have completed Ph.D. or master's degree and have knowledge and experience in such fields as geophysics, geodesy, GNSS and IT although the situation is slightly different depending on agencies.

Table 5-25: Each agency's needs for technology transfer

Agency	Operation	Needs for technology transfer related to data center	Other needs
DOL	Own + some support	Interested in the operation of data center in general and semi-dynamic correction in particular.	-
DPT	Outsourced	No need for technology transfer related to data center operation	Utilization of GNSS data (MMS, etc.) Precision improvement of geospatial information
GISTDA	Own	Data center operation in general (excluding semi-dynamic correction, etc.), RTK service operation	Utilization of precision data Maintenance of CORSs
HII	Own	Analysis (daily coordinate calculation, integrated analysis with other agencies' data), service provision (IGS activities, provision to other agencies, web services, etc.)	Utilization of CORS Application to HII's R&D activities
RTSD	Outsourced	Analysis in general Highly interested in service provision and service improvement	-

Source: Based on the results of surveys conducted by the Team

(1) Needs for analysis techniques

The government agencies have experience in analyzing observation data of GPS and GLONASS. They are also highly interested in new satellite systems such as GALILEO and QZSS as well as new positioning signals such as L5, though they do not have much experience in using them. In addition, there is a need for low-cost single-frequency receivers.

Searching and studying new analysis techniques will also be beneficial to promoting the use of satellite positioning data in future. Introducing advanced techniques according to the present capacities of NCDC will be desirable from the standpoints of stabilizing its operation and promoting the use of data.

(2) Needs to promote utilization

Stable operation of NCDC is a prerequisite to promoting the use of satellite positioning data. Accordingly, capacity development of NCDC personnel will be needed in the ensuing technical cooperation project to ensure the stability of its operation and maintenance. Creation of a mechanism and rules is also needed to promote the use of data in the private sector.

In addition, transfer of advanced analysis techniques and applications is called for to promote the use of satellite positioning data, including, for instance, use of CORS for GNSS meteorology studies and infrastructure facility monitoring. To further promote the use among the private sector, conducting educational/promotional activities by NCDC, as well as seminars and workshops on the use of satellite positioning data, will also be helpful.

Table 5-26: Proposal for technical cooperation and capacity development

Output	Main activities
O&M structure and rules	Coordinate relevant agencies, draft plans, prepare manuals.
Mechanism and rules for NCDC utilization	Coordinate relevant agencies, draft guidelines, monitor the uses.
R&D of advanced analysis	Understand new analysis techniques, prepare training manuals, etc.
Promotion of use of satellite positioning data	Educational/promotional activities by NCDC, workshops/seminars, vitalization of private sectors.

Source: Based on the results of surveys conducted by the Team

(3) Challenges in operation of NCDC and the required human resource development

Based on the surveys so far, the following five points are sorted out as current challenges and the human resource development required to continue the operation and utilization of NCDC after it is constructed.

(a) Establishment of a stable CORS system management structure

At present, the organizational position of the NCDC and the assignment of personnel have not yet been determined (5.2.2. (2)). To achieve a stable management structure, a NCDC management system suitable for organizational structures found in Thailand should be examined and constructed with discussions on the NCDC system proposed by the Team in 5.2.3. In addition, an agreement should be reached between relevant organizations regarding what kind(s) of personnel each organization will (or will not) assign to NCDC members, as well as how to manage member personnel, including the training of new personnel. Furthermore, it will be necessary to clarify the organizational position of NCDC in the Government and establish a system.

(b) Integration of all organizations' CORS systems

As discussed in 5.2.1, the O&M of CORS is currently planned and implemented in accordance with the policies of each organization responsible for their installation. After the establishment of the NCDC, it will be necessary to integrate these to make O&M more efficient. To do so, it will be necessary to reach a consensus between the relevant organizations. Needless to say, it will be necessary to have the ability to coordinate interests between the organizations. Personnel with the knowledge and skills to formulate and implement a specific CORS integration proposal that can be agreed upon will also be essential.

Such personnel will be required to take on roles that include Plan management/Inter-agency coordination and O&M (planning and execution) covered in the NCDC system proposal made by the Team.

