Study on modernizing the General Standard of Operation Specifications for Public Surveys (2)

Estimation of uncertainties regarding the proposed operation specification for control surveys

Masaki MURAKAMI, Japan
Japan Association of Surveyors

Theme of our study

Examining the practical performances of total stations

- Estimating uncertainties of angle and distance measurements in a short range of about 50m plus estimation of centering errors of total station and mirror

Examining the practical performances of double-frequency GNSS receivers

- Estimating uncertainties of baseline measurements for the ranges from 200m to 18km

Examining the proposed control surveys with two tiers of control points (presented at FIG WW 2023)

- The primary control points with the interval of about 200m-500m set up by using GNSS and CORS
- The secondary control points with the interval of about 50m set up by using total stations

Performance classification and its criteria of surveying instruments in Japan ~ no change for a long time ~

Performance criteria of the class-2 total station

Performance of angle measuring section		Performance of distance measuring section	
Minimum reading of graduation		Nominal measurement accuracy	Minimum reading
Horizontal (arcsec)	Vertical (arcsec)		
10 or less	10 or less	$\pm(5\text{mm} + 5\times10^{-6}\cdot D)$ or less	1 mm

- Performance classification of the class-1 GNSS

Number of receiving bandwidths	Observation method	Nominal measurement accuracy	Nominal measurable distance	Minimum analysis value
2 bandwidths (L1, L2)	Double frequency static	$\pm(5\text{ mm} +1\times10^{-6}\cdot D)$ or less	10 km or more	1 mm
	RTK	$\pm(20\text{ mm} +2\times10^{-6}\cdot D)$ or less	---	

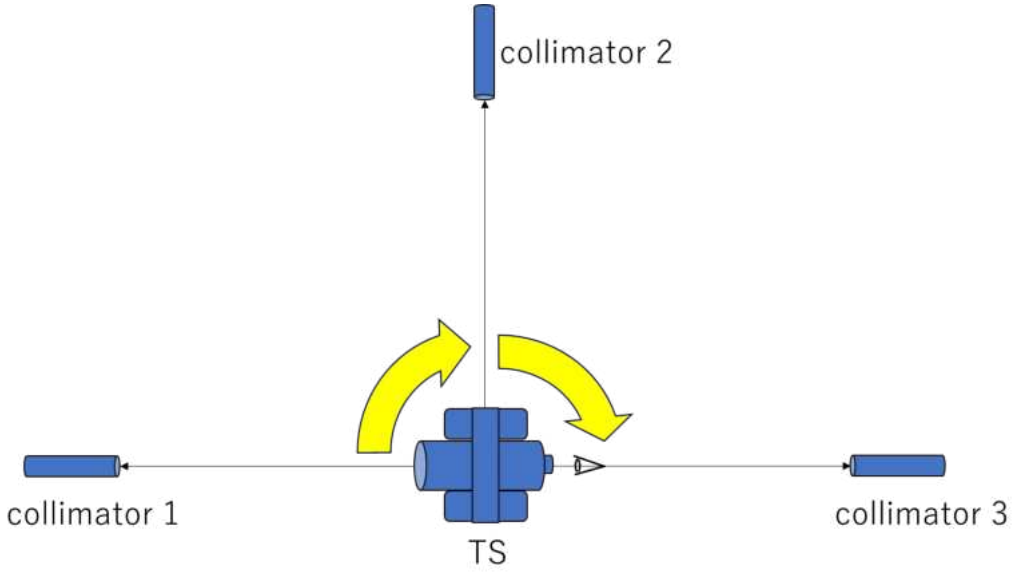
Practical performance of total stations estimated from validation data

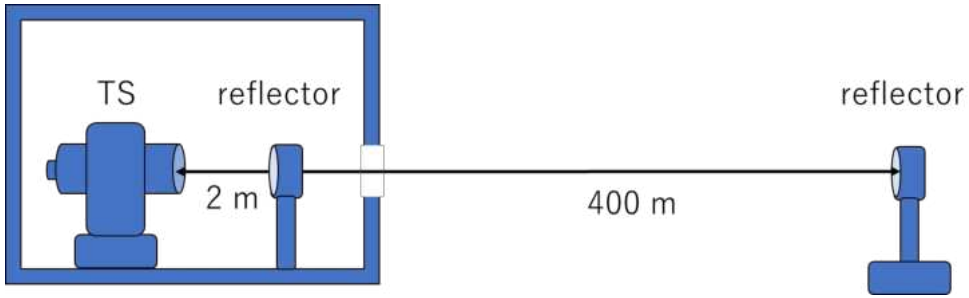
- angle measurements (585 TSs with 5" minimum reading)

the standard deviation per sighting, σ_s = 1.7 "

