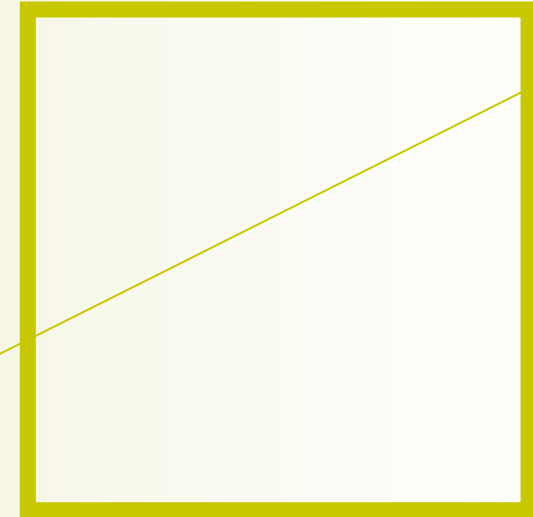


GPS Reference Station Network - Singapore's Experience



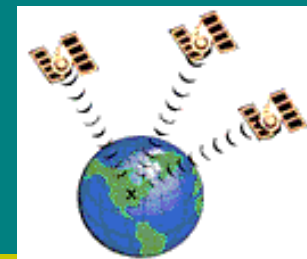
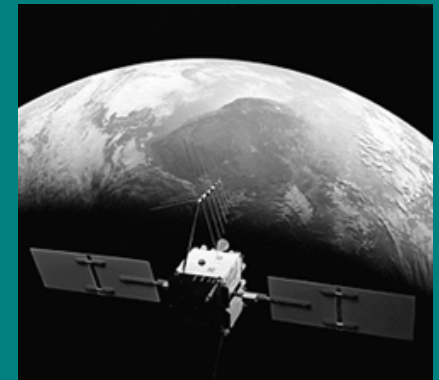
Victor Khoo
Manager
Survey Services, SLA

Presentation Flow

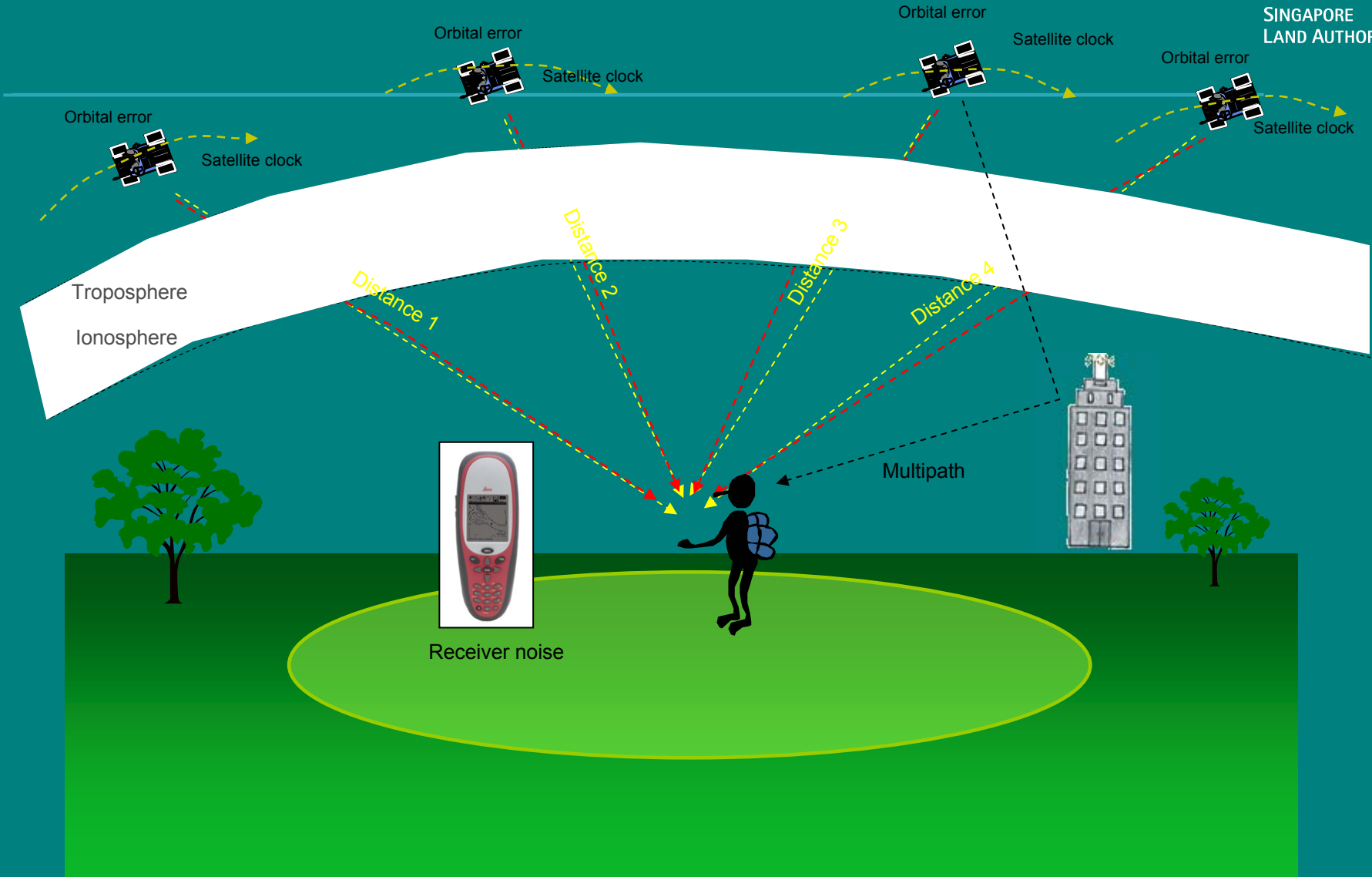
- GPS Reference Station Network
- SiReNT as Nationwide DGPS System
- Applications with SiReNT
 - Survey, GIS and Mapping
 - Navigation and Tracking
 - Deformation Monitoring
 - Atmospheric Monitoring

What is GPS?

- Global Positioning System (GPS) is a satellite-based navigation and positioning system
- GPS can provide latitude, longitude, altitude and velocity information
- Available globally at anytime, anywhere under all weather conditions
- Totally FREE to use once you have a GPS receiver
- > 10 million GPS users worldwide today



Why Low Accuracy?



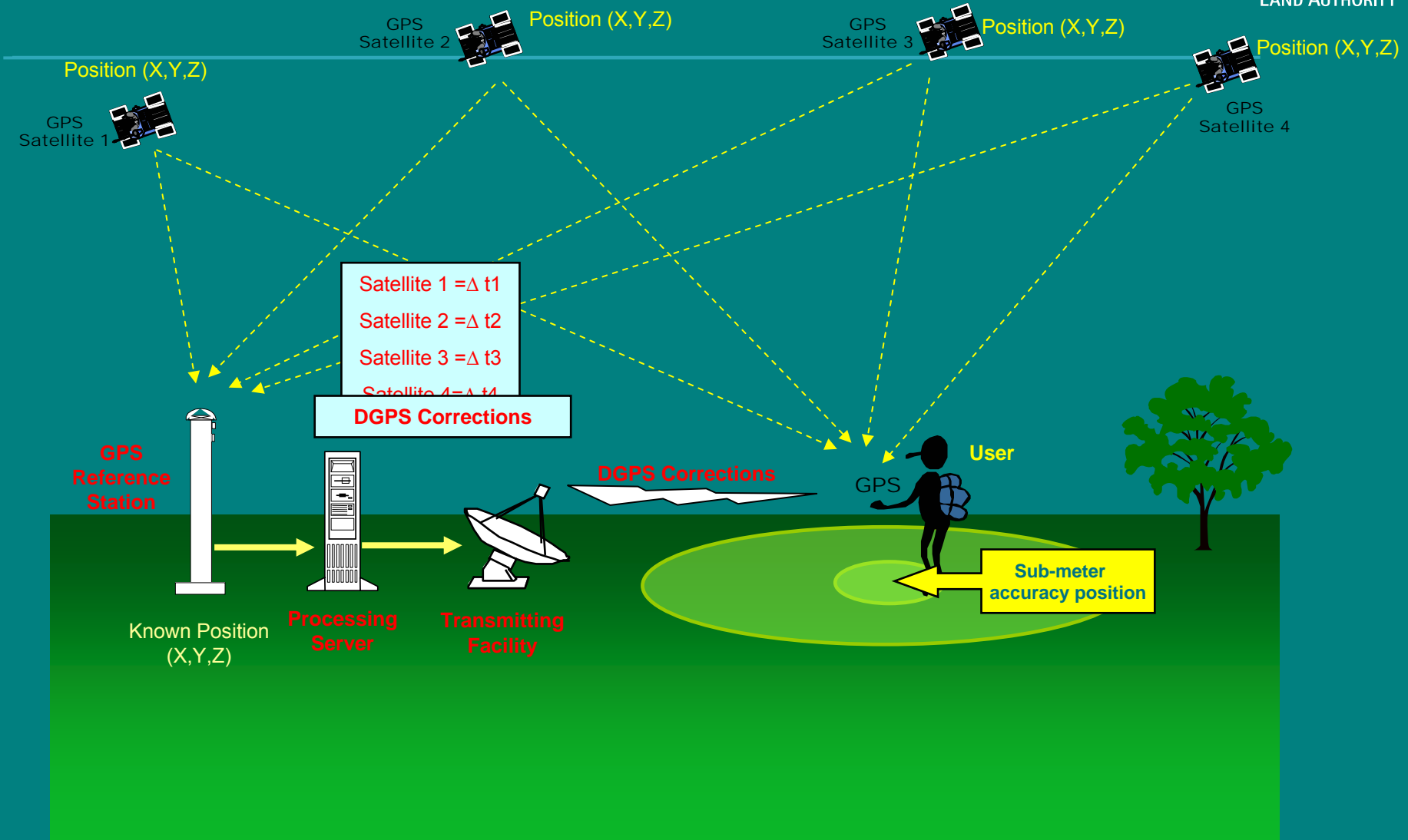
Sources of GPS Error

Standard Positioning Service

<u>Source</u>	<u>Amount of Error</u>
Satellite clocks:	1.5 to 3.6 meters
Orbital errors:	< 1 meter
Ionosphere:	5.0 to 7.0 meters
Troposphere:	0.5 to 0.7 meters
Receiver noise:	0.3 to 1.5 meters
Multipath:	0.6 to 1.2 meters
Selective Availability	switch off