(c) Sharing and improvement of geodetic reference

ITRF2008 has been adopted as the geodetic reference by four of the five organizations in possession of CORSs. Thailand recognizes the need to unify geodetic references across all organizations and plans to do so in the future. The adoption of a new ITRF is under consideration for this unification. ITRF will be updated at an opportune time in the future. The issue of how to deal with geodetic references in Thailand will also arise in the future when this update is made. In addition, the unification of geodetic references is not only an issue on CORS but also a necessary issue for all geospatial information. In order to utilize existing geospatial information, it is important to transform the geospatial information held by all industrial, academic, and government organizations—not just those in possession of CORSs—into a unified geodetic reference, or to make such transformation possible. To do so, it is necessary to train personnel who have technical skills in developing transformation algorithms and software along with knowledge of geodesy.

Such personnel will primarily be needed as personnel responsible for Analysis/Data processing in the NCDC system proposal, but personnel responsible for Plan management/Inter-agency coordination and Publicity/Education will also require these skills to a certain degree.

(d) Training personnel to study analytical methods and promote them in the private sector, etc.

Multi-GNSS methods that integrate and use multiple GNSS satellites—without being limited to specific GNSS satellites—will be a major feature of GNSS analysis in the future. There is a type of constant error called bias among different types of GNSS data, and this causes a problem where the way of handling biases varies depending on the type of receiver and/or software. In addition to this problem, various problems exist in applied researches such as new analysis methods to improve positional accuracy and to ensure stable accuracy even in areas where radio wave reception is difficult (such as processing of new L5 signal, multipath mitigation techniques, and countermeasures against jamming and spoofing), GNSS meteorology, time synchronization, and infrastructure monitoring. It will be necessary to train personnel who can research the solutions to such problems. GNSS will see increased utilization in the private sector in Thailand in the near future, and it will be necessary to train such personnel at universities, national institutions, and public organizations. It will also be necessary for those personnel to promote research results in the private sector.

Such personnel are required not only for universities and research institutes but also as those responsible for Analysis/Data processing in the NCDC system proposal. And considering equipment O&M in response to the latest technologies, personnel responsible for O&M (planning and execution) will also require these capacities. In addition, these kinds of capacities will be necessary to a certain degree in personnel responsible for RTK service (user management) and Publicity/Education.

(e) Making CORS system available to the private sector

It will be necessary not only to set appropriate prices but also to operate stable data distribution services in order to encourage the private sector to use CORS data. There are short-term and long-term aspects to stable distribution. In order to reduce corporate production risks in the short term, times when distribution is not possible and data losses due to failures, etc. must be reduced. And in order to reduce management risks when companies make new investments in the long term, continuity in the availability of data is required. In particular, long-term continuity is a critical factor in determining whether a company will expand a business that uses CORS data. In Japan, the Geospatial Information Authority of Japan has specified the provision of CORS data in the Long-Term Plan for Basic Survey, which has a plan period of 10 years. This reduces the risks involved in private distribution operators investing in related businesses. In addition, since multiple private data providers have been operating since 2002, users can enter into contracts with these operators with peace of mind. Based on the fact that there are still restrictions on the use of geospatial information, particularly in Thailand, it is critical to convey in some form that data will be available and usable in the long term. In addition, it is important to express short-term stability in the form of a SLA, etc.

Such advanced decisions are considered to be made by the superior organization responsible for the NCDC. However, from the perspective of providing materials based on which decisions are made to the organization,

personnel who are responsible for Plan management/Inter-agency coordination and Publicity/Education will also need this type of decision-making capacity.

6. Technical visit to Japan

6.1. Itinerary of the visit

The Team deliberated on the itinerary and contents of the technical visit to Japan to achieve its intended objectives, including providing an opportunity for the participants to learn Japanese technologies using high-precision positioning data and their applications, as well as for the Thai and Japanese sides to agree on the social experiments (Pilot Projects) to be conducted.

The draft itinerary prepared by the Team was presented to Thailand-Japan Joint WG for discussion. After incorporating the requests from the Thai side, the itinerary was finalized as shown in the table below.

