The Hong Kong Satellite Positioning Reference Station (Sat Ref) Data Services Launching Ceremony and Workshop

Integration of SatRef System with the GPS Survey in Railway Project

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Content

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1. Introduction

- **MTR Projects employing GPS technology in the establishment of Primary and Secondary Survey Control Network:**

MTR Projects	Survey Approach
a. West Rail (WR) b. Kowloon Southern Link (KSL)	Conventional GPS Survey to develop Control Network basing on SMO Trigonometric Stations
c. West Island Line (WIL) d. Express Rail Link Hong Kong Section (XRL)	GPS Control Network integrated with SatRef System

- **The Control network is established to provide accurate & consistent control points to facilitate surveys in different construction stages:**

Design stage:	aerial, topographical, boundary & tree survey
Construction stage:	setting-out, monitoring, alignment & record survey
Post-construction stage	tunnel wriggle, as-built, land hand-over & maintenance

2. GPS Control Survey for XRL Project (HK)

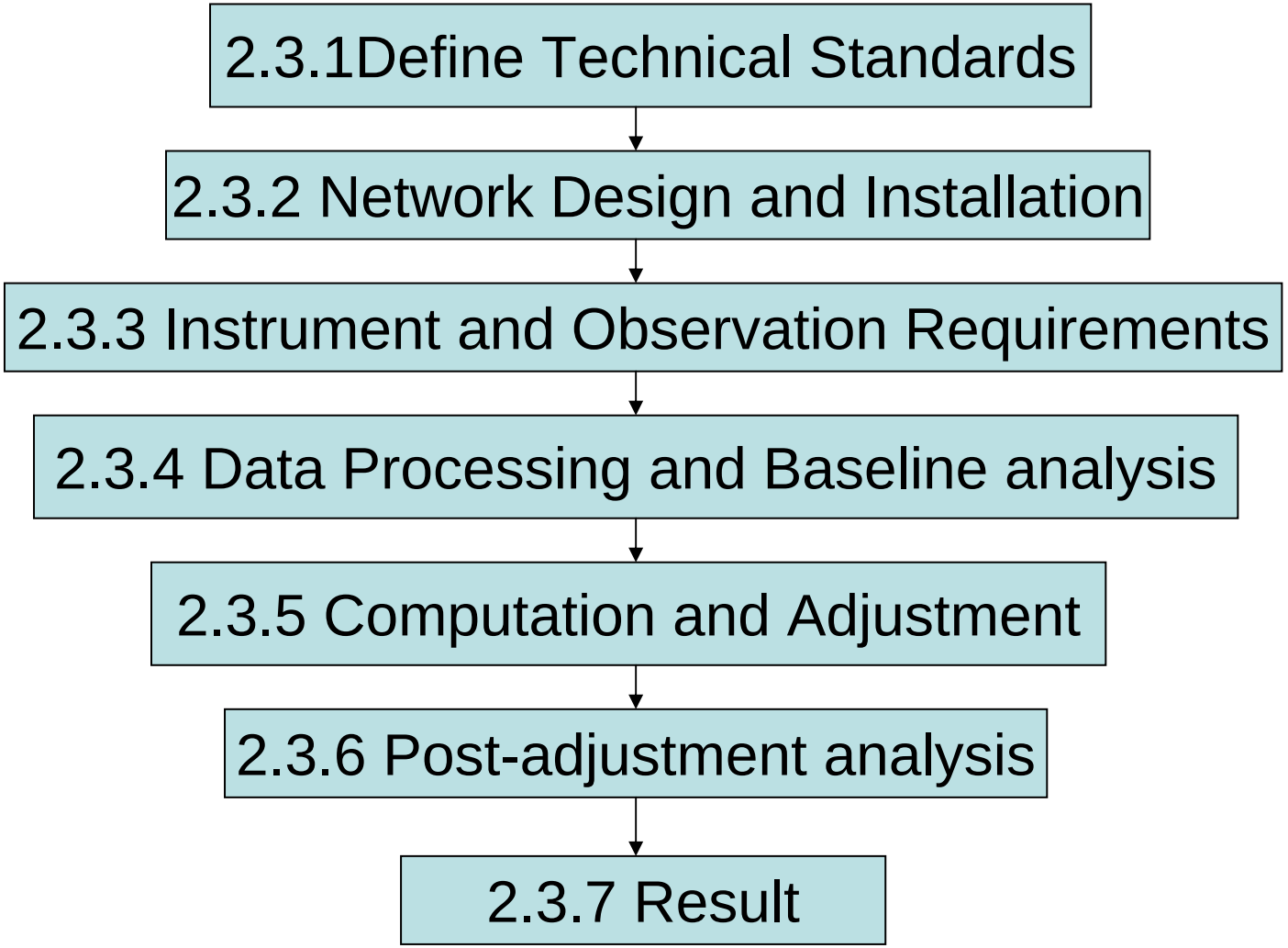
2.1 Background

Express Rail Link (XRL) provides a cross boundary high-speed rail link between Hong Kong and Mainland