Errors are cumulative and increased by poor satellite-receiver geometry

Differential GPS (DGPS) Technique

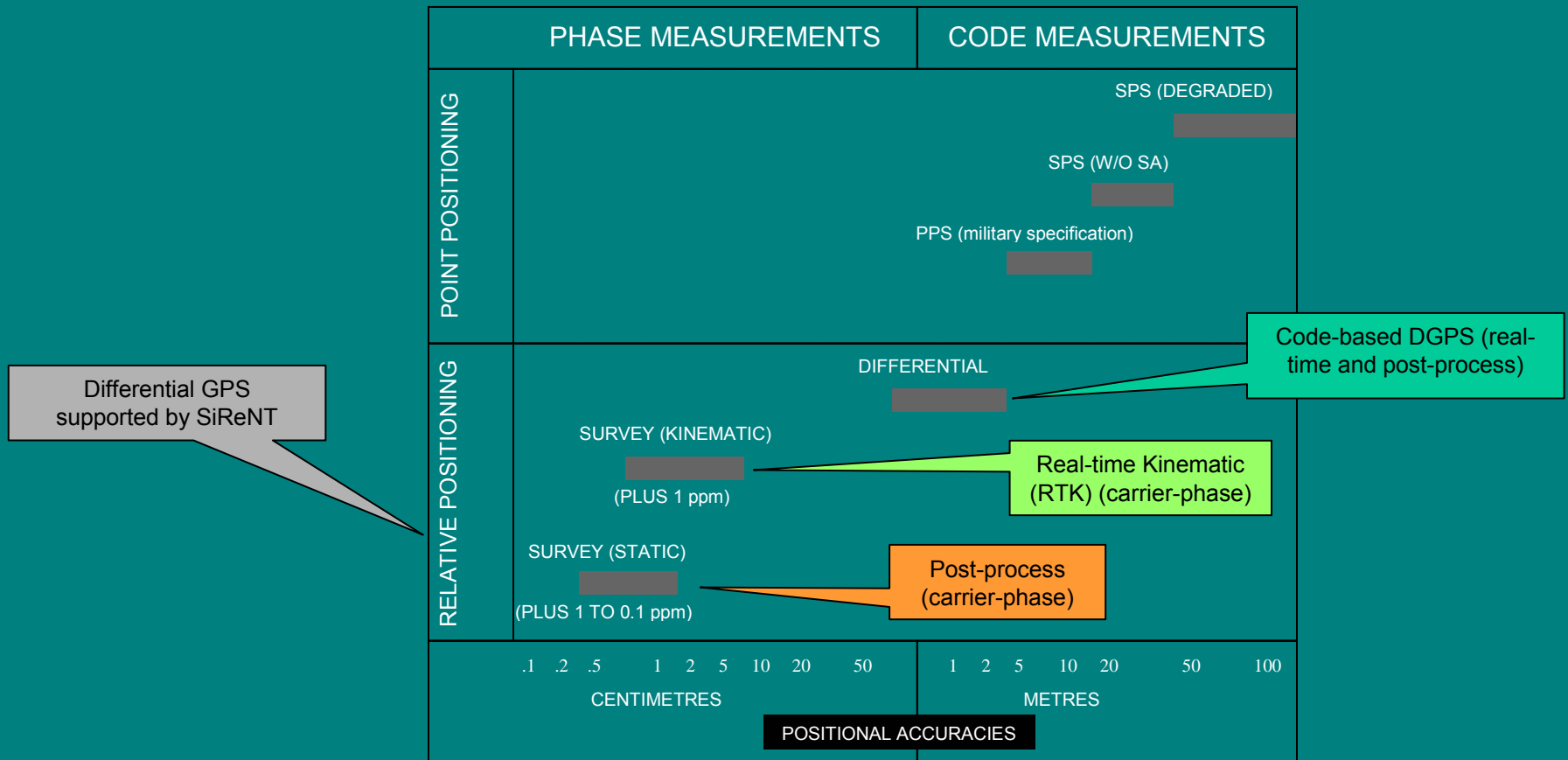


Sources of GPS Error

	<u>Standard Positioning Service</u>	<u>Differential GPS (code)</u>
<u>Source</u>	<u>Amount of Error</u>	<u>Amount of Error</u>
Satellite clocks:	1.5 to 3.6 meters	eliminate
Orbital errors:	< 1 meter	eliminate
Ionosphere:	5.0 to 7.0 meters	0.4 meters (reduce)
Troposphere:	0.5 to 0.7 meters	0.2 meters (reduce)
Receiver noise:	0.3 to 1.5 meters	0.3 to 1.5 meters
Multipath:	0.6 to 1.2 meters	0.6 to 1.2 meters
Selective Availability	switch off	eliminate

Errors are cumulative and increased by poor satellite-receiver geometry

GPS Positioning Accuracies



SA – Selective Availability
ppm – parts per million

SPS – Standard Positioning Service
PPS – Precise Positioning Service

Adopted from “Principles and Practice of GPS Surveying” by Rizos

GPS Reference Station Network

- Established for the main purpose of providing Differential GPS services – users only need one GPS receiver
- Permanent infrastructure to support high precision DGPS – Real-time kinematic (RTK)
- Provide homogeneous reference frame
- Cover larger area with less number of reference stations

