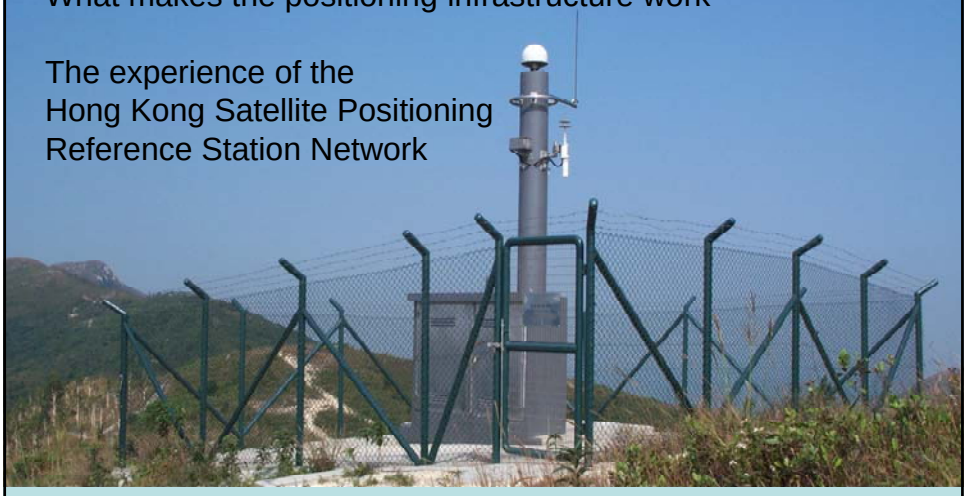
What makes the positioning infrastructure work

The experience of the
Hong Kong Satellite Positioning
Reference Station Network



Simon Kwok
Chairman, Land Surveying Division
Hong Kong Institute of Surveyors

1

What makes the positioning infrastructure works ?

" Deliver Results "

2

The expected results

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

3

The expected results

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

4

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

5

Integration of spatial information

Satellite Positioning Infrastructure for metropolitan area

6

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

7

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

8

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)

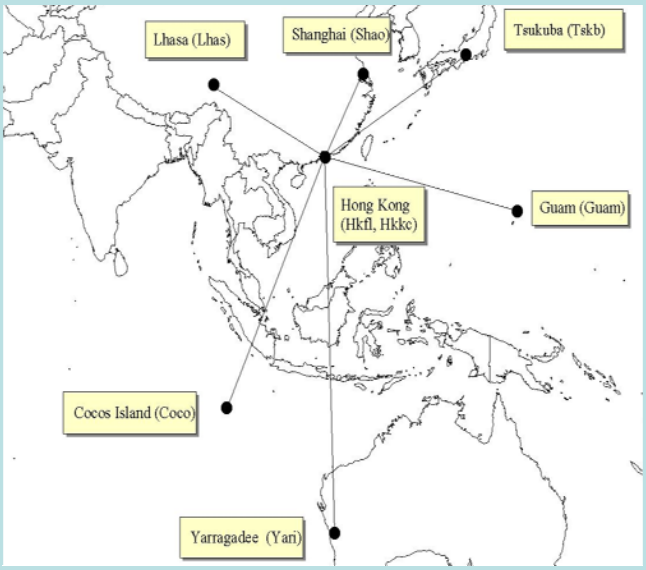
9

The Hong Kong 2000 GPS network

46 stations
Accuracy (5mm +0.2 ppm at 95% confidence level)

10

Linking Hong Kong 2000 GPS Network to International Terrestrial Reference Frame (ITRF96)

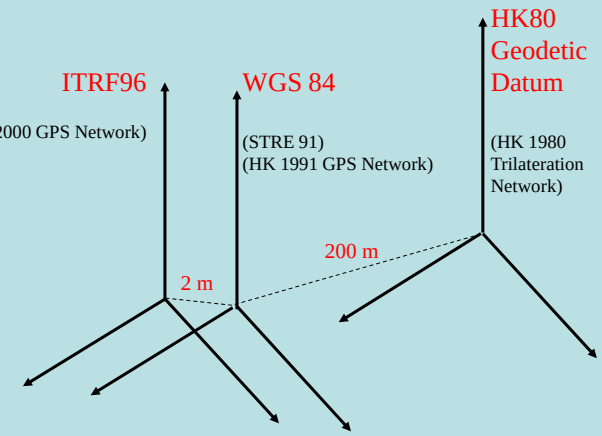


Connection to 6 Global Stations of the International Global Navigation Satellite System (GNSS) Service (IGS)