- **XRL is part of the national high-speed network**
- **Mainland Section ~ 124 km, 6 stations**
- **Hong Kong Section - 24.6 km; -1 station (terminus)**

Express Rail Link (XRL) – HK Section

2.3 Methodology



2.3.1Define Technical Standards

- **Establishing a Survey Control Network using Global positioning System (GPS) method with accuracy up to 1 in 100,000**

- **Reference to Specification for GPS Surveys (PRC National Standard GB/T 18314-2001 中華人民共和國國家標準, 全球定位系統（GPS）規范）**

- **Technical Specification of Class 'C' GPS Control Network (技術指標) is adopted as Technical Requirement for the control of the GPS survey:**
  - **Fixed error (A) = 10mm**
  - **Ratio error (B) = 5ppm**
  - **Baseline standard error (σ) = $\pm\sqrt{[A^2\ mm + (B*L)^2]}$**

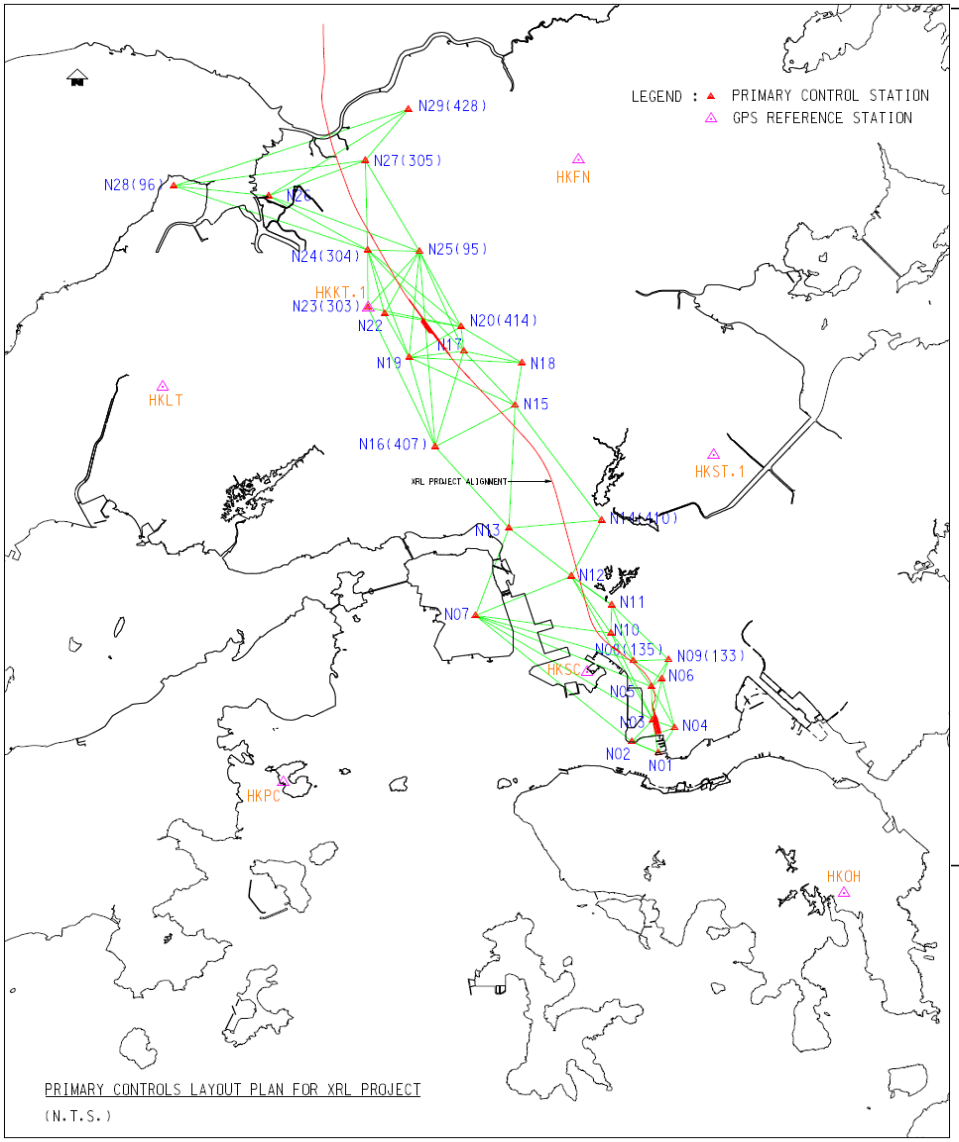
    where L is length of baseline in km

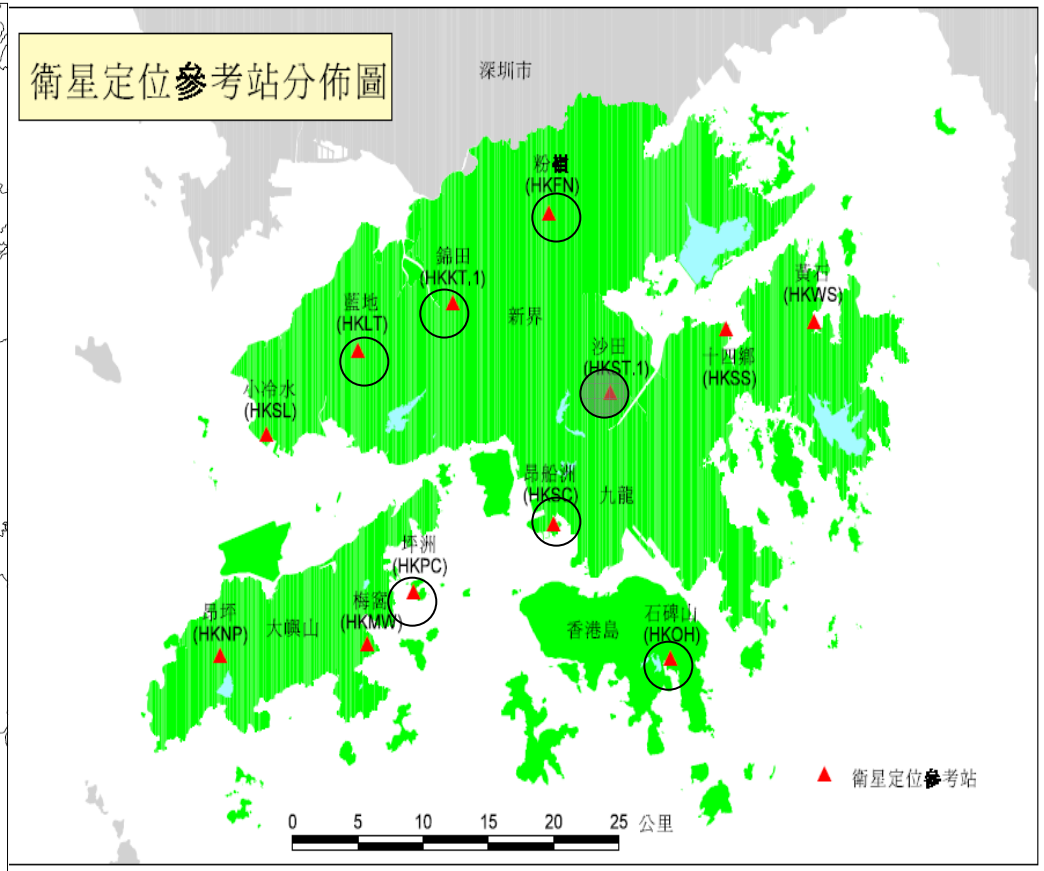
2.3.2 Network Design and Installation

- **The control network consists of 7 newly installed monuments and 11 existing trigonometric stations to keep the baseline length within 2 to 4 km to cover the project area**