Homogeneous Coordinate Reference Frame

Possible consequences of using inconsistent reference systems

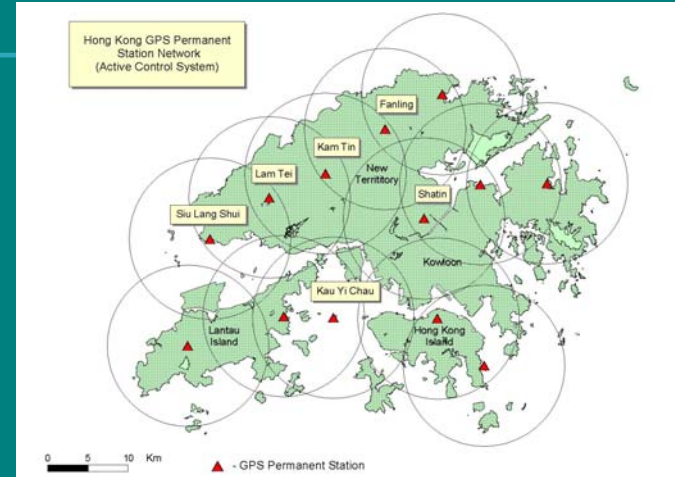


Source: Trimble

GPS Reference Station Network in the Region



Malaysia - MyRTKnet



Hong Kong GPS Reference Station Network



Victoria - GPSnet

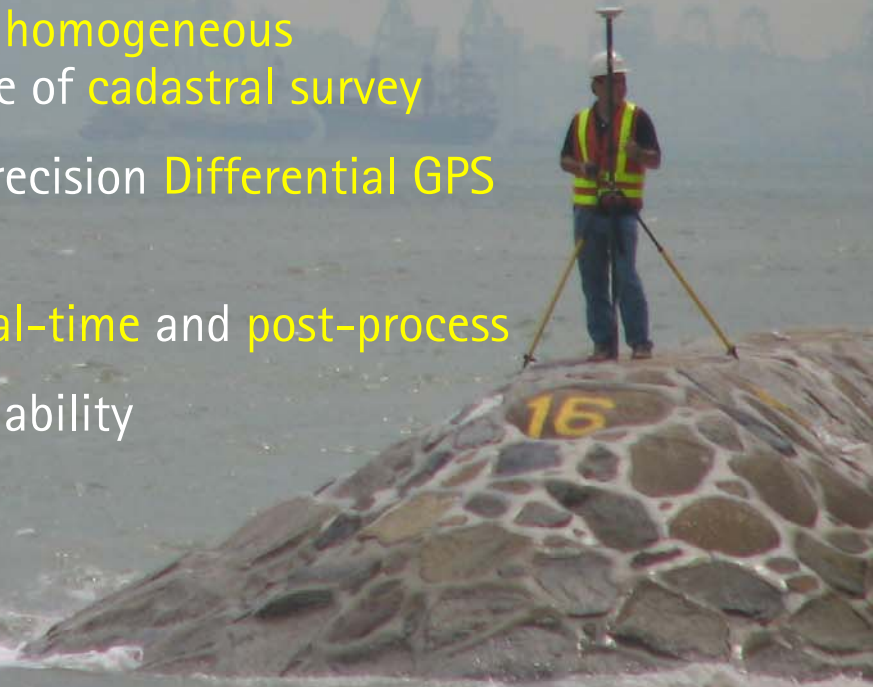


Sydney - Sydnet

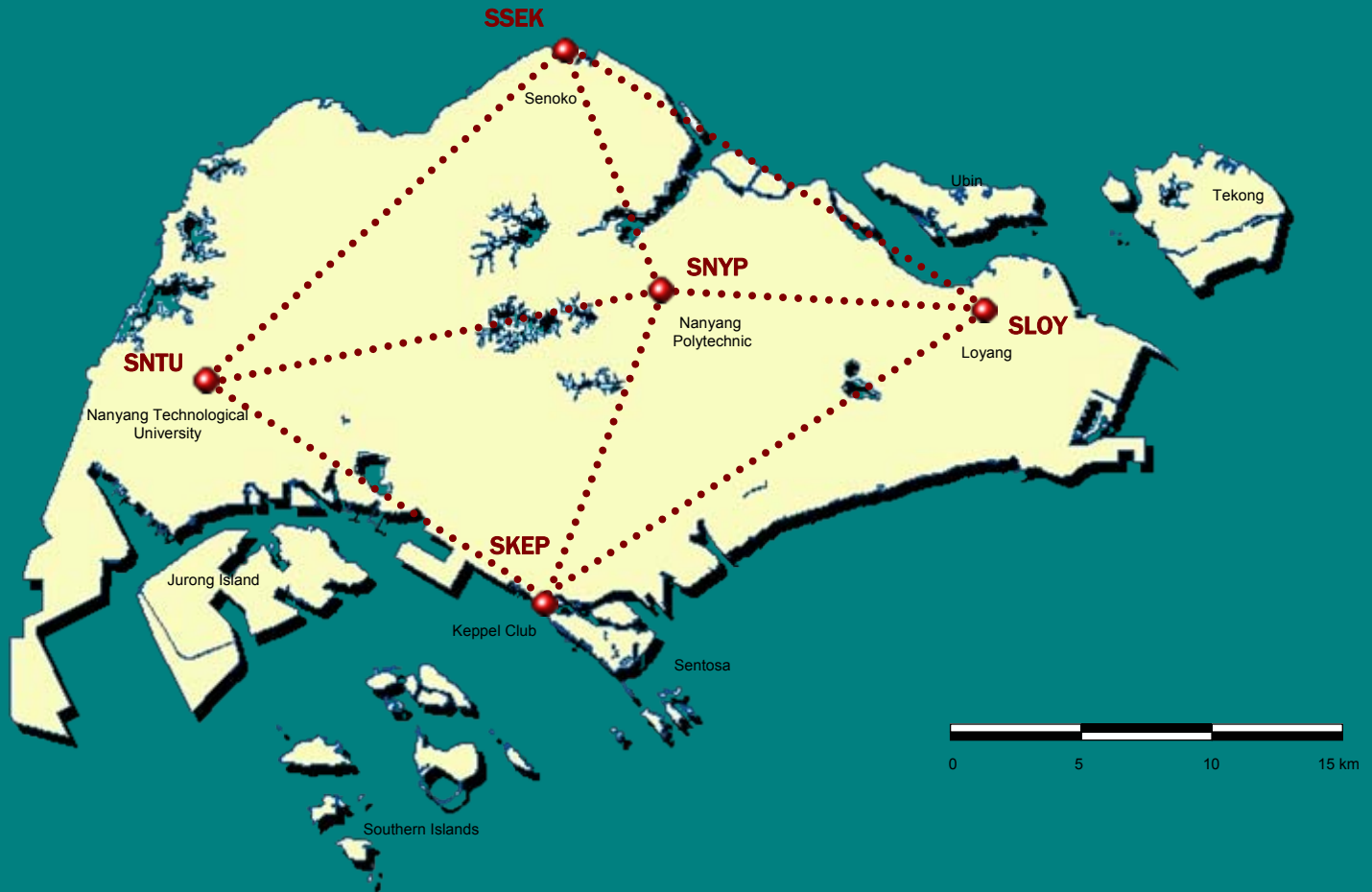


Kunming GPS Reference Station Network

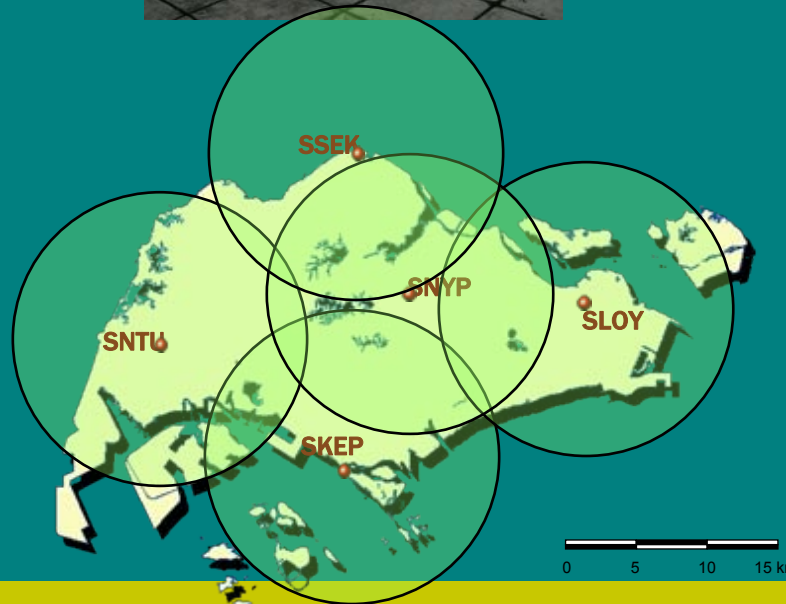
- **SiReNT** – Singapore Satellite Positioning Reference Network
- Implemented by the **Singapore Land Authority**
- Launched on **1 September 2006**
- Replace the old system known as SIMRSN
- The main objective of SiReNT is to provide a **homogeneous geographical reference frame** for the purpose of **cadastral survey**
- Nationwide infrastructure to support high precision **Differential GPS technique**
- Support all types of GPS positioning both **real-time** and **post-process**
- High accuracy, high availability and high reliability
- Flexible and ready for integration



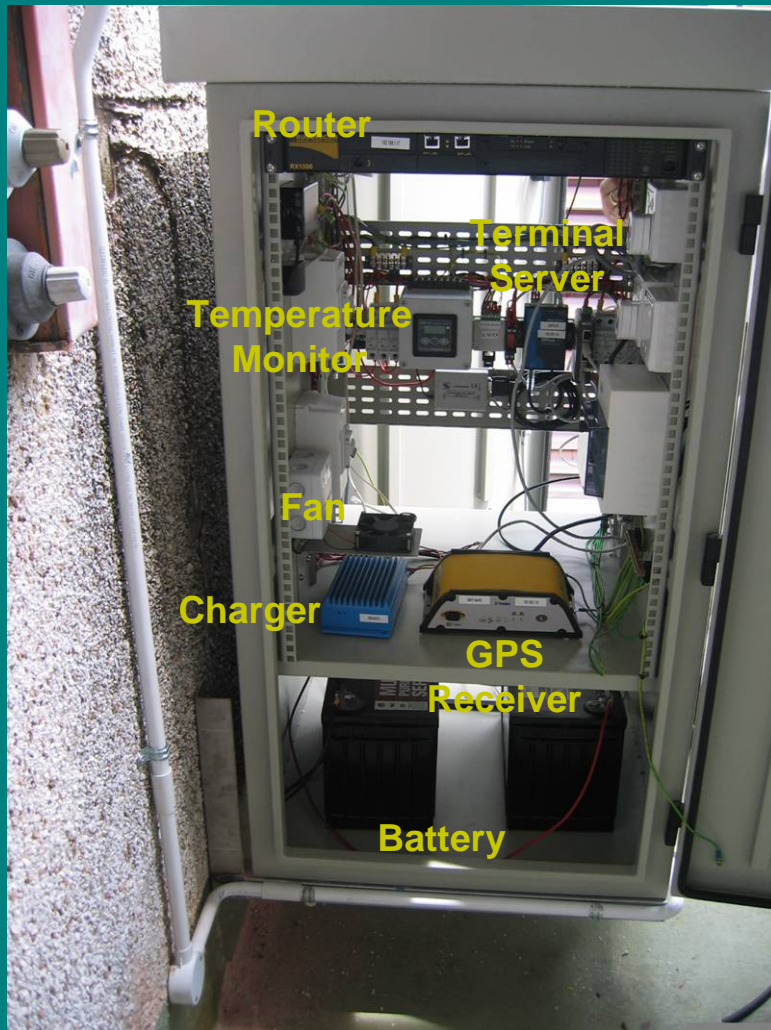
SiReNT Network – Nationwide Coverage



SiReNT GPS Reference Stations



SiReNT GPS Reference Station



GPS Data Flow



Data control centre located at Government Data Centre

- Database management system
- GPS software
- Communication devices

SiReNT – System Characteristics

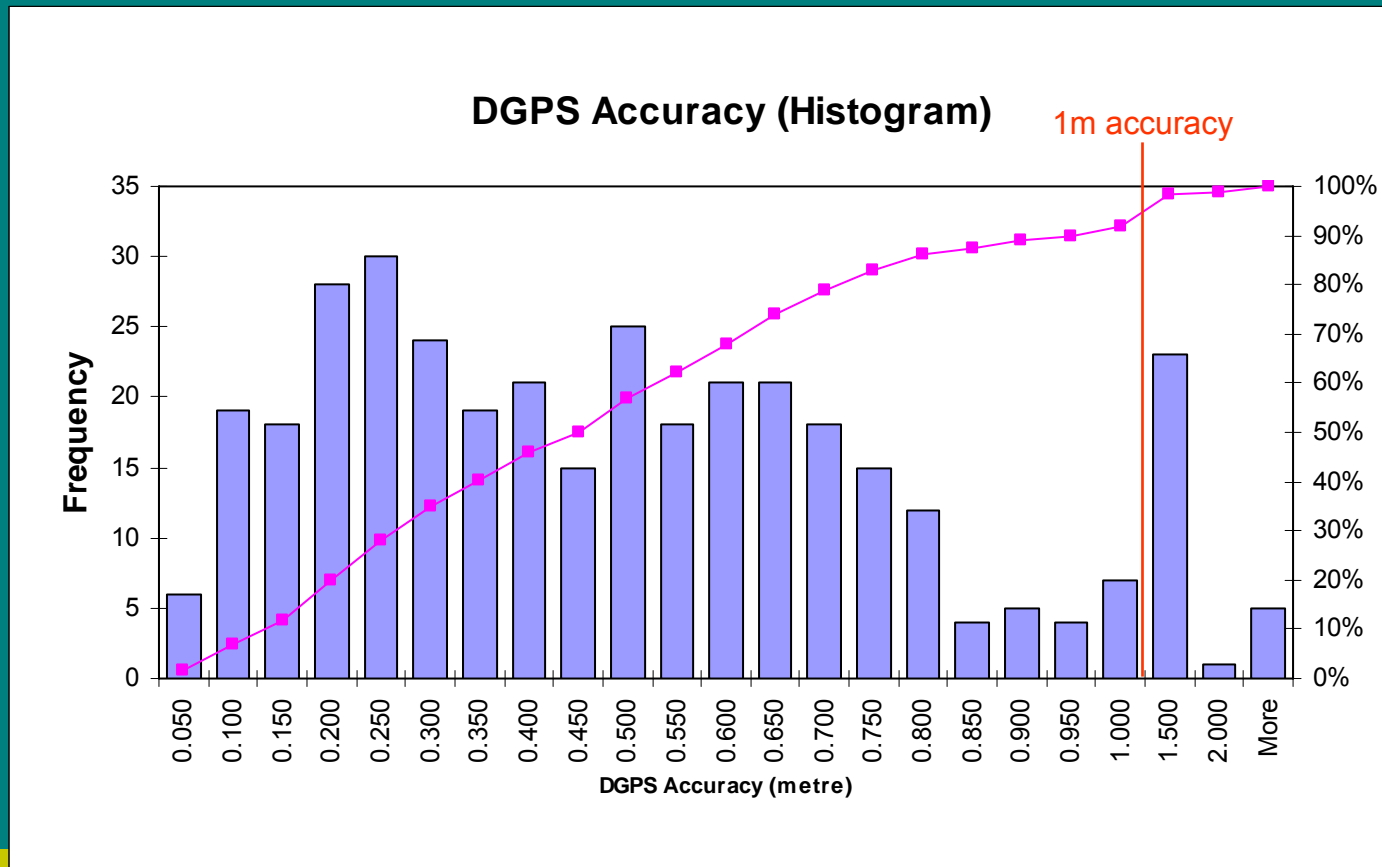
- 3 Basic Services –
 - DGPS (Real-time code-based DGPS): 0.5 – 3 metre (depending on receiver)
 - RTK (Real-time Kinematic) : 1 – 5 cm (+ 1ppm)
 - PP-On-Demand (Post-Process) : 5 – 30 mm (+ 1pmm)
- High availability 99.973%
- High reliability
 - Continuous integrity monitoring
 - Redundancy strategy