- distance measurements (957 TSs)

the mean value, -0.2 mm and the standard deviation, 1.3 mm: $RMSE_d$ = 1.3 mm

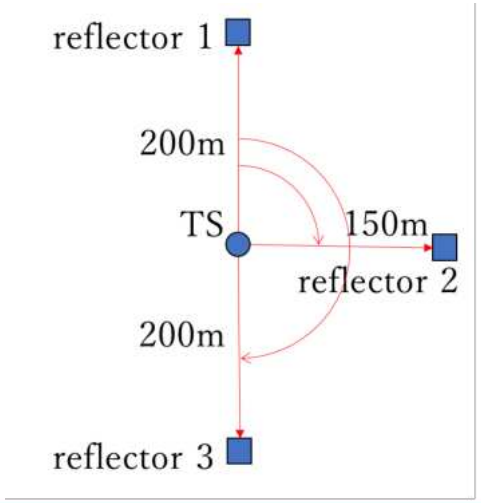




Practical performance of total stations estimated from field experiment data

- angle measurements (three TSs with 5" reading; two sets of three paired observations; repeated 10 times)

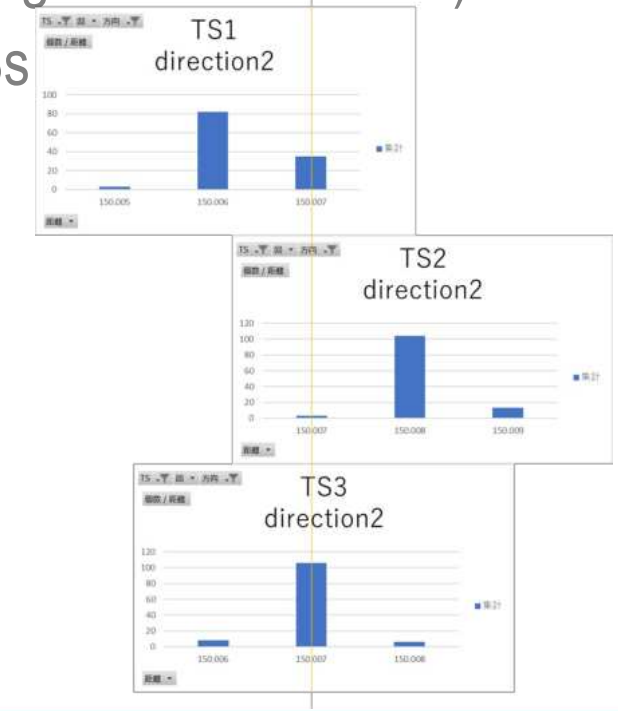
the standard deviation per sighting, σ_s = 2.5 "



- distance measurements (conducted simultaneously with angle measurements)

σ_d = 0.8 mm for three TSs

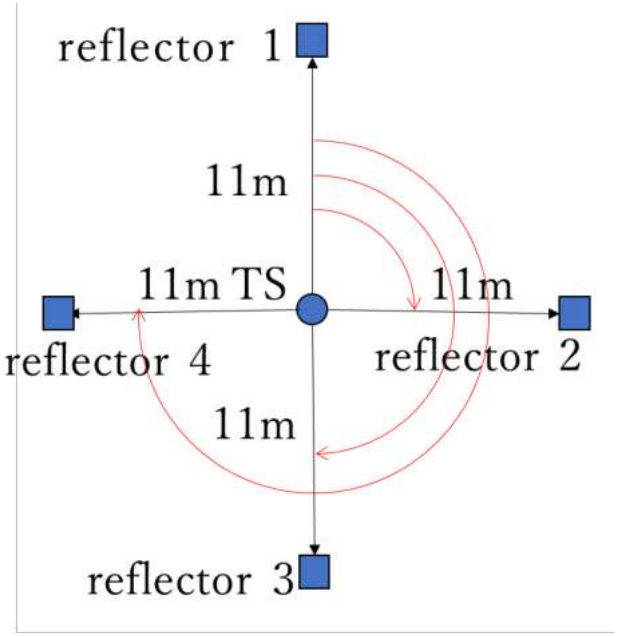
σ_d = 0.5 mm for each TS



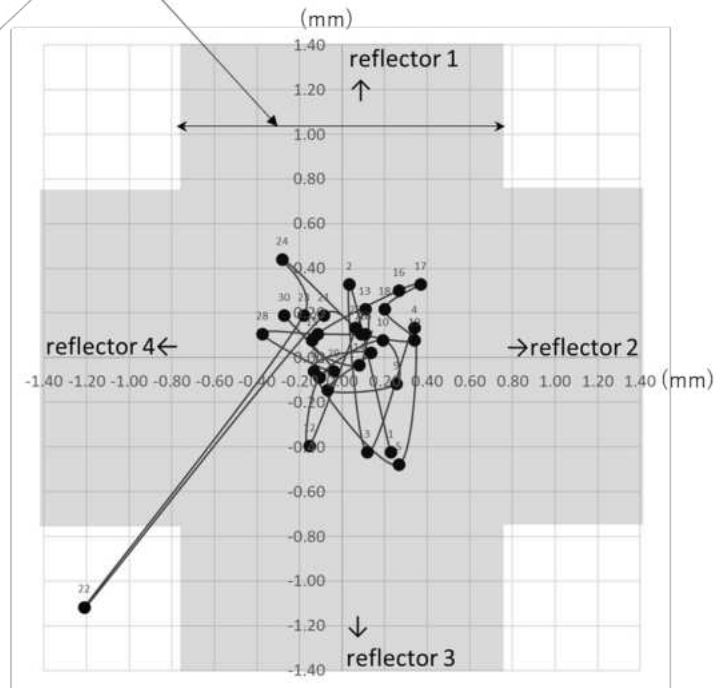
Centering errors of TS and mirror estimated from field experiment data