- Cocos Islands
- Guam
- Lhasa
- Shanghai
- Tsukuba
- Yarragadee

11

Local and Global Reference Frame



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

12

Develop datum transforming parameters

ITRF96 @ 1998:121

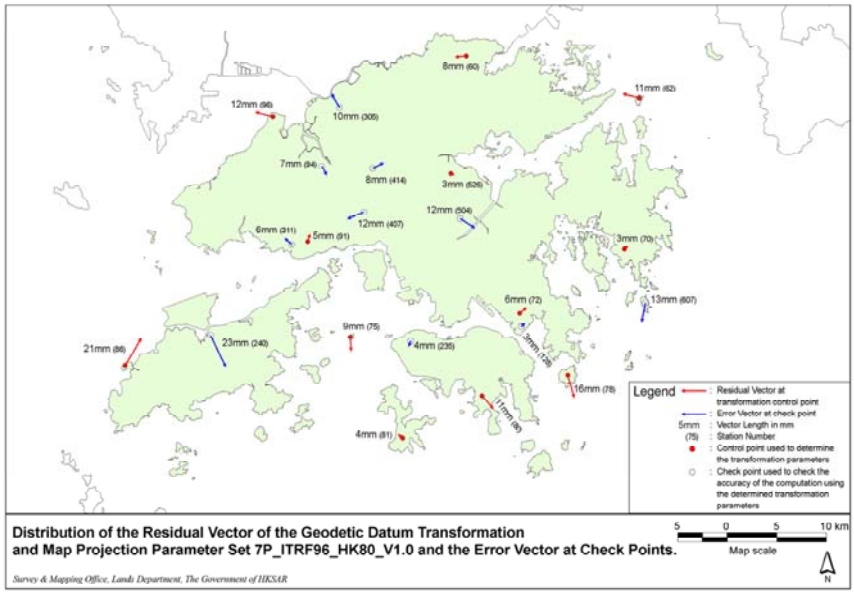
to / from

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

13

Quality of the datum transformation model



Distribution of the Residual Vector of the Geodetic Datum Transformation and Map Projection Parameter Set 7P_ITRF96_HK80_V1.0 and the Error Vector at Check Points.

Survey & Mapping Office, Lands Department, The Government of HKSAR

Standardize the datum transformation parameters

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

15

Height Transformation

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

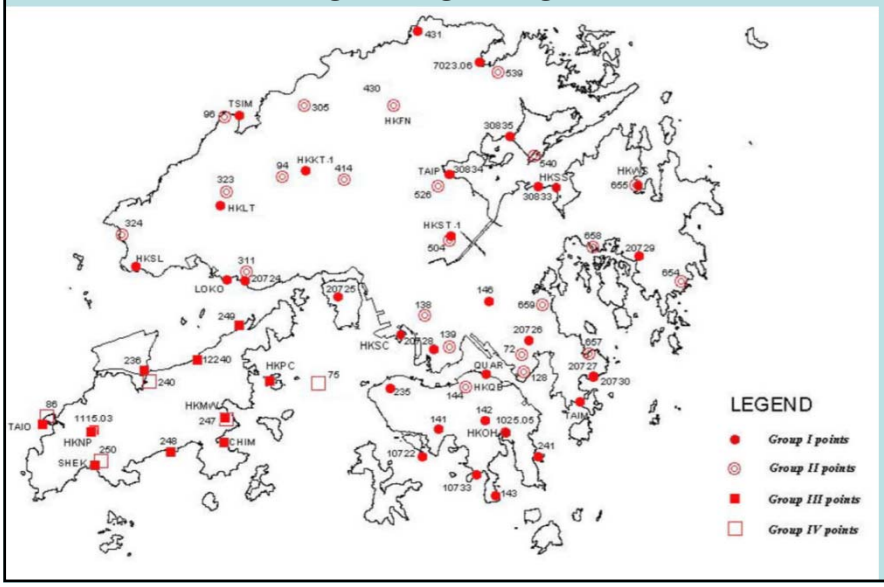
Reference frame of Geodetic Coordinates (Latitude, Longitude & Ellipsoidal Height) is ITRF96.