Table 6-1: Itinerary of the visit to Japan

Date	Destination	Contents of visit/meeting	Location
June 9	Bangkok - Haneda		
June 10	JICA	Briefing, discussion	Tokyo
	Cabinet Office, MLIT	Courtesy calls to Cabinet Office and MLIT	Tokyo
	AKTIO Corporation	Demonstration of GNSS markers	Ichihara, Chiba
June 11	Yanmar Agri Japan	Demonstration of precision agricultural machinery	Sakura, Chiba
	Nishio Rent All Co., Ltd. Topcon Corporation	● Construction work with ICT construction equipment utilizing 3D design data ● Utilization of GNSS and demonstration of i-Construction	
June 12	Kaiteki Kukan FC PASCO Corporation Nikon-Trimble	● Demonstration of UAV flight ● Demonstration of MMS measurement using GNSS	Tsukuba
	GSI	Visits to CORS and data distribution facilities, lectures (24-hour continuous observation, accumulation of observation data, analysis processing, etc.)	Tsukuba
	Meteorological Research Institute	Lecture on GNSS-PWV	

Date	Destination	Contents of visit/meeting	Location
June 13	Kubota Corporation	Presentation of precision agriculture (indoor)	Tokyo
	Kokusai Kogyo Co., Ltd.	Presentation of large-scale crustal movement monitoring by GNSS (indoor)	
	MLIT Cadastral Promotion Division	Lecture on cadastral survey using GNSS	
	JENOBA Corporation	Lecture on real-time CORS data distribution	
	JICA	Discussion on data distribution methods	
June 14	JICA	● Exchange of views with Japan-Thailand Cooperative Council for G-Space Promotion ● Exchange of views with Japanese government agencies about utilization of CORS (JICA, MLIT, Cabinet Office, MOFA, GSI, etc.) ● Presentation and selection of social experiments	Tokyo
June 15	Haneda - Bangkok		

The list of Thai personnel invited to Japan is provided in the table below.

Table 6-2: List of Thai officials invited to Japan

Organization	Department or Division	Position	Name
DOL	Mapping Technology Division	Chief of Satellite Position Development Group	Mr.Peera Yomwan
DOL	Mapping Technology Division	Survey Engineer, Professional level	Mr.Miti Nuntatikul
GISTDA	Space Krenovation Park	Director of Space Krenovation Park	Mr.Damrongrit Niammuad
GISTDA	Space Product Co-Creation Promotion	Innovation Development Officer	Mr.Thotsawat Fukiatisut
HII	Technology and Digital Division	Head of Geoinformatics research Section	Ms.Nuantip Chaladlert
HII	Technology and Digital Division	Geoinformatics Specialist	Ms.Panruthai Tangprasert
RTSD	-	Deputy Director	Maj.Gen.Krith Bunthid
RTSD	Map Information Center	Director of Map Information Center	Col.Attawoot Kiatiwat
DPT	Town and Country Planning Engineering Bureau	Survey and Mapping Expert	Mr.Keattisak Amornprasertsook

Organization	Department or Division	Position	Name
DPT	Town and Country Planning Engineering Bureau	Surveyor Experienced	Mr.Chaiwat Panachat
DOF	Department of Fisheries, Information and Communication Technology Center	Director of Information and Communication Technology Center	Mr.Supawat Komolmarl
NIMT	Electrical Metrology Department	Metrologist (Professional level)	Ms.Thayathip Thongtan
Chula Univ	Department of Survey Engineering	Professor and Head of Department	Mr.Chalermchon Satirapod

6.2. Details of the visit

The following activities were carried out. In addition, discussions were held and opinions were exchanged in regards to possible scenarios of CORS data distribution system and NCDC configuration.

（1） Learning Japanese technologies related to high-precision positioning data and their applications

The participants visited relevant Japanese government agencies and private companies to see their operations and exchange opinions with regard to high-precision positioning data. During visits to private companies, the participants had hands-on experience with remote-controlled construction equipment and saw demonstrations of agricultural machinery, UAV, MMS, etc. using high-precision positioning data, which have not yet been introduced to Thailand. At GSI, the participants deepened their understanding of CORS network operation and maintenance through a lecture on GEONET and its facility visit.

（2） Agreement on social experiments

On the final day, companies who had expressed their interests in participating in social experiment made presentations on their proposals, and both the Thai and Japanese sides agreed to conduct all of the proposed experiments.

7. Execution of social experiments

7.1. Selection and determination of the social experiments

7.1.1. Listing of candidate projects for social experiments

A list of candidate projects for social experiments was created as follows.

(1) Invitation for member companies of related organizations, related councils, etc. to participate in social experiments

Based on the results of the survey in 3.2.2, Japan-Thailand Cooperative Council for G-Space Promotion and S-NET members were invited to participate in the social experiments and a briefing was held. The briefing session explained the purpose of the social experiments and the following requirements, and called for a participation in the social experiments.

