Introduction of Positioning Augmentation Center for High Precision Application in Brunei Darussalam

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***JENOBA CO., LTD, Japan
1. Introduction
   - Satellite based centimeter class augmentation system
   - Application Demonstration
2. How does Geospatial Information work in Brunei?
3. Introduction of “Positioning Augmentation Center”
   - What is “Positioning Augmentation Center”?
   - Data Generation and Distribution
4. Typical design of Augmentation Data Center
5. Conclusion
1. Introduction

- High precision augmentation system is very much promising technology in coming Multi-GNSS era when more than 100 navigation satellites would be available.
- Application of Centimeter class high precision positioning service is expected to grow rapidly in Asia-Pacific region and contributes economic growth in the region.
- The needs in Brunei have been surveyed and analyzed. Authorization of “Mapping” by the government would be an essential to assure its consistency with “Positioning”. Authorized CORS* is a key to assure consistency within the map and “Positioning”.

  * Continuously Operating Reference Station

- Conceptual Design of “Positioning Augmentation Center” using CORS data has been made considering variety of applications.
CMAS using GPS/GNSS multi-constellation, Authorized CORS is distributed through QZSS LEX signal.

GPS/GNSS multi-constellation

QZSS

L1/L2 signals

Coded SSR Message Uplink

Coded SSR Message Downlink LEX (L6) signal

Tracking & Control Station

SSR Server — CMAS (for only Japan, in 2014 currently)

Master Control Station (for Asia-Pacific)

Authorized CORS (GEONET for Japan)

Orbit/Clock Error
Signal Bias Error
Ionospheric Delay Error
500km
80km
11km
0km
Tropospheric Delay Error
L1/L2 signals

Observation per second

※ This figure shows a case of Application Demonstration since 2011
1. Introduction—Utilization Demonstrations
Asia-Pacific accounted for over 50% of global LBS shipments in 2016
2. How does Geospatial Information work in Brunei?

● Why Geospatial Information is so important?
  - Geospatial Information is social infrastructure to support daily life of the people
    ● Land Development of the nation and local areas
    ● Development and Maintenance of Infrastructure
    ● Water Environment, Biological System
    ● Urban Problems
    ● Disaster Mitigation, ....

● How Geospatial Information to be established, maintained, efficiently?
  ● standardization
  ● Integration on the same basis
  ● Information Sharing

“Positioning ” and “Mapping” should be based on the same accuracy and get together for installation and control!
2. How does Geospatial Information work in Brunei?

- Market Survey is done to make a strategic approach for establish “Geospatial Information” infrastructure in Brunei

- Potential Users
  - Government Agencies: 31
  - Private Industries: 7

- Possible Applications

- Analysis
  - Positioning Accuracy
  - Map Accuracy
  - Measurement Technology

Potential Users for Brunei Permanent GNSS Network:

<table>
<thead>
<tr>
<th>No.</th>
<th>Name of Organisation</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Land Department</td>
<td>Registration, administration and management of land to secure socio-economic of the country. Land Register, Land Ownership, Licenses, transportation of soils, sand and gravels.</td>
</tr>
<tr>
<td>2</td>
<td>Survey Department</td>
<td>Providing comprehensive and accurate geomatic information and services. Such as House Numbering, KIHB direction, DSM Digital, Field Survey, Sky watch, topographical survey and map of Brunei. Geodetic, GIS Mapping, International Boundary and even Land Development. Real Data Coordinates for geological studies.</td>
</tr>
<tr>
<td>3</td>
<td>Authority for Building Control and Construction Industry (ABC)</td>
<td>Reference of government agencies that control the development of land and buildings. The safety of newly constructed or renovated buildings</td>
</tr>
<tr>
<td>4</td>
<td>Public Water Department</td>
<td>Managing and Planning of Water resource such as Dams, Drainage and Pipelines.</td>
</tr>
<tr>
<td>5</td>
<td>Public Works Department</td>
<td>To develop a comprehensive infrastructure, buildings and services for nation building towards quality living. PWD plays an important role to realize the national aspirations as set out in Wawasan Brunei - 2035 through our Vision to provide the Built Environment of Distinction. We possess the technical capacity to build the infrastructure &amp; render project management services for sustainable socio-economic development. Planning of Roads, Drainage, Sewerage, Mechanical and Electrical Components such as preparation of national events.</td>
</tr>
</tbody>
</table>

Ministry of Primary Resources and Tourism

The Ministry of Industry and Primary Resources (MIPR) was formed in 1989 and is responsible for promoting and facilitating industrial development. The MIPR is also helping to develop areas of growth as wide ranging as manufacturing, tourism, agriculture, fisheries and forestry.
# 2. How does Geospatial Information work in Brunei?