- **Six GPS stations of the SatRef system were integrated in**

Layout Plan of XRL Primary Control Survey Network





▲ Integrated in XRL Network

▲ Used as check point

2.3.3 Instrument and Observation Requirements

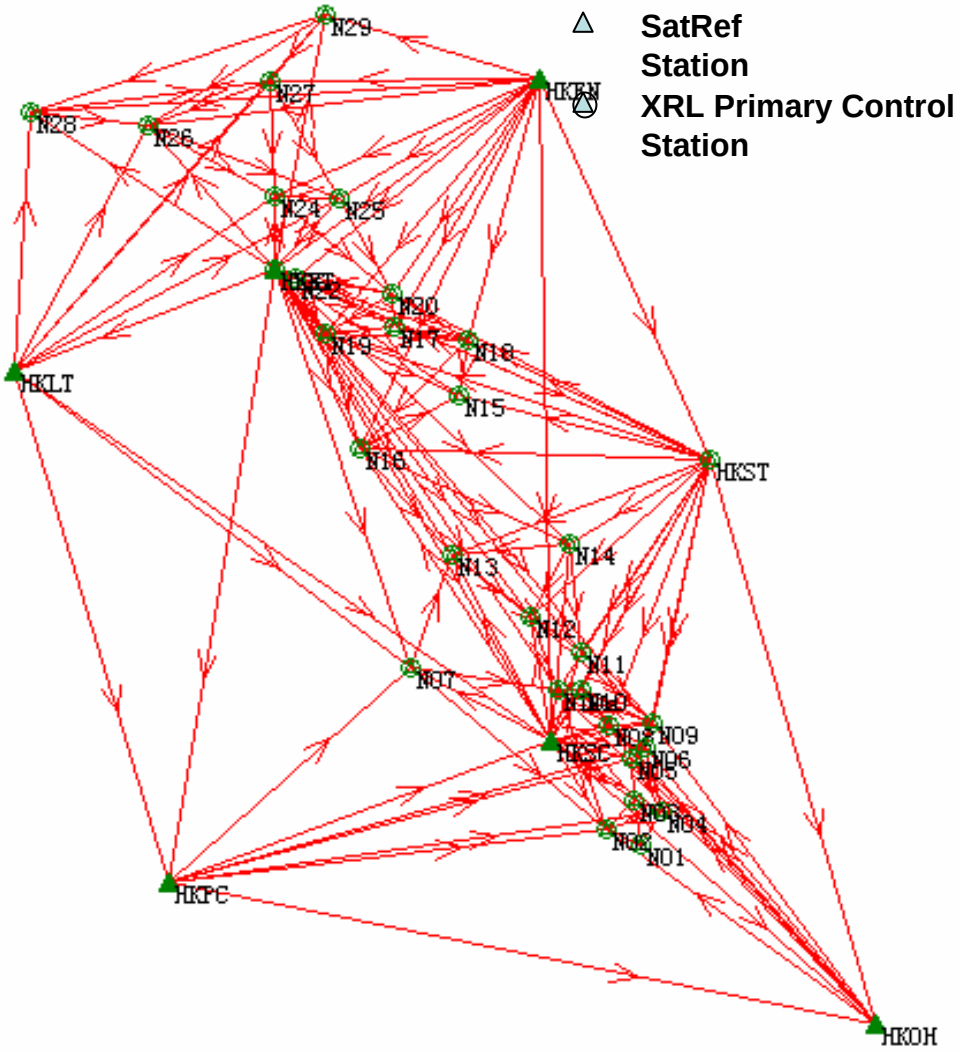
- **Four dual frequency LEICA SR530 GPS receivers were used for the control survey (Accuracy 3mm+0.5ppm)**
- **Observation Planning: side to network approach**
- **Set up field observation procedures**

Basic Technical Requirements:

- **The survey was conducted in static mode with each GPS session lasting for min. 60 minutes for synchronized rings**
- **The logging interval was set as 15 seconds**
- **Cut-off angle 15 degrees**
- **GDOP requirements =< 3**
- **Effective numbers of Satellites = 6**

2.3.4 Data Processing and Baseline analysis (I)

- **Using LEICA SKI-PRO Software package for computation**
- **The whole control network consists of 181 baselines;**
- **A total of 123 Closed Rings is formed by these baselines according to the observation sequence in terms of synchronization and non-synchronization rings**
- **Mis-closure of each rings are checked against the technical requirements to confirm the accuracy of the baselines**



2.3.4 Data Processing and Baseline analysis (II)

- **Baseline vectors computation precision and acceptance criteria:**
- **Synchronized ring misclosure** $<=\sqrt{3}\ \sigma/5$

  ($\sigma = \pm\sqrt{[A^2\ mm + (B*L)^2]}$ where L is length of baseline in km,

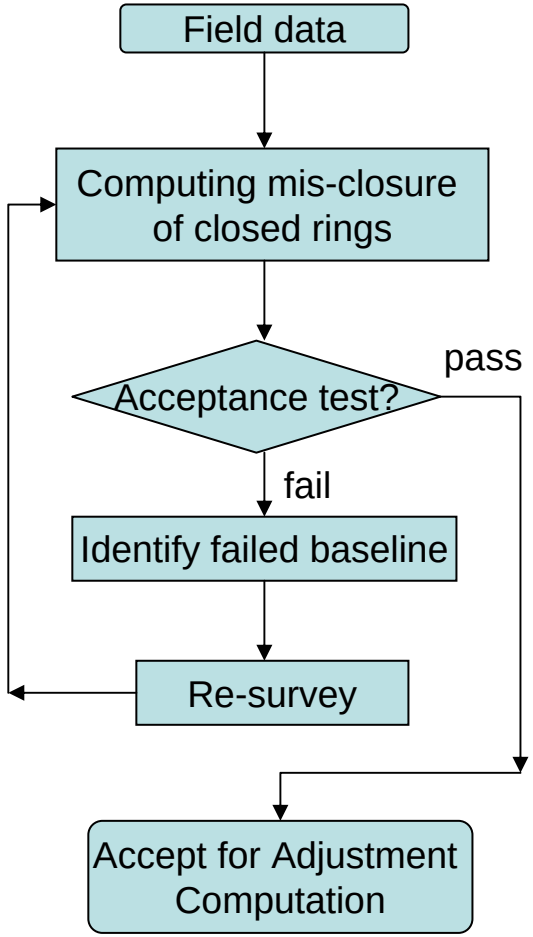
  A=10mm & B=5ppm refers to GB/T 18314-2001 of PRC)
- **Non-synchronized ring misclosure** $<=3\sqrt{n}\ \sigma$