- Utilizes precise positioning data (CORS or MADOCA)
- Has businesses in Thailand or is considering expanding their business to other countries (including reimports to Japan)
- Contributes to the resolution or mitigation of social issues
- Is difficult to implement in Japan

After the briefing session, the intention to participate in and the details of the experiments were confirmed. Those that met the above requirements were included in a list of candidate projects for the social experiments.

(2) Confirmation of suitability for EEC

The suitability of candidate projects for the social experiments created in the previous section was confirmed based on feasibility in the EEC. As shown in 3.4.2. Constraints Concerning Social Experiments (Including EEC Exceptions), the EEC exceptions include the relaxation of the tax system, etc. applied when doing business in a Special Economic Zone. There are no relaxation measures for social experiments. GISTDA gave permission to conduct the experiments performed on the SKP site, so the plan was to consult with the EEC Secretariat as necessary regarding those things conducted outside the SKP site. However, there were no cases that required such applications to the EEC Secretariat.

(3) Call for participation from Thailand and finalization of the list of social experiments

When candidate projects for the social experiments were presented to Thailand-Japan Joint WG, Thai side requested for participation from the Thai government and private companies. As a result of invitation based on this via Thailand-Japan Joint WG, the Team received two applications from HII and one private company.

In the end, a list of 10 candidate projects for the social experiments was finalized.

7.1.2. Determination of the social experiments

As stated in 6.2, based on the agreement between Thailand and Japan at the meeting held on 14th June, it was decided that all social experiments shown in the table below would be executed.

Table 7-1: List of the social experiments

NO.	Implemented by	Social experiment	Site	Use environment	Responsible agency
1	Aktio Corp.	Verification of GNSS markers for aerial photogrammetry with UAVs	SKP	TOPCON	HII
2	Hydro - Informatics Institute	MMS and CORS combination for 3D Dike Model Generation	In and around Bangkok	HII	HII
3	Iwane Laboratories (Thailand) Ltd.	Accuracy Assessment of Mobile Mapping System (MMS) using CORS network	Bangkok and SKP	DOL, HII	DPT
4	Kaitekikukan FC Co., Ltd., PASCO (Thailand) Co., Ltd.	Precision evaluation of basic data contributing to the grasping of disaster situations with UAV laser measurement	SKP and Sri Racha	DOL, HII, TOPCON	RTSD
5	Kokusai Kogyo Co., Ltd.	Verification of immobility of local reference stations using CORS	SKP	TOPCON	RTSD
6	Kubota Corp.	Autonomous operation experiment of agricultural machinery using CORS	SKP	Topcon, reference station	HII
7	Nikon-Trimble Co., Ltd.	Experiment to compare only GNSS and GNSS + IMU on positioning service availability	In and around Bangkok	DOL, HII, TOPCON	DOL
8	Topcon Corp., Nishio Rent All Co., Ltd.	i-Construction demonstrative experiment in Thailand using VRS	SKP	TOPCON	DPT
9	Tokai Clarion, Ltd., Asia Technology Industry Co., Ltd	Autonomous driving of micro EVs with precision GNSS	SKP	TOPCON	GISTDA
10	Yanmar Agribusiness Co., Ltd.	Demonstration of autonomous operation with agricultural machinery	SKP and surrounding farmland	TOPCON	GISTDA

*1 The two underlined companies are SMEs[23]; this survey helped with their related travel expenses and equipment transportation costs.

*2 The Responsible Agency in the table is assigned by Thailand-Japan Joint WG as the agency to observe and inspect the execution of the respective social experiment.

[23] Based on the definition of small and medium enterprises listed on the Small and Medium Enterprise Agency website (https://www.chusho.meti.go.jp/soshiki/teigi.html).

While it was hoped that data acquired during some of the experiments would be sent to Japan, aerial photographs and 3D point cloud data outside the SKP site were not allowed to be sent according to Thai regulations. Therefore, data for outside the SKP site was processed in Thailand.

7.2. Execution of the social experiments

7.2.1. Preparation of social experiment environments

In conducting the social experiments, the environments that can be used in Thailand were examined (existing CORS network). As described above, DOL and HII have implemented a CORS data distribution service on a trial basis, and it was confirmed that this could be used for these experiments. In addition, as a result of interviews with Topcon Corp., it was confirmed that Topcon has continued to own a private CORS network, named T-NET, that was established for a previous Cabinet Office project and that this can be borrowed for this social experiment.