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

16

Height control points for creation of Hong Kong Height Model



17

Accuracy

Efficiency

Productivity

Cost of operation

18

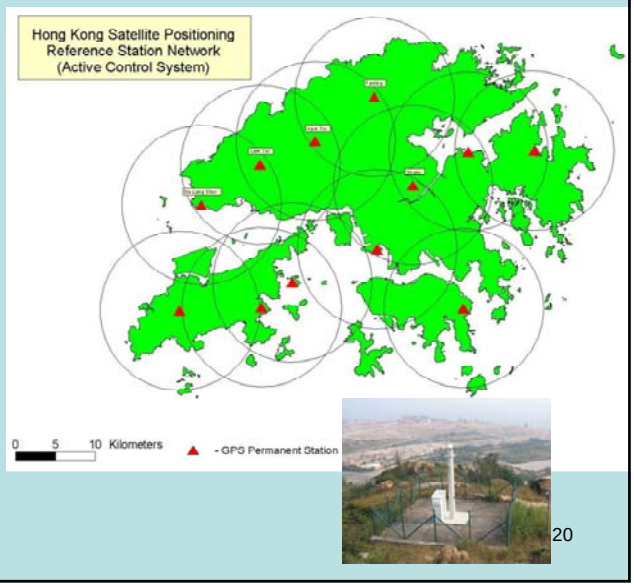
Service Goal

- 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

19

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.



20

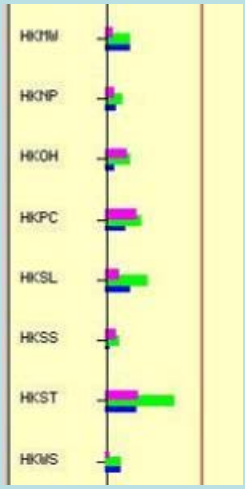
Advantage

- 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

21

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.



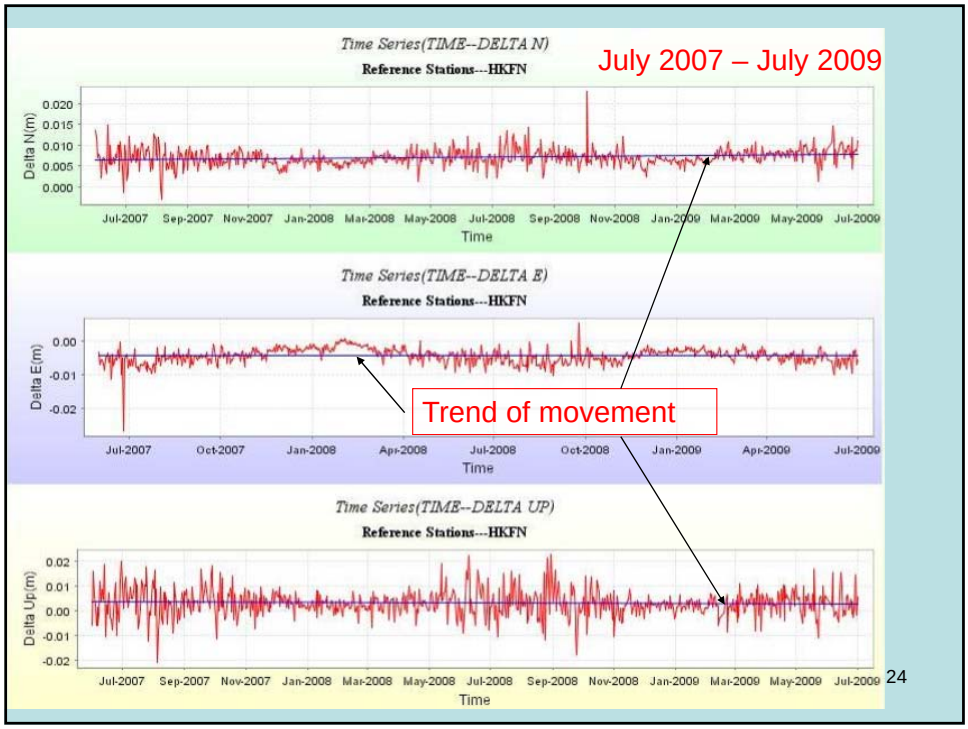
Station Name | dx dy dz | Threshold 8 cm