<table>
<thead>
<tr>
<th>Potential Users</th>
<th>Accuracy</th>
<th>Measurement Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Positioning</td>
<td>Map</td>
</tr>
<tr>
<td><strong>1 Land Department</strong></td>
<td>cm</td>
<td>Special map</td>
</tr>
<tr>
<td><strong>2 Survey Department</strong></td>
<td>cm~m</td>
<td>Level500</td>
</tr>
<tr>
<td><strong>3 Housing and Development Department, Town and Country Planning</strong></td>
<td>cm</td>
<td>Level500</td>
</tr>
<tr>
<td><strong>4 Environment Park and Recreation (JASTRE)</strong></td>
<td>m</td>
<td>Level250</td>
</tr>
<tr>
<td><strong>5 Authority for Building Control and Construction Industry</strong></td>
<td>cm~Decimeter</td>
<td>Special map</td>
</tr>
<tr>
<td><strong>6 Public Water Department</strong></td>
<td>cm~Decimeter</td>
<td>Level500</td>
</tr>
<tr>
<td><strong>7 Public Works Department</strong></td>
<td>cm~Decimeter</td>
<td>Level500</td>
</tr>
</tbody>
</table>
2. How does Geospatial Information work in Brunei?

![Required accuracy in the field](image)
2. How does Geospatial Information work in Brunei?

Measurement technology available in each field (30 field)

- SSR-RTK
- D-GNSS
- TS
- MMS
- Airborne LiDAR
- Remote sensing
- UAV
- TSL
- IMU
- Narrow multibeam sonar

High Precision GNSS Technologies
2. How does Geospatial Information work in Brunei?

Map accuracy required in each field
(30field)
3. Introduction of “Positioning Augmentation Center”

- Augmentation data generation
- Monitoring of operation and measures
- Detection of satellite signal anomaly

Augmentation Data Broadcasting

- GNSS (GPS, GLONASS, Galileo, BDS, QZSS, IRNSS)
- Augmentation Satellites (GEO, IGSO, MEO/LEO)
- Augmentation Data (Satellite clock error, Satellite orbit error, Ionospheric delay, Others)

Ranging Signal Broadcasting

- Ranging Signal Navigation Data
- Ranging Signal Receiving
- Ground Reference Points
- User Terminal
- Calculation of Position
- Observables
- Positioning Augmentation Centers
- Augmentation Data Uplink
- Augmentation Data Generation
3. Introduction of “Positioning Augmentation Center”

The latest satellite positioning methods had better be classified in following 3 steps.

1. Correction References
   - Networked Reference Stations (CORS)
   - Single Reference Station

2. Correction Representation Method
   - State Space Representation (SSR)

3. Position Computing Method
   - RTK-PPP
   - Dual Freq. PPP
   - Single Freq. PPP
   - FKP
   - VRS
   - RTK

Applications
- Civil
- Architecture
- Maintenance
- Mapping
- Oil Plants
- Gas Plants
- Docking
- Vehicles
- Robots
- Drones
- Maritime
- Agriculture
- Construction
- Real-estate
- Surveying
## 3. Introduction of “Positioning Augmentation Center”

### Comparison of Centimeter-class Augmentation Generation Methods

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Network RTK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absolute Positioning</td>
<td>SSR</td>
<td>3cm</td>
<td>One Way</td>
<td>1695 bps</td>
<td>within 1min</td>
<td>Yes</td>
</tr>
<tr>
<td>FKP</td>
<td>3cm</td>
<td>One Way</td>
<td>1.5Mbps</td>
<td>within 30s</td>
<td>Yes</td>
<td>Adaptable</td>
</tr>
<tr>
<td>Relative Positioning</td>
<td>VRS</td>
<td>3cm</td>
<td>Two Way</td>
<td>—</td>
<td>within 30s</td>
<td>Yes</td>
</tr>
<tr>
<td>RTK (Relative Positioning)</td>
<td>3 cm</td>
<td>Two Way</td>
<td>—</td>
<td>within 30s</td>
<td>Yes</td>
<td>Adaptable only near reference stations</td>
</tr>
</tbody>
</table>

[Note] FKP: Flächen Korrektur Parameter (in the German language), VRS: Virtual Reference Station

SSR has advantage in applying to Nation-wide broadcasting cost effectively by;