SiReNT – System Characteristics

- Non-proprietary international standard for ease of integration
 - Adopt standard formats for GPS data i.e. RTCM and CMR
 - Support GPRS data communication
 - Support NTRIP communication protocol through TCP/IP
- Help and information
 - Website for SiReNT information and PP-on-demand GPS data dissemination
 - Helpdesk for technical support

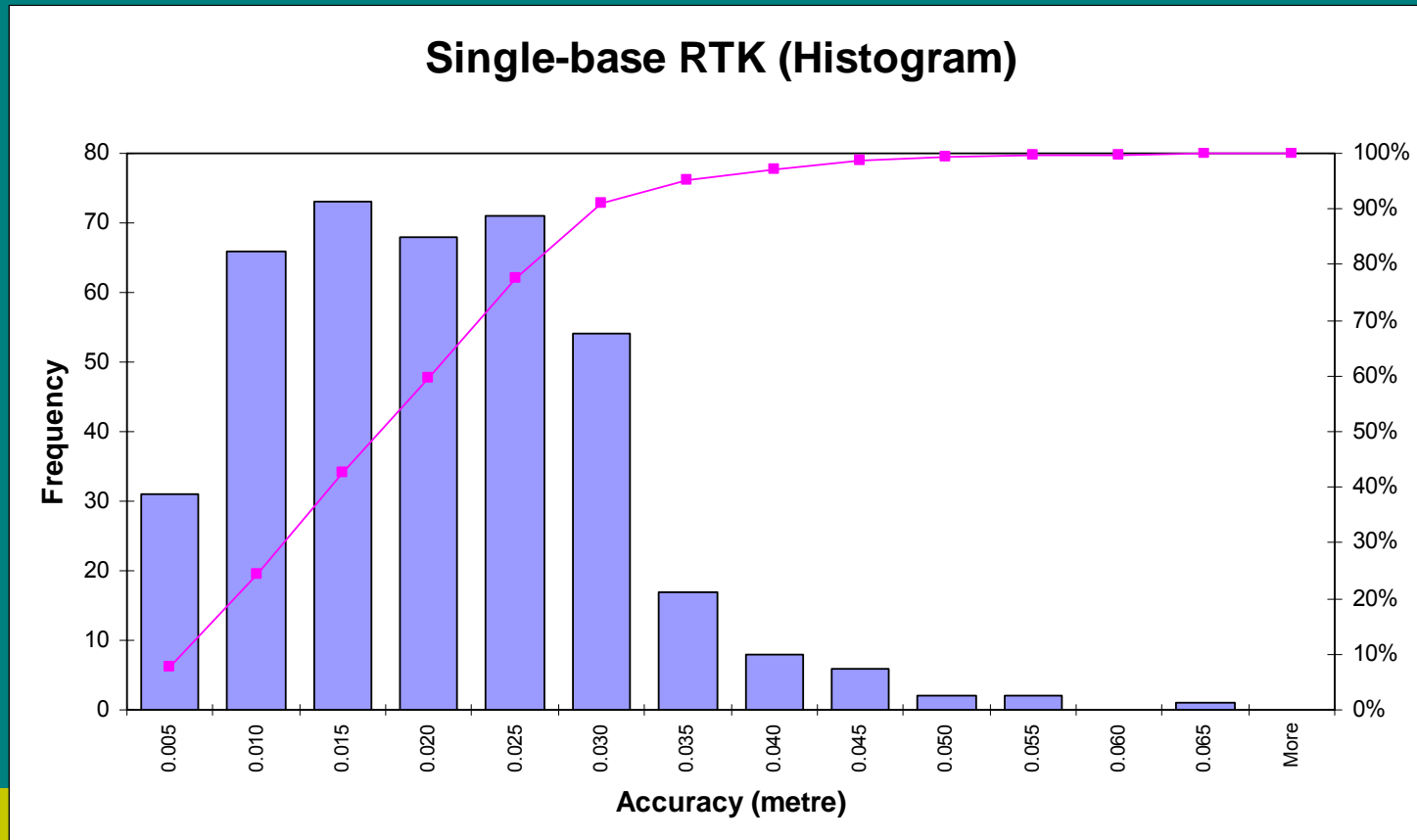
DGPS Positioning Accuracy

- Test carried out on 40 known points (360 data set)
- Positioning accuracy 90% of the time better than 1 metre