  (where n is the total nos. of side within the ring)
- **Baseline repeat measurement: the difference is** less than $2\sqrt{2}$ s

  (s = accuracy of GPS receiver 5mm).
- **among the 181 baseline, 22 are required re-survey;**

Result:

- **Misclosures of all the closed rings (123 nos.) pass the acceptance criteria.**



2.3.5 Computation and Adjustment

- **Computation software package: Leica SKI-PRO v2.5 software**
- **Adjustment approach: un-constrained and constrained adjustment**

Approach	Un-constrained Adjustment	Constrained Adjustment
Purpose	Identify, locate, and eliminate any blunders or outliers	Ascertain the accuracy of the known stations & constrain the adjustment to the known station
Fixed known stations	None (one for computation)	6 SatRef Stations (**HKFN, HKKT.1, HKLT, HKOH, HKPC and HKSC)**
Co-ordinate system	WGS84	WGS84
Co-ord. transformation	none	To HK1980 Grid
Acceptance criteria:		
a. Baseline residuals after adjustment	<= 3 σ ($\sigma = \pm\sqrt{[A^2 \text{ mm} + (B*L)^2]}$ where L is length of baseline in km	<= 2 σ
b. Baseline ratio error	<= 1 in 100,000 (10ppm)	<= 1 in 100,000 (10ppm)

2.3.6 Post-Adjustment analysis

- **One SatRef station (HKST.1) was selected as a check point to verify the accuracy of the adjustment results**
- (difference in coordinates was 13mm)

- **11 existing trigonometric stations were used in the control network**
- (average difference in coordinates was 19mm)

- **Field check by Totalstation on distance and angles for selected short baselines**

  (not practical to base-line over 1km)

