What makes the positioning infrastructure work

The experience of the
Hong Kong Satellite Positioning
Reference Station Network

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What makes the positioning infrastructure works?

"Deliver Results"
The expected results

- Local reference frame for integrating spatial information
- Linkage between local reference system and global reference system

The expected results

- Improve accuracy of positioning
- Enhance efficiency
- Increase productivity
- Reduce cost of operation
The expected results

- Create an environment for innovation.
- Facilitate commercial sectors to provide value added products and services.
- Bring economic benefit to the society
- Improve people’s quality of living

Integration of spatial information

Satellite Positioning Infrastructure for metropolitan area
The local reference frame

Datum parameters of the Hong Kong 1980 Geodetic Datum

- Latitude and longitude of initial point
  - Old trigonometrical (Trig.) station “zero” at the Hong Kong Observatory:
    - Latitude = 22°18’12.82”
    - Longitude = 114°10’18.75”

- Origin of azimuth
  - Trig. 67.2 to Trig. 94 azimuth = 292°59’46.5”

- Reference ellipsoid
  - International Hayford (1910)
    - Semi-major axis (a) = 6378388m
    - Flattening (f) = 1/297

The local reference frame

The Hong Kong 1980 Grid System is the reference coordinate system for positioning activities in Hong Kong

- Trilateration Network
- Traverse Network
- Topographic maps
- Land boundary survey
- Civil engineering and construction works
- Building development control
- Town planning
- Land use control
Global Reference Frame

The First Hong Kong GPS Network

1991 GPS Network

Reference frame: WGS84 (STRE 91)

- Joint effort:
  - Hong Kong, Macau
  - British Forces
    (512 Specialist Team Royal Engineers (STRE))

- 15 Stations in Hong Kong
  - 13 existing triangulation stations
  - 4 satellite Doppler stations (control origin)

The Hong Kong 2000 GPS network

46 stations
Accuracy (5mm $+0.2$ ppm at 95% confidence level)
Linking Hong Kong 2000 GPS Network to International Terrestrial Reference Frame (ITRF96)

Connection to 6 Global Stations of the International Global Navigation Satellite System (GNSS) Service (IGS)
- Cocos Islands
- Guam
- Lhasa
- Shanghai
- Tsukuba
- Yarragadee

Local and Global Reference Frame

The positional differences between Local geodetic datum (HK80) and global datum (WGS 84 / ITRF)
Develop datum transforming parameters

**ITRF96 @ 1998:121**

to / from

**Hong Kong 1980 Geodetic Datum**

- Convert geodetic coordinates to cartesian coordinates
- Carry out Seven Parameters Transformation (scale, shift and rotation)
- Perform Transverse Mercator map projection

Quality of the datum transformation model
Standardize the datum transformation parameters

- Lands Department published the standard parameters for transformation between the ITRF96 geodetic coordinates and the HK80 grid coordiantes.

Height Transformation

Vertical datum of local height is Hong Kong Principal Datum (HKPD).

Reference frame of Geodetic Coordinates (Latitude, Longitude & Ellipsoidal Height) is ITRF96.

Creation of the Hong Kong Height Model with the following data:

- Height control points with accurate ITRF 96 ellipsoidal height and HKPD height
- 640 gravity observations with station spacing 2 km on land and 2-4 km on sea.
- Terrain model of Hong Kong
Height control points for creation of Hong Kong Height Model

Accuracy
Efficiency
Productivity
Cost of operation
Service Goal

• Support high precision positioning
  – Centimeter accuracy
    Real time (network RTK)
    Post possessing (Static, fast static, kinematic)

• Multi-purpose application
  – Meter accuracy (DGPS)

• Services provided
  – REINX data download
  – Network RTK
  – DGPS
  – Automatic Computation

Design Principle

• Station Spacing
  – 20 km

• Enable users to measure baselines from at least 2 reference stations which are within 10 km from the user.
Advantage

• Static survey
  – short observation time (10 to 15 minutes) to achieve 2 - 3 cm accuracy
  – Reduce labour cost and operation time

• Kinematic survey
  – Ensure RTK accuracy at 5 - 10 cm at all areas of Hong Kong