22

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

23



24

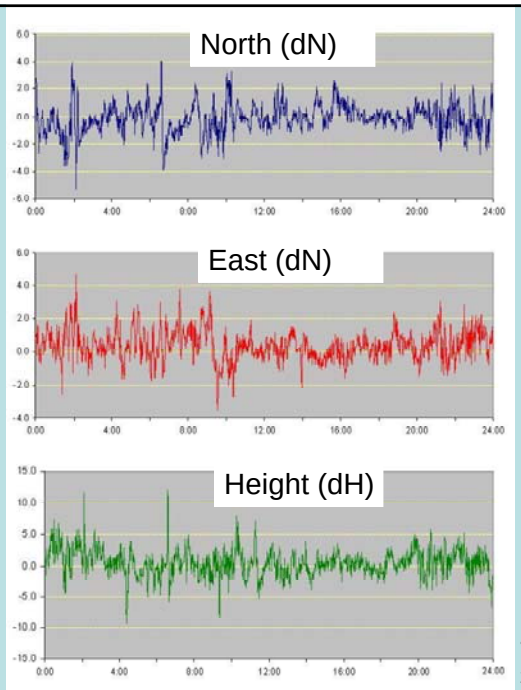
Network RTK data quality check

- Network RTK data are checked at 3 monitoring stations

Network RTK data quality monitoring stations

25

cm



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

Network RTK data quality

26

Protection of the reference station

- Security fences

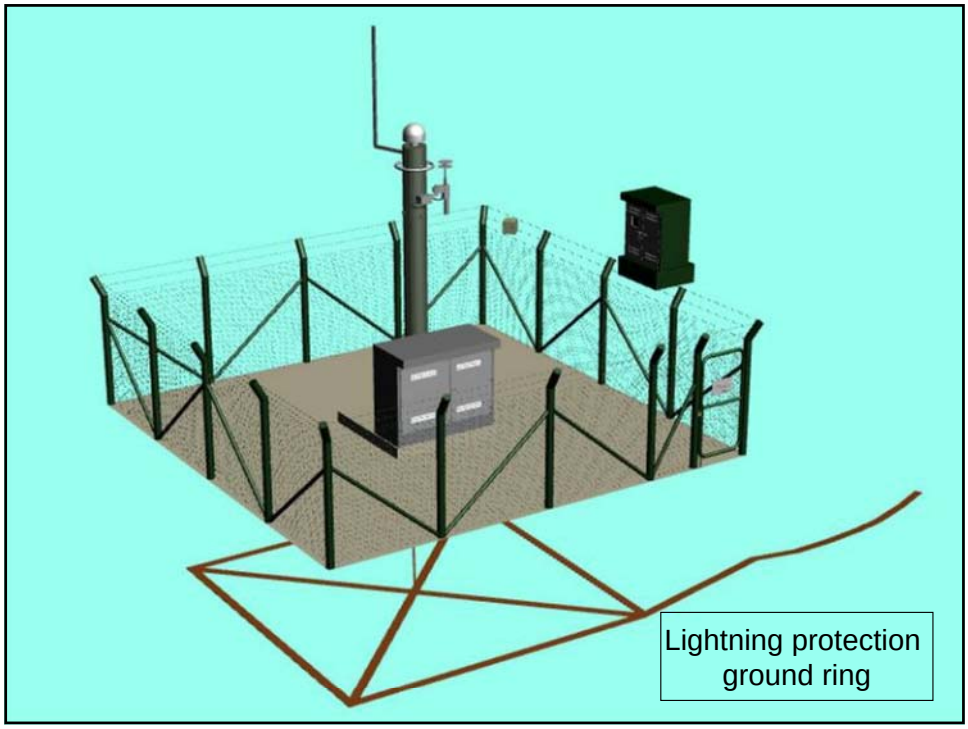
- 8m x 8m Concrete Platform
  - protect the site from bush fire
  - Prevent lost of supporting soil

27

Protection of reference station site

- Lightning protection system

28



Business Continuity

- Telecommunication
- Electricity supply
- Redundant system to ensure continuation of the service during system maintenance and equipment failure
- Disaster recovery