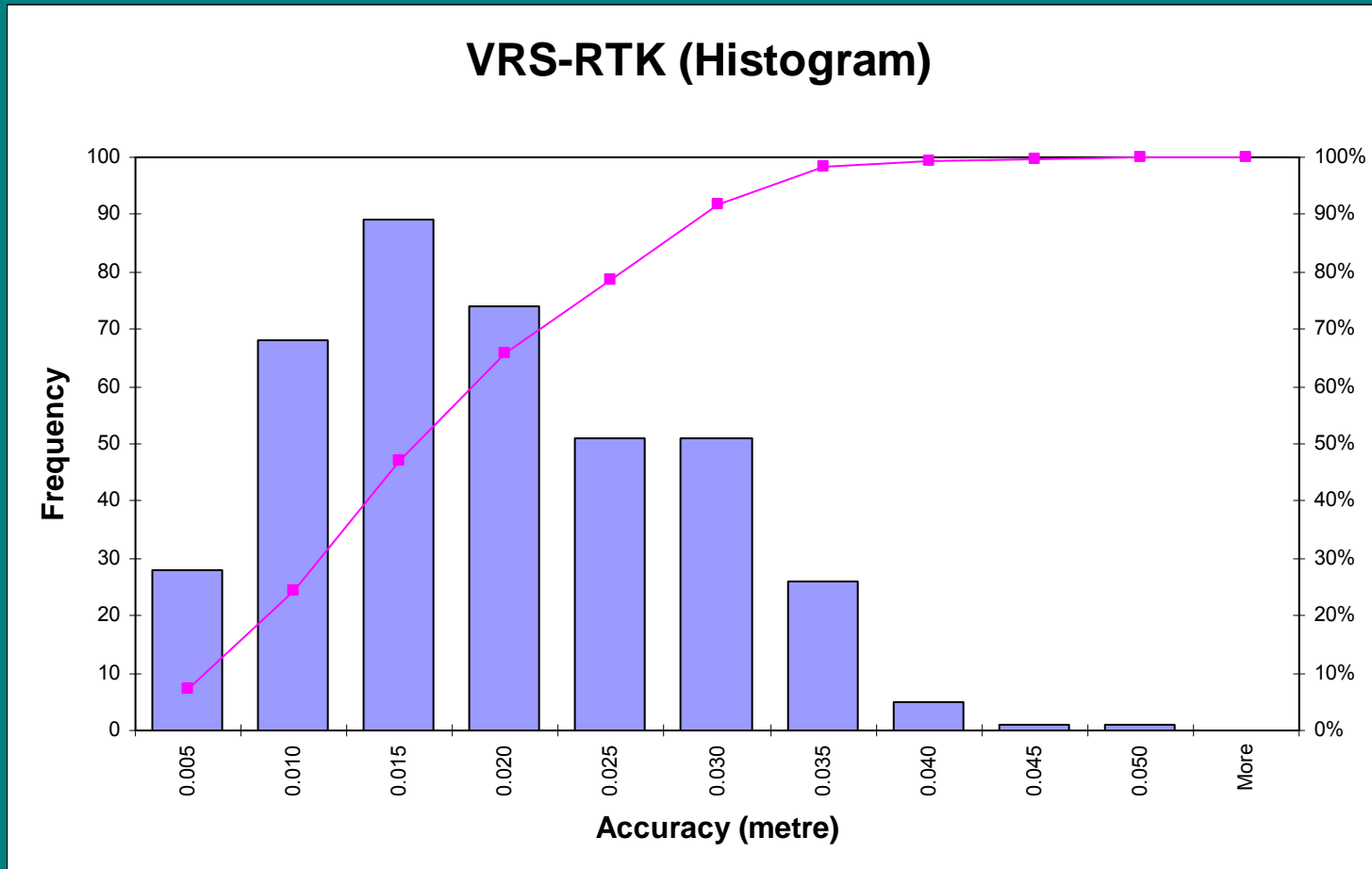


RTK Positioning Accuracy

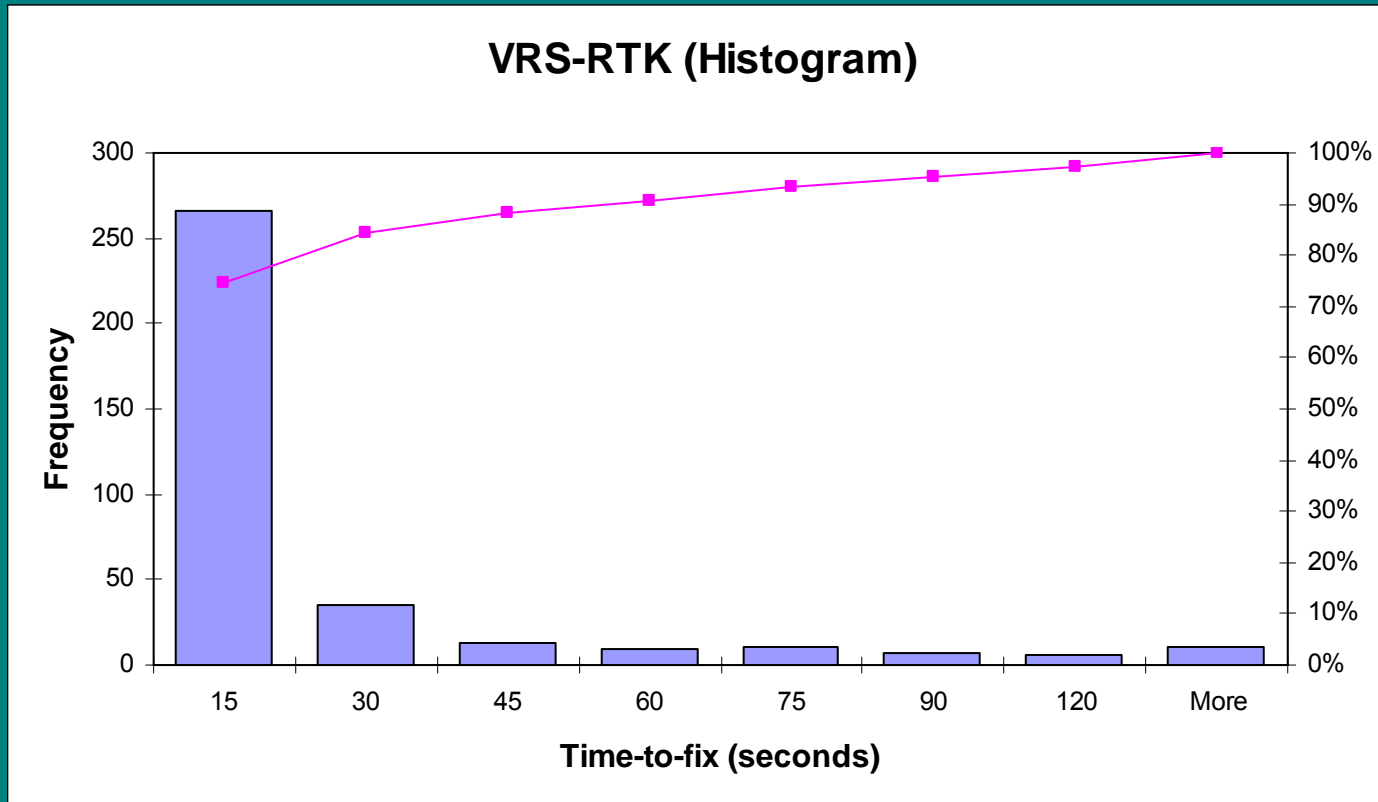
- Test carried out on 40 known points (360 data set)
- Positioning accuracy 95% of the time better than 35mm (2 DRMS)



VRS-RTK Positioning Accuracy



Time-to-fix for VRS-RTK with SiReNT

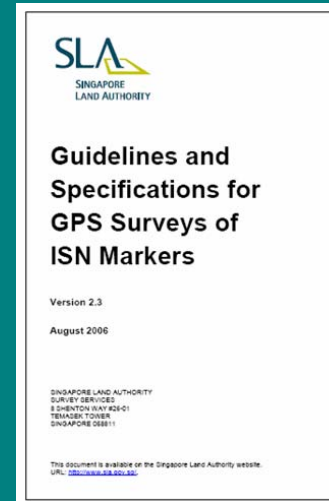


SiReNT Applications

- Survey, GIS and Mapping
- Navigation and Tracking
- Deformation Monitoring
- Atmospheric Monitoring

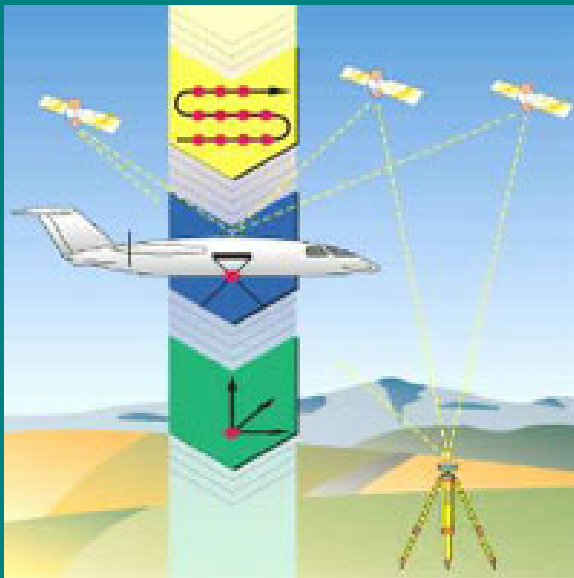
ISN Survey using SiReNT PP-On-Demand

- Static GPS survey
- Guidelines provided
- Connect to at least 2 SiReNT reference stations
- Access SiReNT website for data generation
- Data available 1 hour after observation



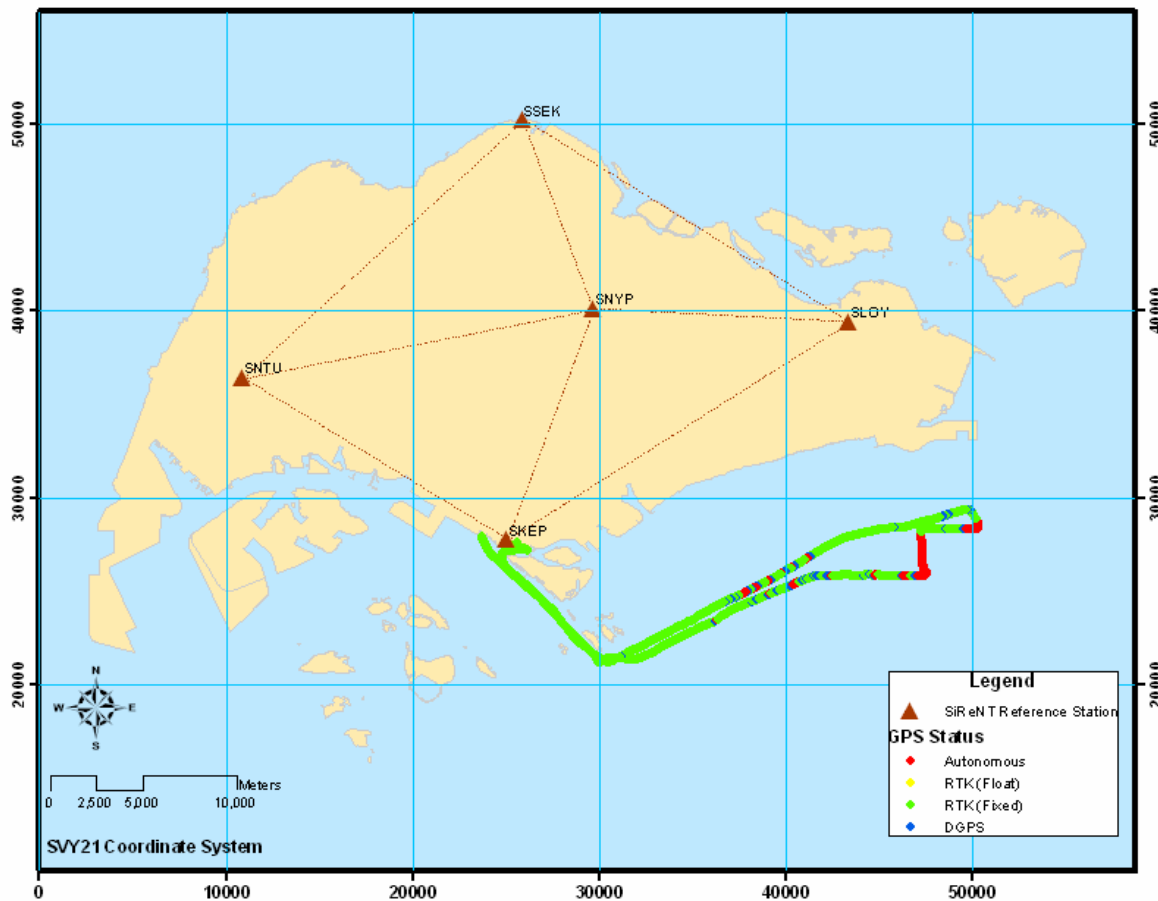
Aerial Photogrammetry

- SiReNT data is used to determine the flight path and location of ground control points



Hydrographical Survey

SiReNT Offshore Testing with MPA on 19th April 2007



GIS Mapping in difficult sites condition

- Conditions when direct DGPS is not possible
 - Points under large canopy, near high-rise structure
 - Points difficult to reach e.g. heavy traffic, across a river etc.