2.3.7 Results

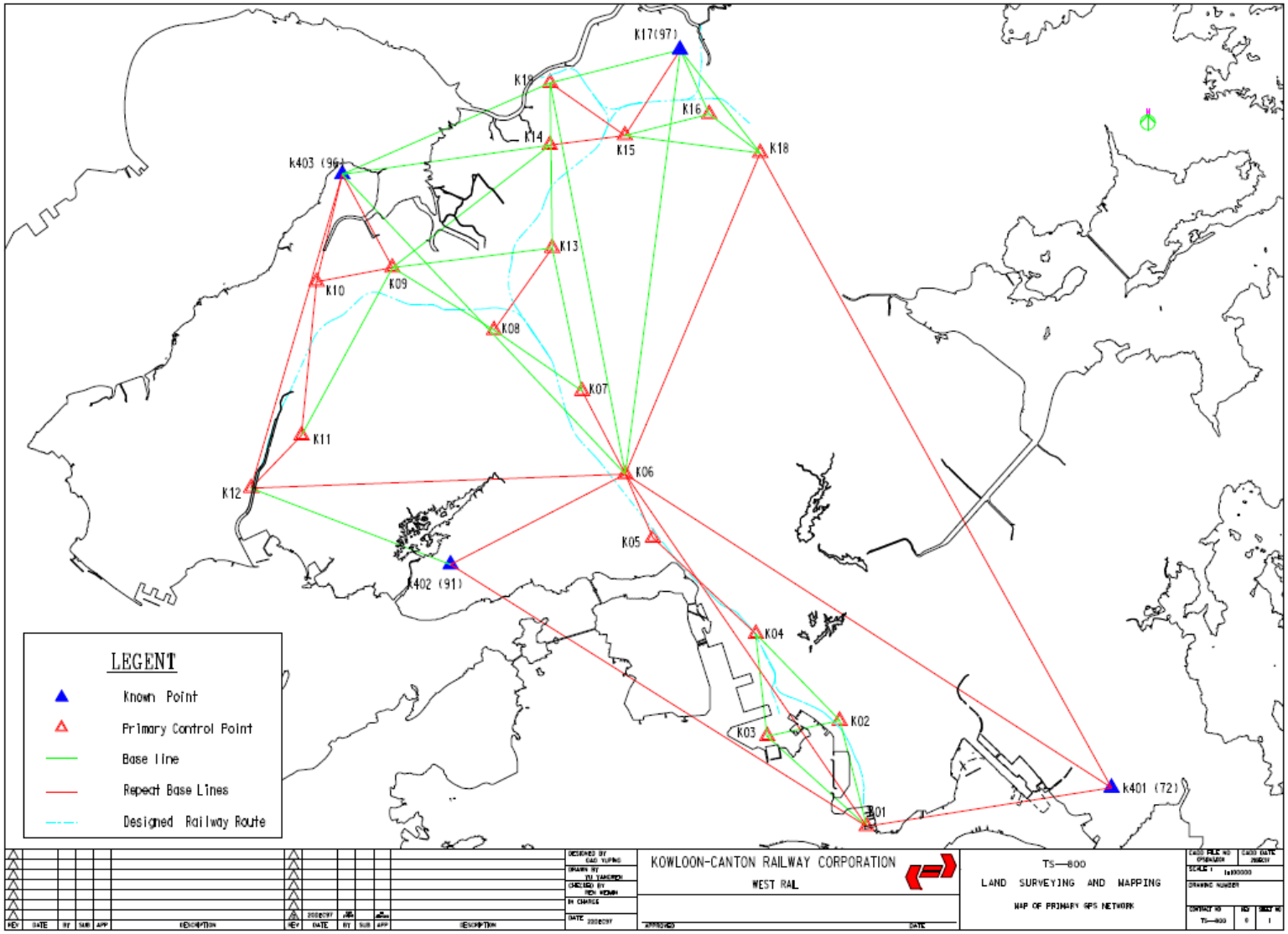
Point Id	Northing	Easting	Orth. Height	Quality Pos.	Quality Hgt.
HKFN	839454.966	832285.140	44.460	0.000	0.000
HKKT.1	833946.138	824913.087	38.062	0.000	0.000
HKLT	830988.470	817709.927	129.666	0.000	0.000
HKOH	812103.834	841595.061	168.689	0.000	0.000
HKPC	816235.675	821939.903	21.367	0.000	0.000
HKSC	820351.389	832591.320	23.119	0.000	0.000
HKST.1	828445.570	837026.635	261.541	0.005	0.012
N01	817333.463	835079.094	22.632	0.028	0.049
N02	817754.573	834158.796	4.500	0.015	0.030
N03	818559.691	834893.301	200.671	0.021	0.036
N04	818268.790	835657.406	94.969	0.014	0.026
N05	819810.279	834839.914	155.024	0.008	0.013
N06	820098.268	835211.341	149.704	0.011	0.017
N07	822456.801	828677.534	172.524	0.018	0.037
N08	820770.858	834209.881	51.600	0.008	0.015
N09	820813.820	835443.886	51.531	0.007	0.014
N10	821804.210	833425.861	172.599	0.013	0.028
N11	822851.969	833450.685	173.759	0.011	0.020
N12	823928.766	832035.832	342.898	0.010	0.018
N13	825720.848	829850.479	189.146	0.011	0.022
N14	826015.632	833096.828	337.919	0.009	0.018
N15	830295.228	830063.963	693.771	0.023	0.048
N16	828757.126	827260.218	579.717	0.010	0.019
N17	832318.060	828267.605	38.096	0.021	0.049
N18	831883.651	830305.975	546.012	0.011	0.024
N19	832090.057	826351.149	25.521	0.009	0.020
N20	833230.693	828170.769	63.849	0.010	0.019
N22	833718.106	825489.379	7.206	0.019	0.040
N23	833945.122	824907.889	34.128	0.014	0.028
N24	836091.490	824895.007	375.588	0.009	0.016
N25	836039.036	826713.928	573.480	0.011	0.019
N26	838108.576	821424.350	3.281	0.013	0.024
N27	839433.028	824816.446	67.345	0.014	0.027
N28	838477.950	818097.269	69.846	0.016	0.031
N29	841342.107	826318.508	67.506	0.020	0.039

Weakest Point

3. Summary of GPS Control Survey for West Rail Project

- GPS Control Network was established in 1997 with Accuracy is 1 in 100,000
- Technical standard refer to PRC National Standard of Specification for GPS Survey (GB/T)
- Survey Origin: Four Major Trigonometic Stations (72, 91, 96 & 97) were used as fixed stations
- Instrument: Four dual frequency GPS receivers were used for the control survey
- Software: GPS field data was processed by Leica software SKI Version 2.10; and Control Network was adjusted by FILL NET Version 3.0 of ASHTECH INC.