The three environments above are summarized below.

Table 7-2: Summary of candidate social experiment environments (as of March 2019)

Item	DOL	HII	TOPCON (T-NET)
Number of CORS	128	25	10
Coverage	Across Thailand	In and around Bangkok and EEC	In and around Bangkok and SKP
Data format	RTCM 3.0 and 3.2	RTCM 3.0 and 3.2	RTCM 3.0 and 3.2
Type of signal (correction data)	VRS	VRS	RRS, VRS
Types of satellites	GPS, Glonass	GPS, Glonass	QZSS, GPS, Glonass, BeiDou
Restrictions/concerns	Registration is not possible without a Thai identity card.	Since the network also uses CORS possessed by government agencies other than HII, it is necessary to coordinate with other agencies when using the network.	Inspection and maintenance according to conditions are necessary.

Source: Based on the results of surveys conducted by the Team

Fig. 7-1: TOPCON's CORS network (T-NET)

Most of the companies who expressed intentions of implementing their social experiments, asked to use TOPCON's environment because CORSs are installed in and around SKP. In turn, companies that conduct social experiments in the suburbs of Bangkok also requested the use of DOL and HII's CORS networks

Based on the above, it was decided that DOL, HII, and Topcon's CORS networks would be used for these social experiments.

7.2.2. Details of the social experiments

Below is a overview of each social experiment. For more details, see the report by the organization conducting the respective social experiment attached at the end of the report.

[1] AKTIO Corporation

Title	UAV Photogrammetry and reference point surveys using GNSS Markers for Aerial Photogrammetry
Period	27th -29th August 2019
Location	SKP
Contents	Use GNSS markers as airphoto signals in UAV photogrammetry. Examine whether the markers can be used as surveying equipment. (GCP (ground control point) surveys)
Potential benefits	1) to contribute to the improvement of survey efficiency and precision through high-precision aerial photogrammetry employing GNSS markers and 2) Increase efficiency by simplifying GCP surveys.
Equipment used/ Photos	 

[2] HII

Title	Mobile Mapping System (MMS) and Continuously Operating Reference Stations (CORS) combination for 3D Dike Model Generation
Period	1st May 2019 -31st July 2019
Location	Bangkok and its outskirt
Contents	Use GNSS markers as air photo signals in UAV-borne aerial photogrammetry. Verify if GNSS markers can be used as survey instruments (for control point surveys).
Potential benefits	1. A suitable survey method of MMS to create 3D Dike Model 2. A data analysis method to create 3D Dike Model 3. Accuracy of dike surface height from MMS data
Equipment used/ Photos	

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

Title	Accuracy Assessment of Mobile Mapping System(MMS)using CORS network
Period	14th – 28th August 2019
Location	SKP
Contents	Capture image data on the roads using MMS and calculate the positional accuracy with GNSS and GNSS (post process using CORS network)
Potential benefits	Improved positional accuracy of MMS data after applying trajectory which is processed by CORS network
Equipment used/ Photos	

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

Title	Accuracy Evaluation of Basic Data for Determination of Disaster Situation Based on UAV-Borne Laser Survey
Period	27th – 29th August 2019
Location	SKP and Sri Racha
Contents	Conduct an aerial 3D survey using an UAV-borne compact laser system. The purpose of the verification test is to evaluate the positioning accuracy and the state of data acquisition to determine the usefulness of the acquired data for disaster prevention.
Potential benefits	An application of the data to disaster management plans and public works in Thailand will contribute to shorter time from survey to design and more advanced projects.
Equipment used/ Photos	 

[5] KOKUSAI KOGYO CO., LTD.

Title	Behavior Grasp of a Local Base Point and Correction for GNSS-based Displacement Monitoring by Using its Neighboring CORS
Period	23rd – 30th August 2019
Location	SKP
Contents	A local base point for GNSS-based displacement monitoring of ground, infrastructure, etc. is usually set up in the immobile neighborhood of a target to be monitored. However, the point often not being immobile enough, the experiment grasps its behavior and corrects mm-level displacement values by its neighboring CORS.
Potential benefits	The experiment expects improvement in the mm class accuracy of the monitoring for an area, having large-scale ground movement, where the immobility of a local base point cannot be secured easily. There being cases, where it is difficult to secure the immobility of a local base point, including but not limited to the following monitoring targets, the utilization of the CORS being prepared in Thailand should be able to bring a big effect.
Equipment used/ Photos	 