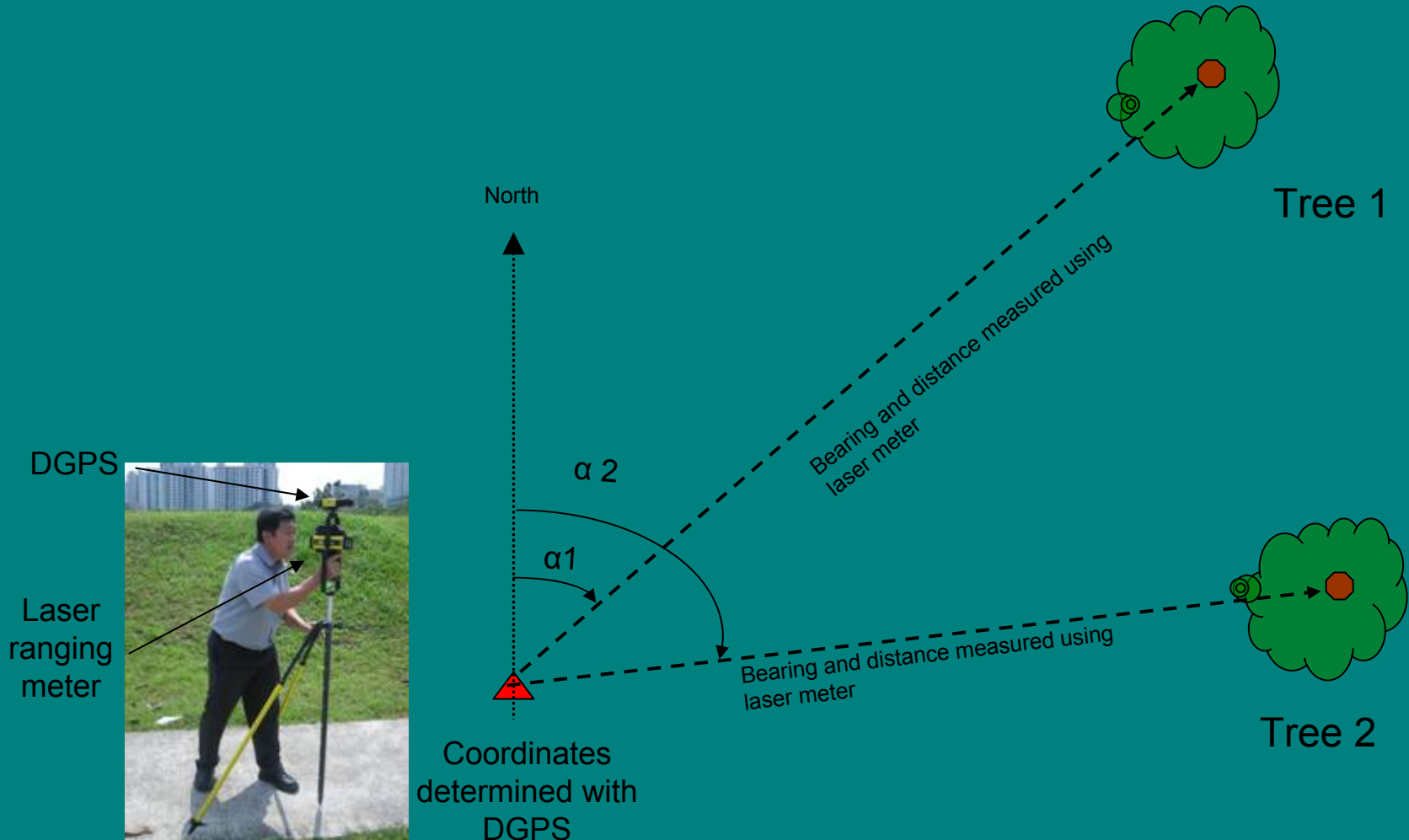


DGPS and Laser Ranging Device for GIS Mapping

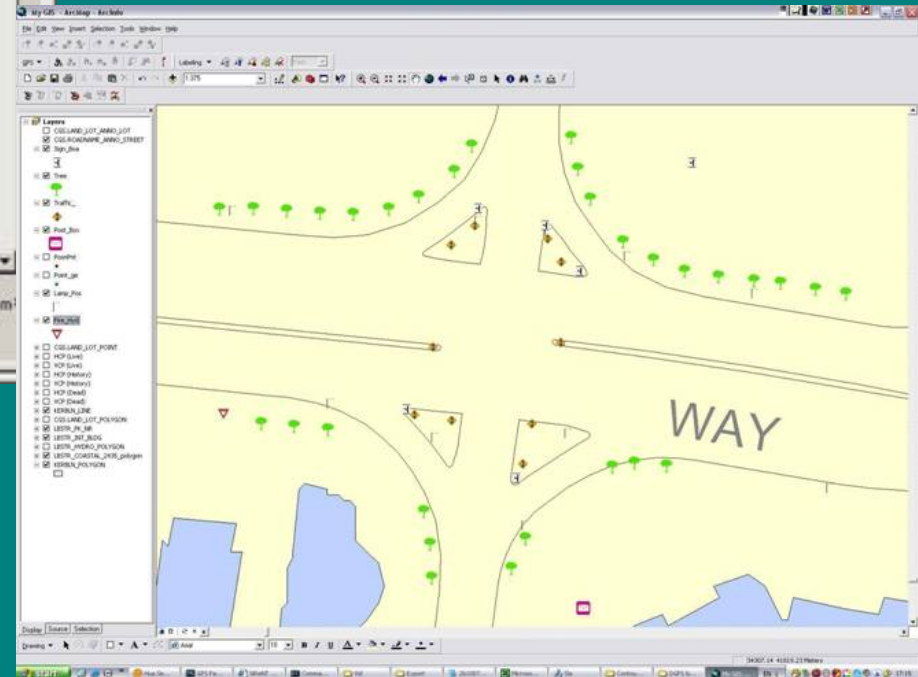
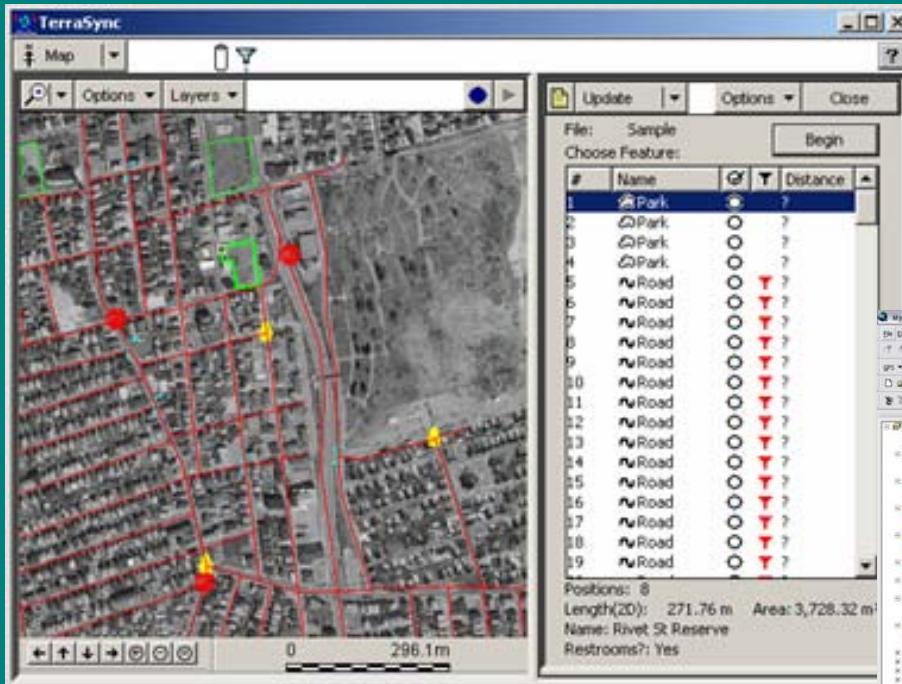
- Integration of DGPS with laser ranging device
- Bluetooth connection
- Offset method is used in determining the coordinates of object
- Positioning accuracy achievable with the integrated method = sub-metre to 3 metre



Offset method - Bearing & Distance



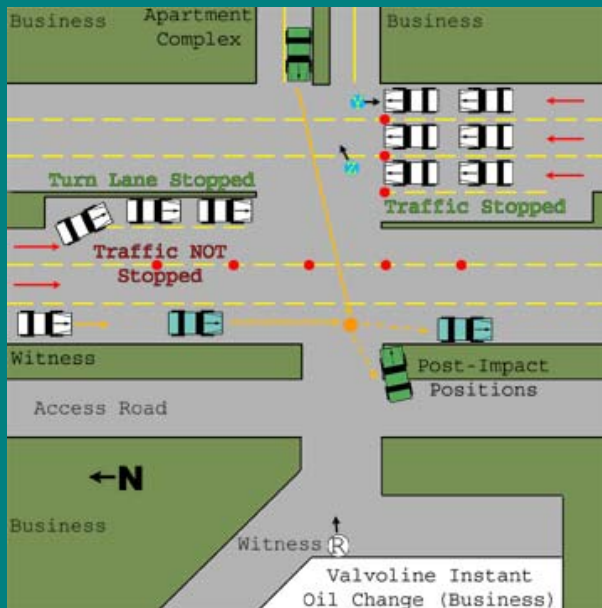
DGPS + GIS = Real-time mapping



Real-time Land Slide Mapping (example)



SiReNT for Traffic Accident Mapping (potential application)



Laser ranging



DGPS + Camera

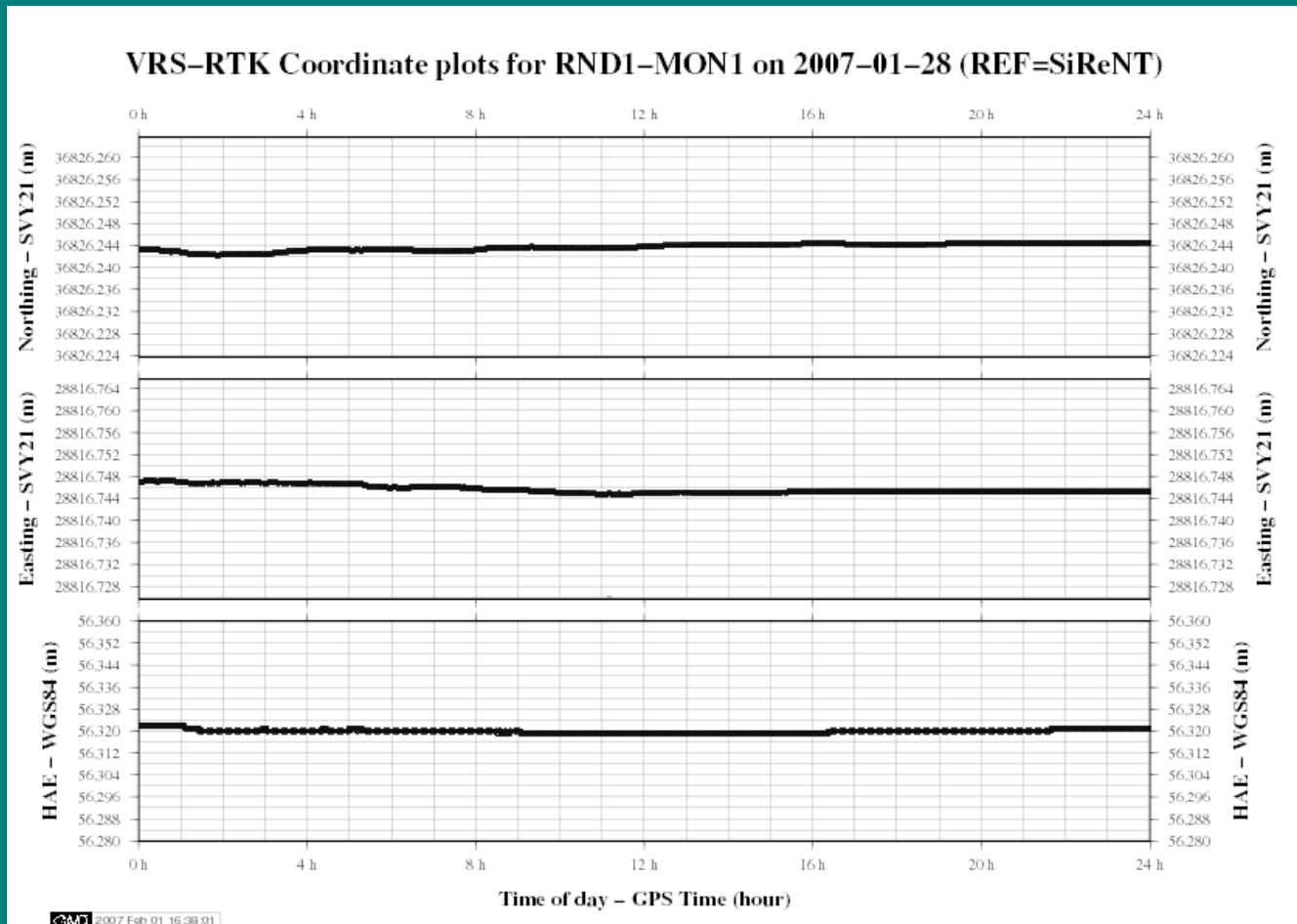
Traffic Accident Mapping System

- Absolute positioning (high accuracy)
- Using GIS with road line data
- Efficient
- Real time