30

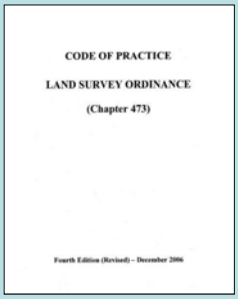
Creating an enabling environment
to make the positioning infrastructure work

31

Legal Requirements
Accuracy Standards
Practice Guide

- Land Survey Ordinance
  Code of Practice

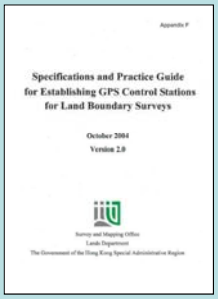
  Specifications and practice guides for establishing GPS control stations for land boundary surveys


CODE OF PRACTICE

LAND SURVEY ORDINANCE

(Chapter 473)

Fourth Edition (Revised) – December 2006


Specifications and Practice Guide
for Establishing GPS Control Stations
for Land Boundary Surveys

October 2004
Version 2.0

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


Accuracy Standards of Control Survey

(Version 1.0)

July 2004

Geodetic Survey Section
Survey and Mapping Office
Lands Department

32

Human resource development

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

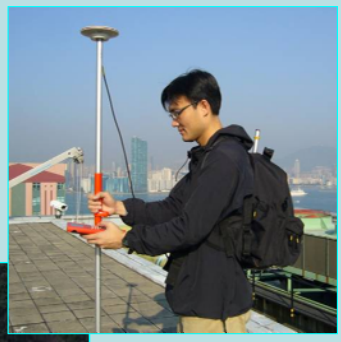
33

Satellite Positioning Training activities
of the Lands Department
(1992 to July 2009)

Type of activity	Training Objective	Number of trainees / participants
Courses provided by manufacturer	Skill to use equipment and tools	401
In house training	Work practices to meet organizational needs	730
Advanced course offered by local and overseas universities	Knowledge for development of workflow, procedures and services	152
International / Local Conference	• Communicate with the customers and understand their needs • share experience, innovation and new opportunity	74