[6] KUBOTA Corporation

Title	Pilot test of autonomous agricultural machine utilizing GNSS-base station
Period	Test field in Chon Buri prefecture: 5th August 2019 Experimental field in SKP: 26th and 27th August 2019
Location	Chon Buri prefecture and SKP
Contents	Perform autonomous straight traveling based on precise positioning (RTK) using correction data from CORSs. Assess its accuracy (to verify the positioning performance and straight traveling performance.)
Potential benefits	Understanding on the level of accuracy of autonomous driving in contrast to skilled workers, with a view to achieving higher efficiency and labor-saving through the use of CORSs in agriculture in Thailand.
Equipment used/ Photos	

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

Title	Comparison of positioning availability by GNSS only and GNSS with IMU in Thailand
Period	22nd August - 30th September 2019
Location	Bangkok and its outskirt
Contents	Perform positioning in an area where GNSS-only positioning is feasible and an area where positioning requires a combination of GNSS and IMU (Inertial Measurement Unit) and compare the results.
Potential benefits	With the level of dependency on IMU identified as a result, we will be able to examine whether high-performance, expensive devices such as FOG and LRG are needed or low-cost MEMS is sufficient and to plan a detailed system configuration.
Equipment used/ Photos	 

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

Title	i-Construction Trial in Thailand
Period	19th – 30th August 2019
Location	SKP
Contents	Perform the entire sequence of an i-Construction project and all the steps of the construction works and the verification of the outcomes.
Potential benefits	An implementation of three-dimensional design data and 3DMC systems that control construction equipment using precise positioning information (VRS) will boost the productivity in construction workflows and the infrastructure in Thailand.
Equipment used/ Photos	

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

Title	Intelligent Transport System
Period	July – August 2019
Location	SKP
Contents	1. Test the autonomous driving of a micro EV with the help of precise positioning data. 2. Monitor real-time footage from the EV during its autonomous driving.
Potential benefits	Low-cost autonomous-driving EVs with high reliability will become a reality thanks to precise positioning.
Equipment used/ Photos	

[10] YANMAR AGRIBUSINESS CO., LTD.

Title	Autonomous driving demonstration of agricultural machines
Period	23rd – 24th July 2019, 30th August 2019
Location	A farm in Sri Racha and SKP
Contents	Verify the autonomous traveling capability based on Ntrip-based positioning using the CORSs in Thailand, through autonomous traveling of agricultural machinery equipped with GNSS antennas.
Potential benefits	Testing the use of CORSs present in Thailand will lead to an actualization of autonomous traveling of agricultural machinery in the country.
Equipment used/ Photos	

7.2.3. Participation in Thailand Japan GNSS DEMO DAY

All participants of the social experiments participated in the Thailand Japan GNSS DEMO DAY held at SKP on 30th August, demonstrating their technologies and services. About 300 people from Thailand, Japan, and other countries (Lao PDR, Singapore and Cambodia etc.) attended the event. Those who attended the event commented that it was the first time to see so many technical demonstrations in one place, and the technologies demonstrated were impressively high level. A Japanese company received an inquiry through this event. This has led to future business expansion in Thailand. Furthermore, the event was featured by media outlets in Thailand and Japan, and this has contributed to increased recognition of precise positioning data.

Table 7-3: Thailand Japan GNSS DEMO DAY program

Thailand-Japan GNSS DEMO DAY Time Table

Site / Time	1 Smart Agriculture (Kubota)	2 Smart Agriculture (YANMAR AGRIBUSINESS)	3 Real-time displacement monitoring (Kokusai Kogyo)	4 i-Construction (NISHIO RENT ALL & TOPCON)	5 Micro EV (Tokai & ATI) GNSS/IMU (NIKON-TRIMBLE)	6 MMS (HII)	7 MMS (Iwane)	8 UAV (AKTIO)	8 UAV (Kaiteki Kukan FC)
9:00-10:00	Opening								
10:00-10:30	V.I.P / A	V.I.P / G	E	-	D	C	B	F	-
10:30-11:00	-	A	G	V.I.P / E / F	V.I.P / -	D	C	-	B
11:00-11:30	C	B	A	-	E / F	V.I.P / -	V.I.P / -	D / G	-
11:30-12:00	-	C	V.I.P / -	A / B	G	F	D / E	-	V.I.P / -
12:00-12:30	D	-	B / C	-	A	G	F	E	-
12:30-13:30	Lunch								
13:30-14:00	E / F	D	-	G	B	A	-	-	C
14:00-14:30	-	E	D / F	-	C	B	A / G	-	-
14:30-15:00	B / G	F	-	C / D	-	E	-	-	A