VRS-RTK for Deformation Monitoring

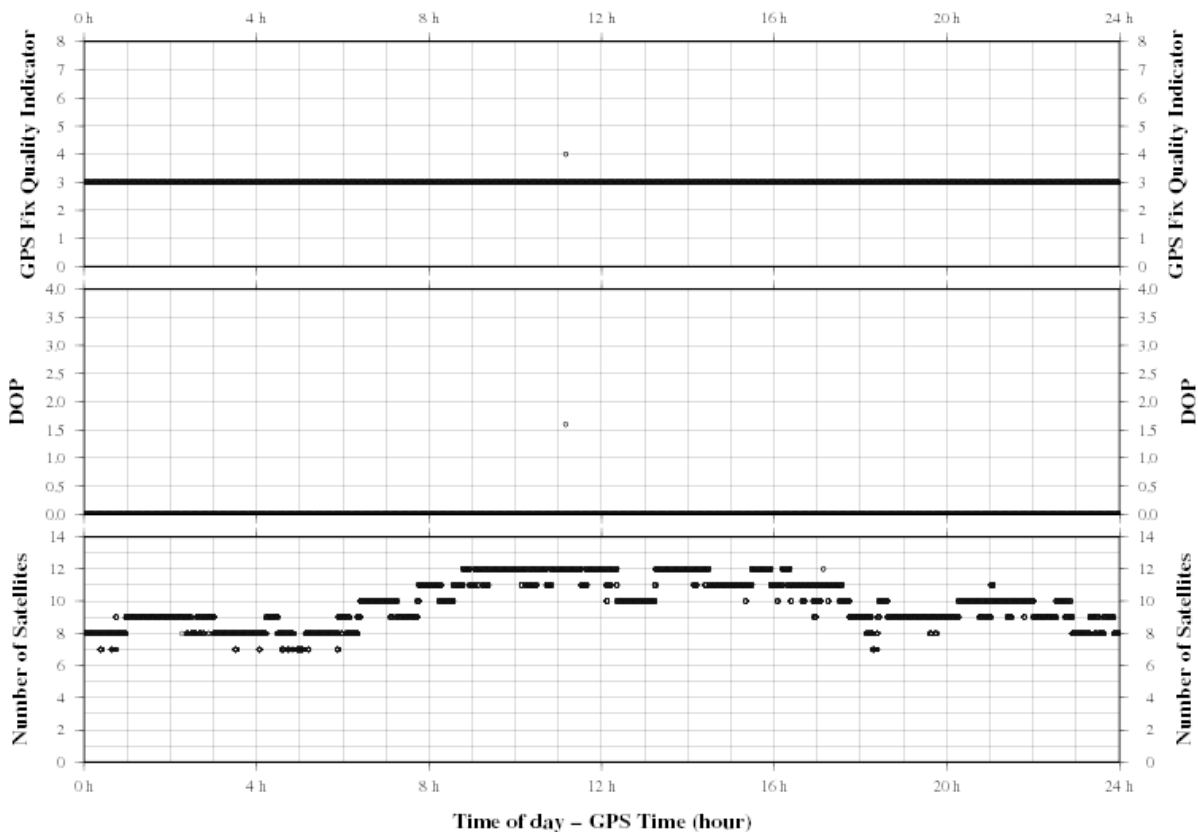
- Development of GPS techniques i.e. Network-DGPS, VRS and wireless communications as well as the availability of GPS network infrastructure have made the GPS become a powerful and cost-effective tool for deformation monitoring
- VRS-RTK, precision achievable (over 60 minutes)
 - horizontal component = $\pm 1\text{mm}$
 - vertical component = $\pm 3\text{mm}$
- VRS-RTK is a feasible technique for deformation monitoring
 - Detection of harmonic movement
 - Displacement estimation
 - Long-term deformation

Time Series – Northing, Easting and HAE



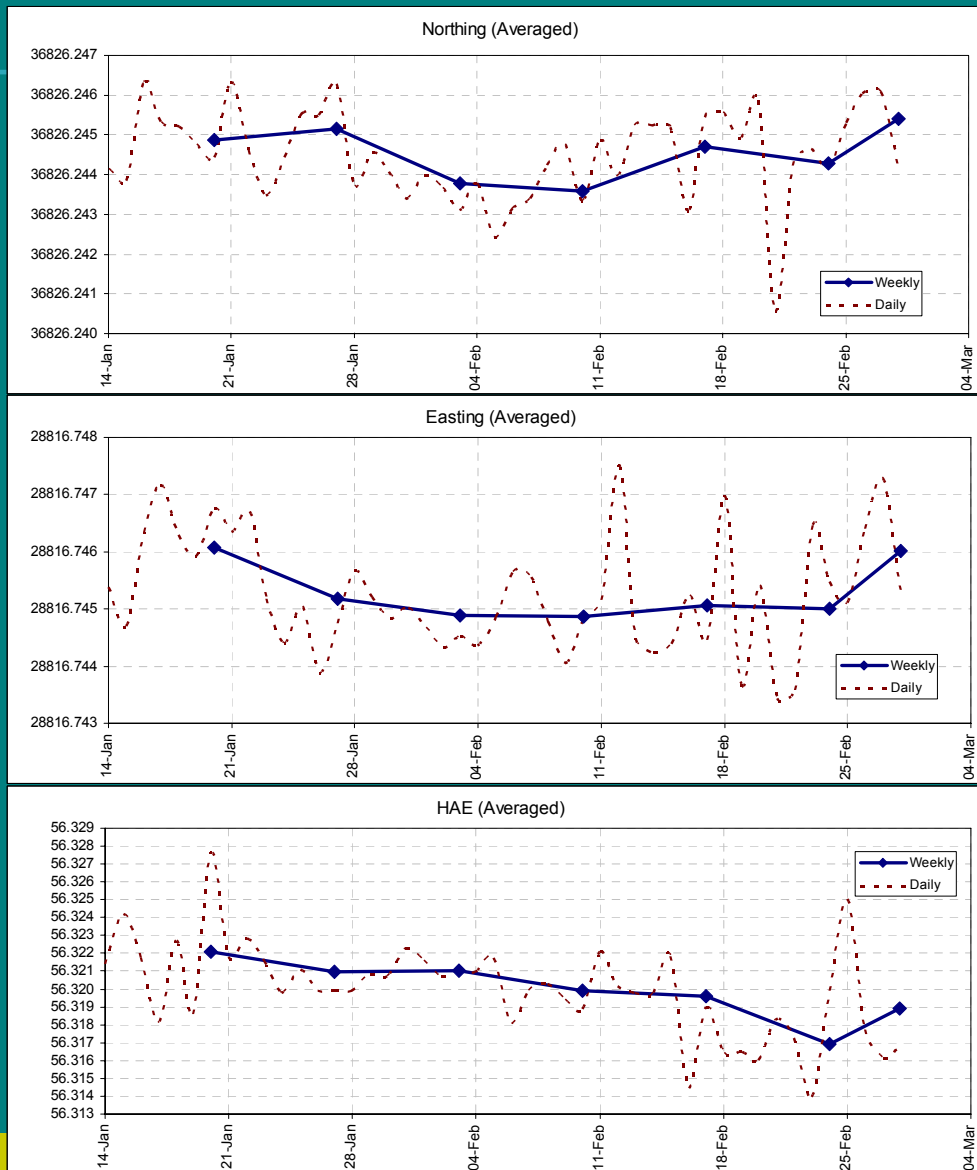
GPS Quality Indicator, PDOP and No. of Satellites

VRS-RTK Supplementary plots for RND1-MON1 on 2007-01-28 (REF=SiReNT)



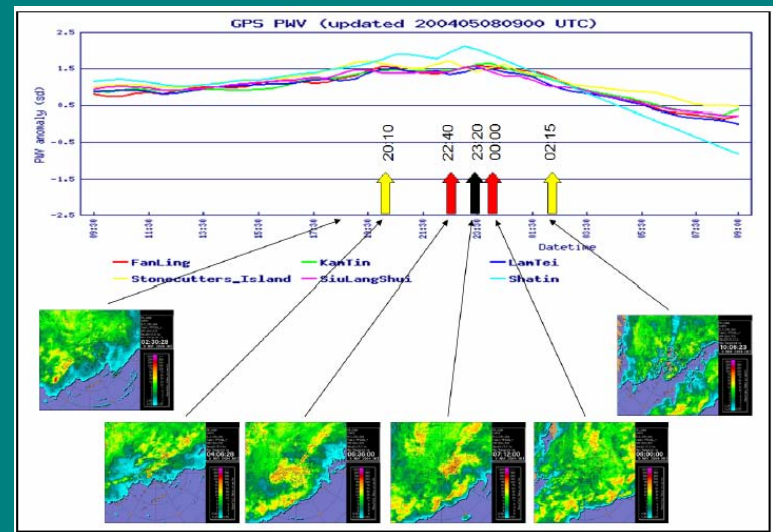
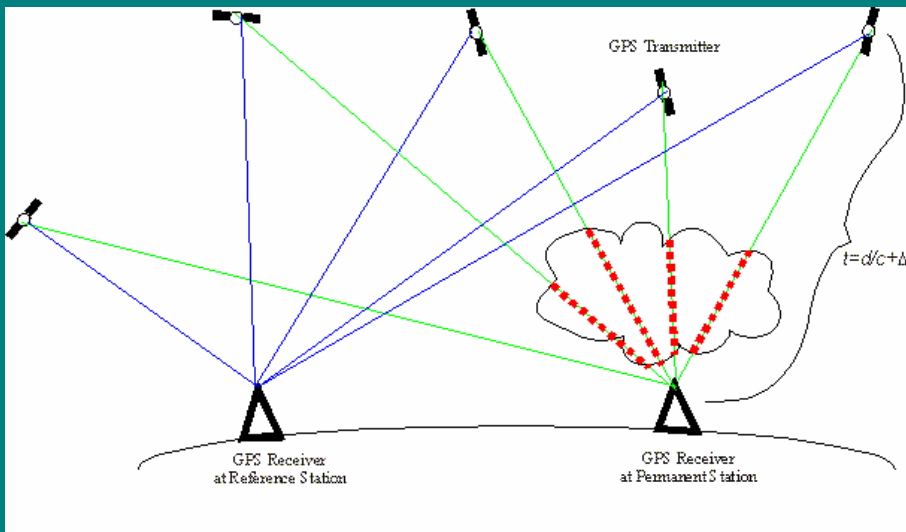
2007 Feb 01 16:28:03