Layout plan of WR Primary Control Survey Network



4. Comparison of GPS Control Survey between XRL and West Rail Projects (I)

Summary:	XRL Project	West Rail Project
Accuracy requirement	1 in 100,000	1 in 100,000
Network coverage	26km	32km
Survey Origins	6 SatRef GPS stations	4 Trig. Stations
GPS Receiver	4 (dual frequency)	4 (dual frequency)
Computation Software	Leica SKI-PRO Ver. 2.5	Leica SKI Ver. 2.10, **ASHTECH INC. FILL NET Ver. 3.0**
Nos. of Control Stations	28(primary)+ 131(Secondary)=159	18(primary)+184(secondary)=202
Nos. of Baselines	181(primary)+ 661(secondary)=**842**	55(primary)+ 471(secondary)=**521**
Nos. of Closed rings	123(primary)+ 493(secondary)=**616**	88(primary)+ 326(secondary)=**414**
Observation sessions	Min. 60 minutes 150 sessions/ 34 man-day	120 minutes 138 sessions/ 62 man-day
Station Installation	25 man-day	40 man-day
Data processing	10 man-day	15 man-day

4. Comparison of GPS Control Survey between XRL and West Rail Projects (II)

	XRL	WR
Survey Approach	Network integrated with SatRef System (many-to-1)	Conventional GPS survey method based on Trigonometry stations (2-to-1)
Network Design	Simplify – less control points, Allow direct linkage from SatRef stations to unknown points	Complicate – more control points, Strengthen of network depends on numbers of control stations
Error (known station)	No instrument error as SatRef stations are setup permanently	Instrument error caused by repeat setup at known stations on task basis
Accuracy	Higher: more redundancy observations directly from known stations; error spread through the network consistently	Lower: redundancy observations is limited by the constrains of instruments and manpower; error may distribute through the network unevenly
Resources (manpower, transportation, instrument)	Reduced: no need to occupy instrument on known stations	Increased: manpower and instrument requires for every baseline connecting to known stations
Time / progress	Fast; easy planning as SatRef station operating round-the-clock	Slow; careful planning, constraint with resources
Cost	Lower	Higher

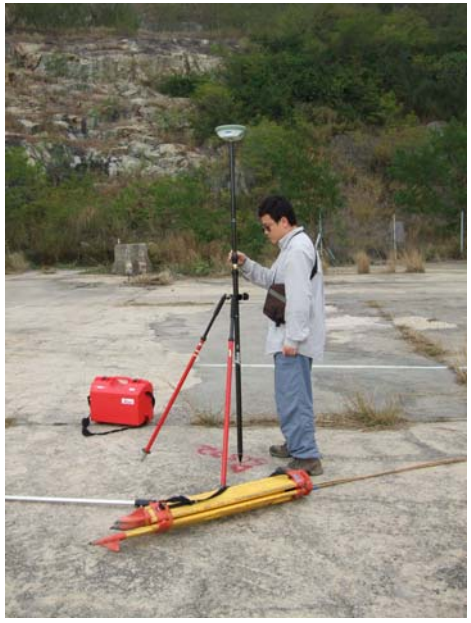
5. Application of Real Time Kinematic (RTK) mode by using SatRef System and Ntrip Technologies in XRL Project

Typical applications:

- Setting out land boundary at remote site area
- Topographical survey
- Tree survey