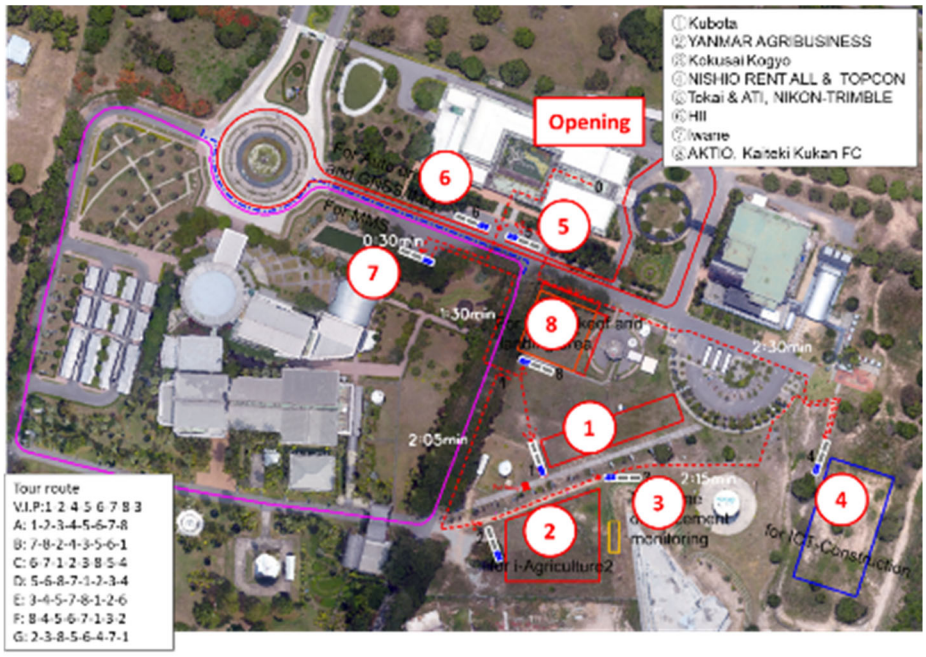


Fig. 7-2: Venue map

Photo 7-1: Thailand Japan GNSS DEMO DAY

7.2.4. Summary of the social experiments

Through these social experiments, it was confirmed that Japanese technologies, products, and services can be applied in Thailand without the risk of any major technical problems. While these social experiments were conducted with limited time and space, in the future, when performing further technical verification, identifying non-technical issues for practical use, and examining solutions, experiments should be conducted using real-time data distributed from NCDC at actual sites (farms, construction sites, roads, etc.) or similar environments.

The real-time distribution services used in these experiments saw cases where distribution was interrupted or where problems occurred in the distributed data, causing the experiments to be interrupted. These problems occurred in experiments on precision agriculture (Kubota), autonomous driving (ATI), and drone operation (KaitekikukanFC). Two companies that participated in the experiments expressed the following issues.

- Considering using CORS data for precision Agriculture, there is concern regarding the impact on stable data distribution based on the fact that the distances between CORSs is greater than in Japan (Yanmar Agribusiness).
- For i-Construction, it is necessary to match the inconsistency in the coordinates between the existing national reference points and CORSs in order to create precise 3D design data (Topcon).

An issue related to NCDC operation in the future is the stable distribution of accurate correction data.

An opinion was also shared that said it was necessary for Thailand to conduct a pilot project to promote the convenience of and build awareness of ICT construction in order to increase ICT construction within Thailand.

In addition, there was a situation in which data of the Thai geoid model could not be downloaded despite the fact that it was open to the public on the RTSD website. It is necessary to consider how to provide the geoid model so that they can be easily downloaded and used by users from other countries.