Daily and Weekly Average



Estimation of Integrated Water Vapor using GPS

- Project collaboration with NTU
- SiReNT real-time data from the 5 reference stations will be used to compute the IWV in the atmosphere
- IWV is an input to the numerical weather prediction system

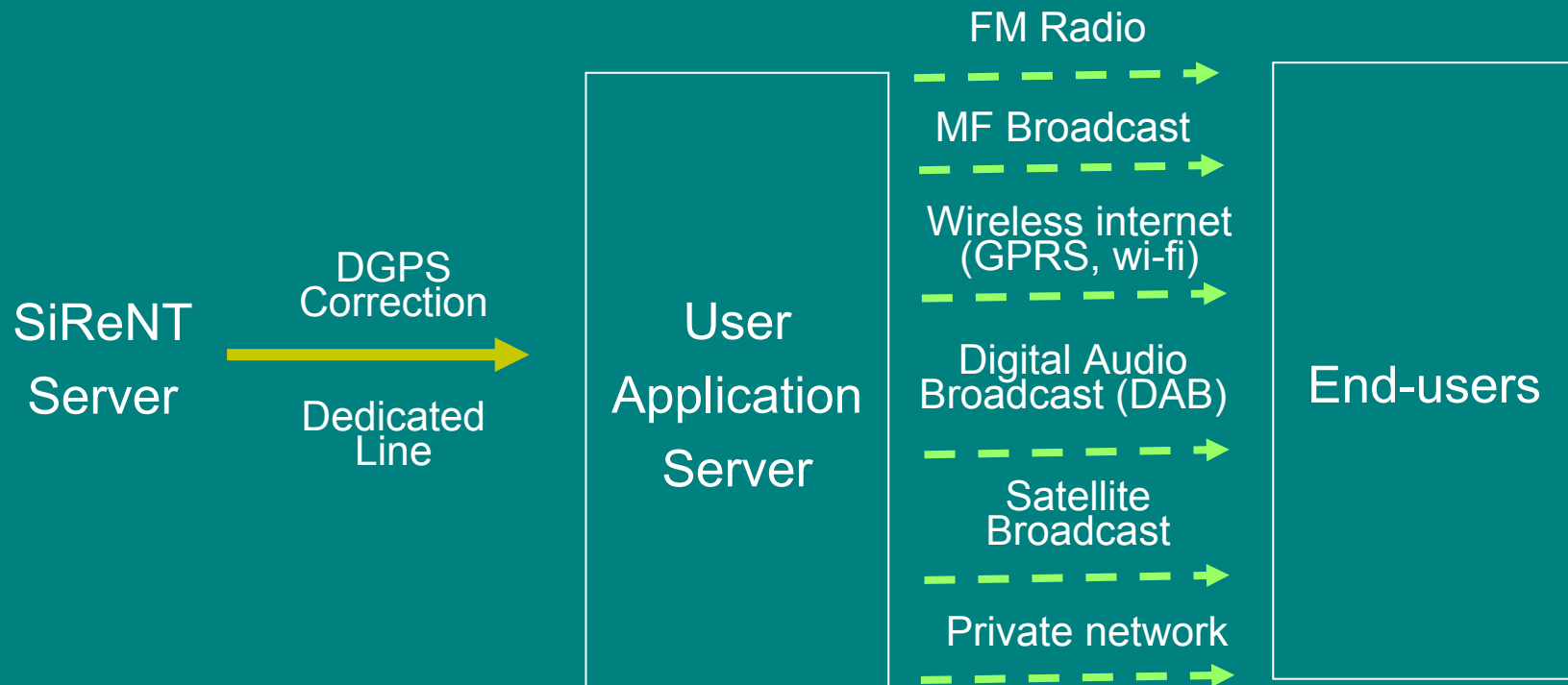


Advantages of GPS_IWV Measurement

- Availability of existing infrastructure of ground-based GPS network stations. No additional cost for hardware and software installation.
- Relatively lower on hardware cost
- Provide reliable, continuous and all-weather water vapor information
- High spatial coverage
- Abundance of long term data

SiReNT services for navigation, tracking

- Real-time DGPS (customised solution)
- System integrator to integrate DGPS into solutions
- DGPS correction can be forwarded to service provider for further dissemination

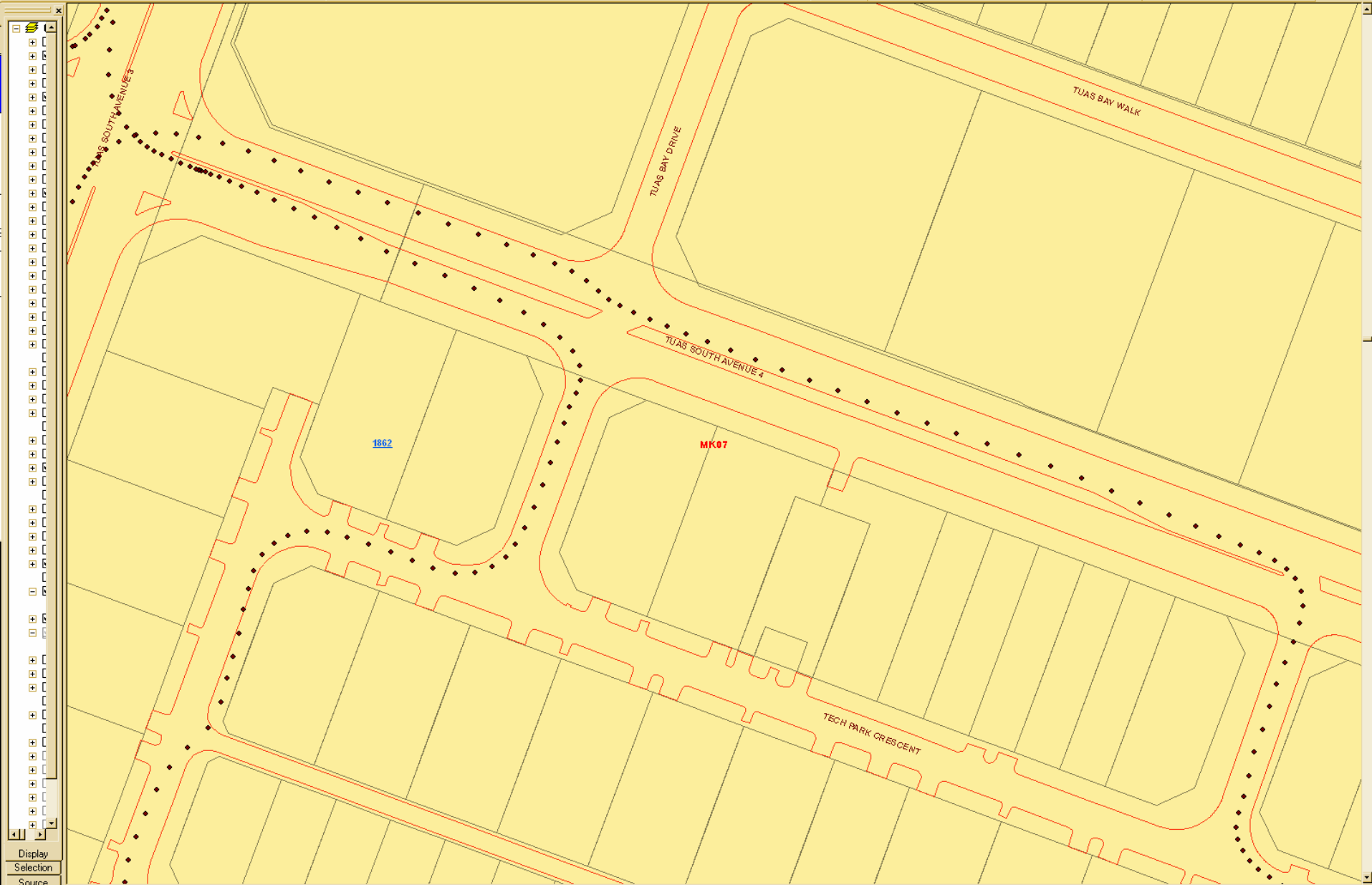


Potential usage of SiReNT for Navigation and Tracking

- Land Transportation
 - Intelligent Transportation System
 - Automated bus information system
 - Taxi Dispatch
 - Commercial Fleet Management
- Homeland Security
 - Hazmat
 - Emergency Dispatch



1:1,000 Task: Create New Feature Target: Georeferencing Layer: Drawing Arial 10 B I U A GPS SMS Layer: Point_ge Labeling



Display
Selection
Source

Summary – SiReNT

- SiReNT increases the accuracy and reliability of GPS positioning
- Infrastructure to support all types of DGPS positioning in Singapore
- Simple integration – internet based system
- Multi-purpose – designed as an infrastructure, hence many types of applications can be built on SiReNT
- With the increased accuracy and reliability, many new applications can be developed

Future Plan for SiReNT

- To incorporate GLONASS and Galileo
- To improve coverage by adding new GPS reference station in the southern island

Thank You