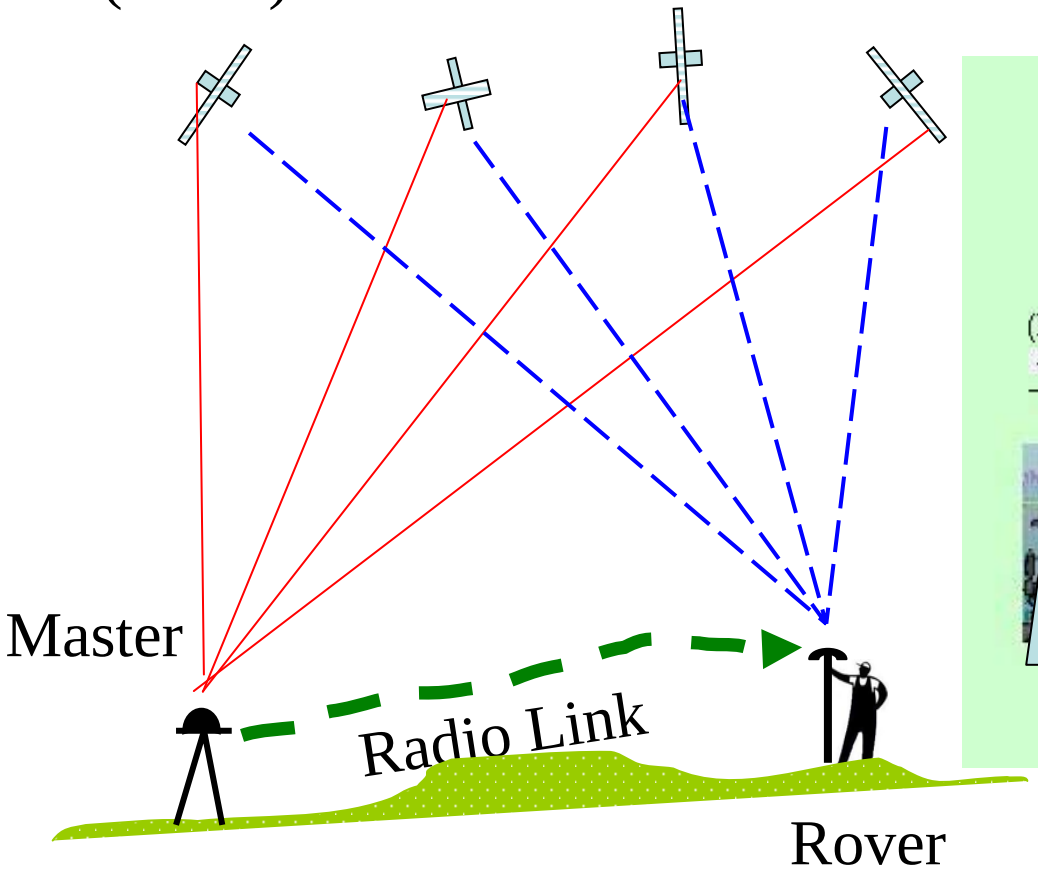
Feedback:

- Convenient
- Rapid response
- More accurate
- Positioning reliable
- Less manpower

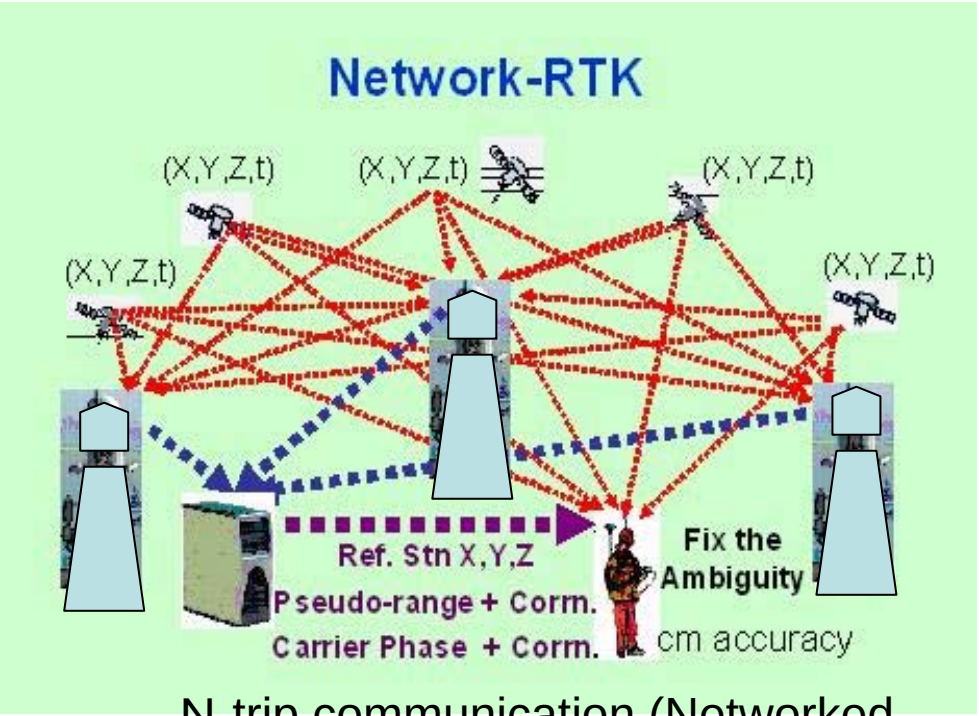


5.1 GPS Survey with Real Time Kinematic (RTK) mode

(a) Traditional RTK Method (1 to 1)



(b) SatRef system network RTK (many to 1)



N-trip communication (Networked Transport of RTCM via Internet Protocol)

6. Conclusion

- **The launching of the SatRef system provides a variety of GPS applications in land and engineering survey industry and forms a very strong foundation for future development of surveying activities**

- **With the integration of the GPS control network to the SatRef system for XRL project, the advantages are clearly identified:**

a. Improve in overall accuracy
b. High efficiency & productivity
c. Less manpower resources
d. Reduce operational cost

- **Furthermore, Network-RTK GPS with N-trip technology becomes the main trend in field data capturing**

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End of Presentation

Q & A