In addition, while support was received from GISTDA and other Thailand-Japan Joint WG member organizations, a great deal of labor and time was still required to import and export the equipment necessary for the experiments and to apply for NBTC and the Civil Aviation Authority of Thailand (CAAT). The details of some experiments also had to be changed and their schedules revised. More specifically, the permit application for drones to CAAT is officially supposed to take about two weeks, but in practice it took two months. When operating a drone in Japan, the application period for pilots and aircraft before permission is obtained from the Civil Aviation Bureau is about one week, and the period for permission to operate a drone in practice is just one to two days. Requiring two months from the planning of shooting from the drone until the permission to operate the drone is a hindrance when planning work processes. Since drone operation is expected to utilize NCDC's CORS correction data distribution services, the period from the planning of shooting to the permission to the drone operation should be as short as possible. When planning similar social experiments in the future, it will be necessary to carefully confirm the required procedures and consider possible solutions.

8. Holding of a seminar

8.1. Planning of a seminar

8.1.1. Time, date, and venue

During the planning phase of the survey, the Team considered organizing an independent local seminar. However, as GISTDA requested cooperation with National Space Policy Secretariat of the Cabinet Office, the Team has decided to hold the seminar within the Multi GNSS Asia (MGA) during the Thailand space Week, which GISTDA will hold in the last week of August 2019. As MGA is an annual international conference concerning GNSS with many participants both from government and private entities inside and outside Asia, the Team could expect a larger audience and appealing effect than an independent seminar organized by the Team alone.

After coordinating with GISTDA and Cabinet Office, it was decided to hold the seminar at 9:00 – 10:30 on 28th August, the second day of MGA, under the title "Thailand-Japan Special Session". GISTDA says that they added this session as an exception to MGA although it is an international conference, because of the special relationship between Thailand and Japan.

As a side event to MGA, "Thailand Japan GNSS DEMO DAY" was held at SKP, Sri Racha on 30th August, where HII and all companies participating in the social experiments under this Survey conducted demonstrations using high-precision positioning data. Details of this side event are provided in Section 7.2.3: Participation in Thailand Japan GNSS DEMO DAY.

8.1.2. Selection of agenda items and lecturers

The Thailand-Japan Special Session included keynote speeches by experts and introduction of NCDC and this Survey followed by presentations on the social experiments using high-precision positioning data for the purpose of deepening the participants' understanding of the usefulness of high-precision positioning data and expanding ideas for their applications.

Considering the nature of the joint session, it was decided to invite one keynote speaker from Thailand and one from Japan, namely, Professor Chalermchon from Thailand and Assistant Professor Miyazaki of Center for Spatial Information Science, the University of Tokyo, from Japan, who is a prominent researcher in the use and application of position information of mobile objects, to accommodate the request of Thailand-Japan Joint WG for a lecture on location-based services.

8.2. Thailand Japan Special Session

The Thailand Japan Special Session was held according to the following schedule.

Table 8-1: Outline of Thailand Japan Special Session

Date and time	Wednesday, 28th August 2019 9:00 – 10:30
Venue	Impact Arena Muong thong Thani Bangkok, Thailand
No. of participants	approximately 150

Table 8-2: Session agenda

Time	Content
9:00-	Opening Remarks By Dr. Damrongrit Niammuad, GISTDA By Mr. Satoshi Kogure, National Space Policy Secretariat, Cabinet Office
9:05-	Keynote Speech “Location-based Services for Smarter Society” By Mr. Hiroyuki Miyazaki, Ph.D., University of Tokyo & Asian Institute of Technology
9:15-	Keynote Speech “GNSS CORS as the National Positioning Infrastructure to support Thailand 4.0” 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, Thailand-Japan Joint 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

In his lecture, Assistant Professor Miyazaki showed with examples how position information can be useful in assessing traffic flow, population distribution, and demographics, as well as expediting disaster response and transport logistics. Professor Chalermchon reported the status of CORS installation in Thailand and the endeavors toward the establishment of NCDC and explained why utilization of high-precision positioning data is essential to the realization of Thailand 4.0. Professor Chalermchon also expressed his appreciation for Japan’s continued support following the Joint Statement by the Prime Ministers of Japan and Thailand in 2015.

Col. Attawoot from RTSD explained the purpose and structure of NCDC, as well as the methodology and results

of streaming tests between RTSD and DOL and future activities. This was followed by the presentation by The Team on the social experiments and their significance. In the last segment, representatives of HII and the companies participating in the social experiment projects outlined the objectives and overview of each project.

Photos 8-1: Thailand Japan Special Session (top left: Prof. Chalermchon, top right: Assistant Prof. Miyazaki, down left: audience, down right: group photo of presenters)