1. One way data transmission
2. Small data transmission rate
# Data Distribution Methods

<table>
<thead>
<tr>
<th>Ground Network</th>
<th>One Way</th>
<th>Two Ways</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radio Broadcasting</strong></td>
<td>△</td>
<td>△</td>
</tr>
<tr>
<td><strong>Fixed Line Internet</strong></td>
<td>○</td>
<td>×</td>
</tr>
<tr>
<td><strong>Mobile Phone</strong></td>
<td>○</td>
<td>△</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Satellite Network</th>
<th>One Way</th>
<th>Two Ways</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Broadcasting Type Satellite Usage</strong></td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>Communication Type Satellite Usage</strong></td>
<td>○</td>
<td>○</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Network Evaluation</th>
<th>Capacity</th>
<th>Coverage</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Examples</strong></td>
<td>○</td>
<td>○</td>
<td>○</td>
</tr>
<tr>
<td><strong>Examples</strong></td>
<td>○</td>
<td>△</td>
<td>△</td>
</tr>
<tr>
<td><strong>Examples</strong></td>
<td>○</td>
<td>○</td>
<td>×</td>
</tr>
</tbody>
</table>

- **DGPS using radio freq.**
- **Global augmentation service**
- **Network PPP**
- **EGNOS using Inmarsat**
- **CMAS using QZS**
- **Global augmentation service**

**DGPS:** Differential GPS using radio frequencies
**SBAS:** Space Based Augmentation System using Geostationary Satellite
SSR Server developed by SPAC can generate “augmentation data” to correct position error due to ionosphere, troposphere, etc. The data are universally applicable to any positioning method to be chosen for Forest Management or other purposes.

4. Typical design of Augmentation Data Center

- CORS Network
- SSR Server (ISO18197)
- Correction Distribution
- Augmentation Satellite
- Positioning Receiver
  - RTK-PPP
  - Single Frequency PPP
  - Dual Frequency PPP

【NOTE】SSR: State Space Representation. Standard Corrections for all types of error factors.
4. Typical design of Augmentation Data Center
(Case study for Brunei)

**Data Centre in Brunei**

**Brunei CORS**

- CORS Observables
- SSR Network RTK corrections

**Downstream Application**

- User
- Integrated GIS
- MMS
- Drone etc.
- SW tool HW
- LIDAR
- Remote Sensing etc.
- SW tool HW

**Ground Network**

- User
- User
- User

**Data Centre**

- mgn
- SSR Server
- Providing Server
- RTCM
- Ntrip

**QZSS**

- QZSS Ground System

*Future alternative to be studied*
## Network Coverage for High Precision Services

(Case study for Brunei)

<table>
<thead>
<tr>
<th>Priority</th>
<th>Application</th>
<th>Expected Working Area</th>
<th>Mobile Phone Coverage</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Construction</td>
<td>Urban area</td>
<td>95%</td>
<td>Better coverage in Urban Areas since more development at Urban.</td>
</tr>
<tr>
<td>2</td>
<td>Transport</td>
<td>Urban and Certain Rural Areas</td>
<td>70% (Certain areas no coverage at all)</td>
<td>Old highway infrastructure has better coverage. New highway from Telisai to Lumut has limited coverage.</td>
</tr>
<tr>
<td>3</td>
<td>Mapping</td>
<td>Urban area is the first priority</td>
<td>80%</td>
<td>Better coverage in Urban Areas.</td>
</tr>
<tr>
<td>4</td>
<td>Oil &amp; Gas</td>
<td>Onshore (Coastline/Offshore using their offshore radar reception)</td>
<td>60%</td>
<td>Oil Rigs, Platforms and Jetty Control Post.</td>
</tr>
<tr>
<td>5</td>
<td>Farming</td>
<td>Forest/Certain Rural Areas</td>
<td>40% Very weak</td>
<td>Very low and limited coverage.</td>
</tr>
<tr>
<td>6</td>
<td>Forestry</td>
<td>Certain Forest/Inlands/Offshore</td>
<td>Less than 40% Extremely weak</td>
<td>Very low and limited coverage.</td>
</tr>
</tbody>
</table>
Satellite Network Usage for High Precision Services

‘Centimeter in seconds at anyplace and anytime’

**RTK**
- 10 Kilometer Area from a Reference Station
- 10km within a Reference Station
- RTK Correction Service Area

**Network RTK**
- Ground-based Transmittable Area
- Cell-Phone Service Area

**RTK-PPP**
- Nation-wide Area Per a Satellite Channel
- QZSS Service Area

**RTK to RTK-PPP evolution**
- Since 1990s
- Since 2000s
- Since 2010s

QZSS Application Demonstration started on 27 Dec 2010.
6. Conclusion

● High precision augmentation system is very much promising technology in coming Multi-GNSS era.
● Surveyed results the needs of Geospatial Information in Brunei have suggested that authorization of "Mapping" and "Positioning" is very much important.
● Authorized CORS* is a key to assure consistency between Map and Positioning.
● Conceptual Design of “Positioning Augmentation Center” using CORS has been made considering variety of applications. SSR method has been focused.
● Geospatial Information should be stored, exploited and shared as “Treasure” of commodity.