• DGPS (meter accuracy)
  – Provide more than 1 reference station as backup

Quality Assurance - Hourly check

• REINX files collected from the reference stations are processed every hour

• Hourly solution compared with the known position (dx,dy,dz)

• Poor results or no solution indicate problem in data quality, equipment error, communication problem.
Station stability check

- Daily REINX files of each station are processed with precise orbit using Bernese software
- Detect trend in station movement with time series of years of observation
Network RTK data quality check

- Network RTK data are checked at 3 monitoring stations

- Every epoch (1 second) of RTK measurement is checked against the known position of the monitoring station

Network RTK data quality monitoring stations

Network RTK data quality

<table>
<thead>
<tr>
<th>cm</th>
<th>North (dN)</th>
<th>East (dN)</th>
<th>Height (dH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discrepancy between the measure and the known values</td>
<td></td>
<td></td>
<td></td>
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</table>

0 hour to 24 hour
Protection of the reference station

• Security fences

• 8m x 8m Concrete Platform
  – protect the site from bush fire
  – Prevent loss of supporting soil

Protection of reference station site

• Lightning protection system
Business Continuity

• Telecommunication

• Electricity supply

• Redundant system to ensure continuation of the service during system maintenance and equipment failure

• Disaster recovery
Creating an enabling environment to make the positioning infrastructure work

Legal Requirements
Accuracy Standards
Practice Guide

- **Land Survey Ordinance Code of Practice**
  Specifications and practice guides for establishing GPS control stations for land boundary surveys

- **Accuracy Standards of Control Survey**
  - Horizontal / Vertical Control stations surveyed by GPS
  - Published by the Geodetic Survey Section of the Lands Department
Human resource development

- Building up the ability to do the task well.
- All stakeholders participate
  - Government
  - Professional Institutions
  - Academics
  - Industry and manufacturer
  - Users

<table>
<thead>
<tr>
<th>Type of activity</th>
<th>Training Objective</th>
<th>Number of trainees / participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Courses provided by manufacturer</td>
<td>Skill to use equipment and tools</td>
<td>401</td>
</tr>
<tr>
<td>In house training</td>
<td>Work practices to meet organizational needs</td>
<td>730</td>
</tr>
<tr>
<td>Advanced course offered by local and overseas universities</td>
<td>Knowledge for development of workflow, procedures and services</td>
<td>152</td>
</tr>
</tbody>
</table>
| International / Local Conference                      | • Communicate with the customers and understand their needs
                                                        • Share experience, innovation and new opportunity | 74                               |
Reference station data service for surveying applications

Number of Network RTK Connections in June 2009 = 2987
RINEX Data Download (June, 2009)

Users

- Government Department: 285
- Government Contractor: 83
- Research / Academics: 105
- Land Surveying: 76
- Engineering Construction: 9
- Navigation:
- Others: 115
- Total: 675

Number of Download

Innovation
Add Value
Social Benefits
Quality of living
Use of the Satellite Positioning Reference Station Data Services for multi-discipline applications:

Satellite Positioning + structural engineering
+ geotechnical engineering
+ land use control
+ weather forecast
+ GIS spatial data infrastructure
+ geodynamic
+ location base services
+ customer market
  (shopping, sight seeing, restaurants, hiking, sport)
+ ......................

Measure building movement and vibration frequency under strong wind

Building Height: 415.8m
Number of stories: 88

(Courtesy of the City University of Hong Kong and Leica Geosystem)
Automatic real-time monitoring of a slowly moving slope

(Courtesy of the Civil Engineering Department of Hong Kong)
The Planning Department uses the Network RTK data services to take measurement for enforcement and prosecution of unauthorized development under Town Planning Ordinance.

Hong Kong Observatory used the Reference Station Network data for real-time atmospheric water vapour estimation and rainfall nowcast in Hong Kong.
GIS Infrastructure for the Asia and Pacific Region

The Hong Kong Satellite Positioning Reference Stations Network participate in the annual Asia and the Pacific Regional Geodetic Project (APRGP) observation campaign.

The consumer market has not yet fully explored the potential of:

- DGPS
- RTK
- Wireless Internet
- Information
- Light weight and low cost devices
The success factors for Positioning Infrastructure

- Brings innovation to business
- Speeding up work efficiency
- Enabling creation of value added services

- Improve quality of life