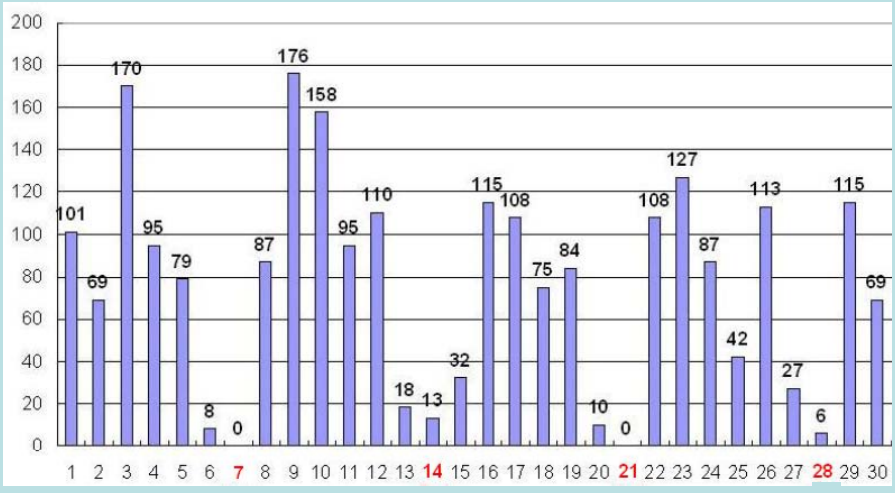
34

Reference station data service
for
surveying applications



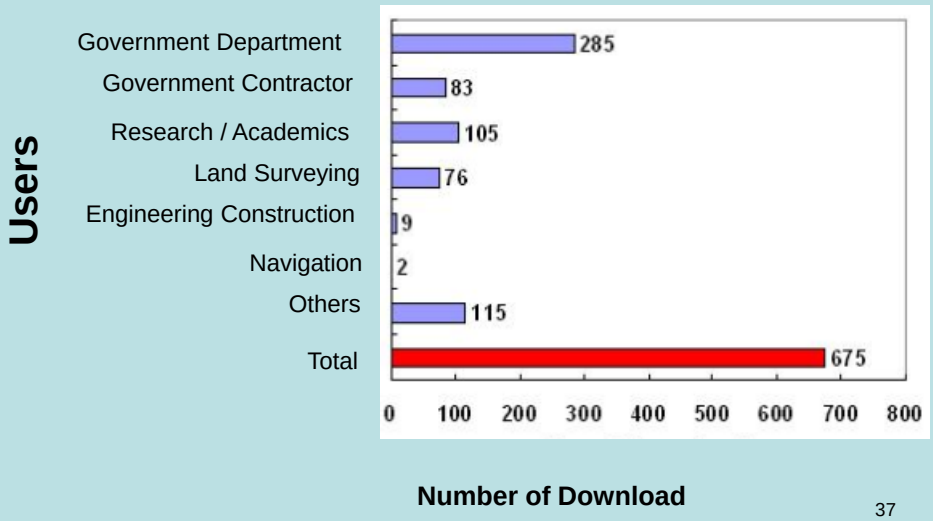
35

Number of Network RTK Connections in June 2009 = 2987



36

RINEX Data Download (June, 2009)



37

Innovation

Add Value

Social Benefits

Quality of living

38

Use of the Satellite Positioning Reference Station Data Services for multi-discipline applications :

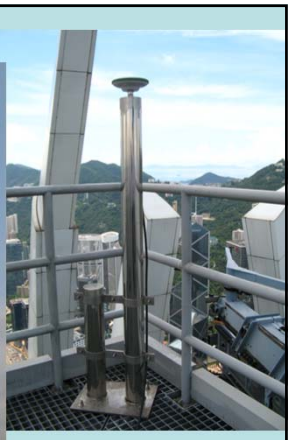
Satellite Positioning + structural engineering
+ geotechnical engineering
+ land use control
+ weather forecast
+ GIS spatial data infrastructure
+ geodynamic
+ location base services
+ customer market
(shopping, sight seeing, restaurants, hiking, sport)
+ ……..

39

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)



The International Finance Centre

40

Automatic real-time monitoring of a slowly moving slope

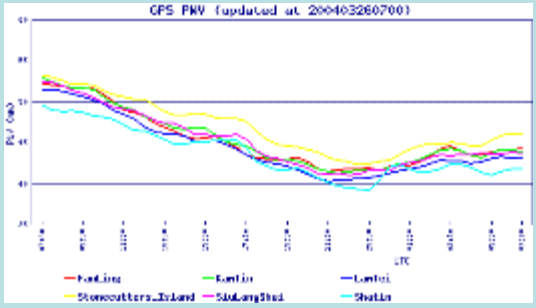
(Courtesy of the Civil Engineering Department of Hong Kong)

42

The Planning Department uses the Network RTK data services to take measurement for enforcement and prosecution of unauthorized development under Town Planning Ordinance.

43

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



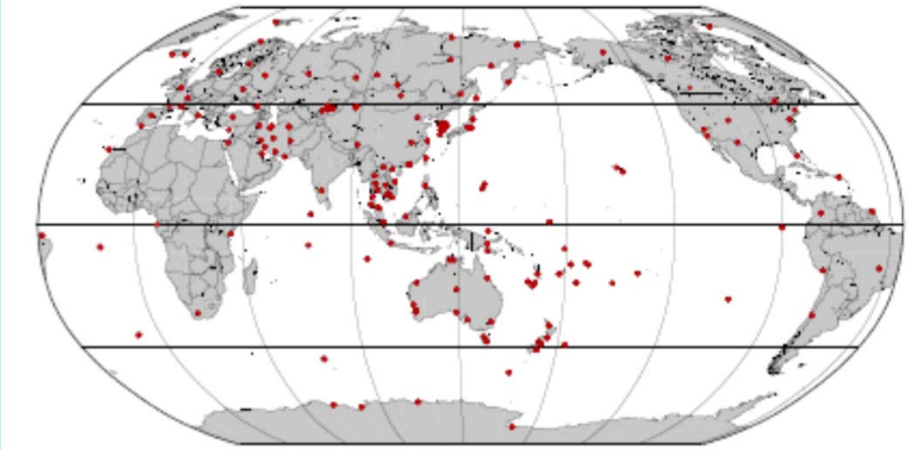


Figure 7: Global map, PCGIAP and IGS GPS stations, 2002.

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.

45

The consumer market has not yet full explore the potential of :

- DGPS
- RTK
- Wireless Internet
- Information
- Light weight and low cost devices

46

The success factors for Positioning Infrastructure

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

Improve quality of life

47