* CORS : Continuously Operating Reference Station
* SSR : State Space Representation
Thank you for your kind attention.

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Complementary Slides
## CMAS major specification

<table>
<thead>
<tr>
<th>Items</th>
<th>Specification</th>
<th>Remark</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broadcasting Target</td>
<td>Stationary and Mobile</td>
<td>• Use dual frequency carrier phase (When using single frequency carrier phase, only TTFF degrades.)</td>
</tr>
<tr>
<td>Position Accuracy</td>
<td>Stationary</td>
<td>Horizontal 3 cm RMSE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vertical 6 cm RMSE</td>
</tr>
<tr>
<td></td>
<td>Mobile</td>
<td>Horizontal 3 cm RMSE</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Vertical 6 cm RMSE</td>
</tr>
<tr>
<td>Time To First Fix (TTFF)</td>
<td>within 60 s</td>
<td>• Using dual frequency carrier phase</td>
</tr>
<tr>
<td>Transmission Rate of Augmentation Data</td>
<td>1695 bps</td>
<td>• QZSS L6 signal</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• 1/1000 High-level compression</td>
</tr>
</tbody>
</table>

(*1) : Position accuracy under condition of good visibility and alignment of satellites  
(*2) : Receiver error not considered.
ISO 18197 : Centimeter-class positioning

CMAS is original system which derived ISO 18197 in 2015. It can convert position errors due to 6 different causes into one set of augmentation data, pseudorange and carrier-phase, so that the augmentation data volume to be broadcasted becomes far smaller than conventional methods.

Augmentation Data by State Space Representation (SSR)

① GNSS Orbit Correction
② GNSS Clock Correction
③ GNSS Code Bias
④ GNSS Phase Bias
⑤ Ionospheric Correction
⑥ Tropospheric Correction

These augmentation data are provided by SSR server.

Space systems — Space based services requirements for centimetre class positioning

Systèmes spatiaux — Exigences de services fondés sur l’espace pour le positionnement de la classe centimètre
RTK-PPP covers Diverse Needs

RTK-PPP has all of corrections to realize centimeter-accuracy. Partial uses of corrections enable various needs at terminals.

- **RTK-PPP**
  - Satellite Clock & Orbit
  - Inter-Signal Bias
  - Ionospheric Delay
  - Tropospheric Delay
  - 1 minute to Fix & Centimeter-class Quality

- **DF-RT-PPP**
  - Satellite Clock & Orbit
  - Inter-Signal Bias
  - Ionospheric Delay
  - Tens of minute convergence & 10 centimeter-class Quality

- **SF-RT-PPP**
  - Satellite Clock & Orbit
  - Ionospheric Delay
  - Rapid Fix & Decimeter-class Quality

<Application Example>
Highly Accurate Maritime Positioning

<Application Example>
Advanced Navigation in Urban Canyon

Tokyo Marunouchi
# Glossary

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Full Form</th>
</tr>
</thead>
<tbody>
<tr>
<td>CORS</td>
<td>Continuously Operating Reference Station</td>
</tr>
<tr>
<td>G.</td>
<td>Government</td>
</tr>
<tr>
<td>GIS</td>
<td>Geographical Information System</td>
</tr>
<tr>
<td>GNSS</td>
<td>Global Navigation Satellite System</td>
</tr>
<tr>
<td>HW</td>
<td>HardWare</td>
</tr>
<tr>
<td>I/F</td>
<td>InterFace</td>
</tr>
<tr>
<td>LIDAR</td>
<td>Laser Imaging Detecting And Ranging</td>
</tr>
<tr>
<td>Ntrip</td>
<td>Networked Transport of RTCM via Internet Protocol (RTCM 10410.1)</td>
</tr>
<tr>
<td>mgn</td>
<td>Managing GNSS Network (SEGAL)</td>
</tr>
<tr>
<td>MMS</td>
<td>Mobile Mapping System</td>
</tr>
<tr>
<td>QZS</td>
<td>Quasi-Zenith Satellite (G. of Japan)</td>
</tr>
<tr>
<td>QZSS</td>
<td>Quasi-Zenith Satellite System (G. of Japan)</td>
</tr>
<tr>
<td>RINEX</td>
<td>Receiver INdependent EXchange Format (RTCM SC-104)</td>
</tr>
<tr>
<td>RTCM</td>
<td>Radio Technical Commission for Maritime services</td>
</tr>
<tr>
<td>RTK</td>
<td>Real-Time Kinematic GNSS data (RTCM 10402.3 and 10403.2)</td>
</tr>
<tr>
<td>SSR</td>
<td>State Space Representation (RTCM 10403.2)</td>
</tr>
<tr>
<td>SW</td>
<td>SoftWare</td>
</tr>
</tbody>
</table>