- total station (one TS; three paired measurements; repeated 30 times)

$\sigma_x = \sigma_y = 0.3$ mm

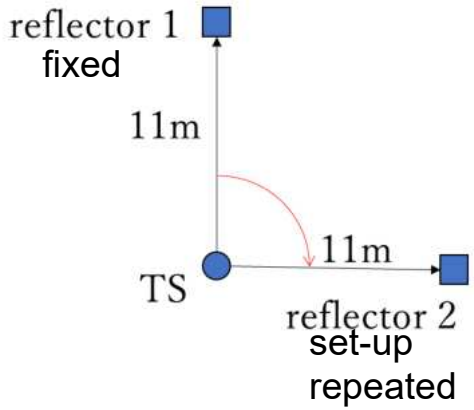


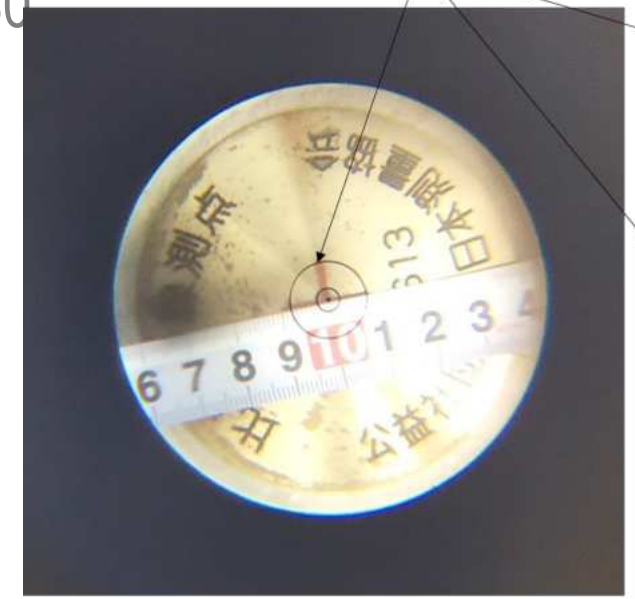
width of a cross line: 1.5mm

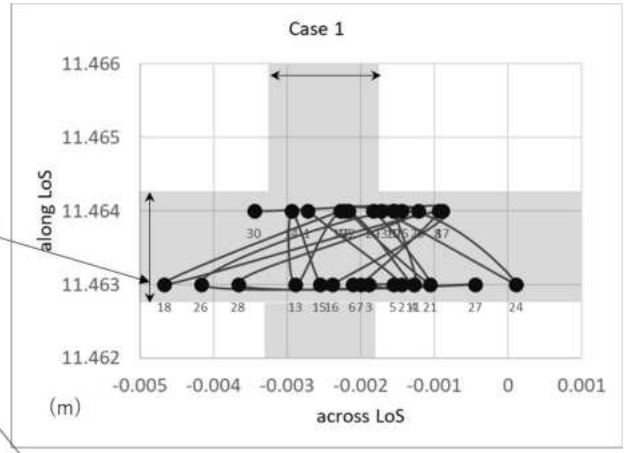


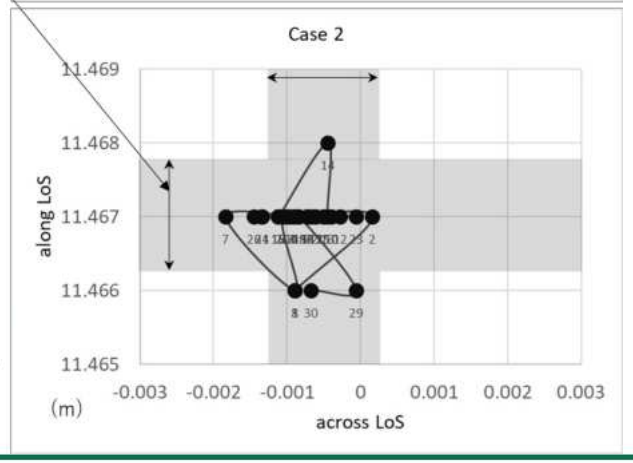
Centering errors of TS and mirror estimated from field experiment data

- mirror (one mirror fixed; one mirror set up each time when a set of three paired measurements is over; set-up repeated 30 times x 2 rod person)
  $\sigma_x \sim \sigma_y \sim 0.6$ mm









Uncertainty budget of measurements by total station

assuming the distance between two control points be 50 m, minimum reading of angle be set to 5”

uncertainty of angle measurement per sighting: 2.5”

uncertainty of distancee measurement per side: 1.3 mm

uncertainty of centering of total station: 0.3 mm

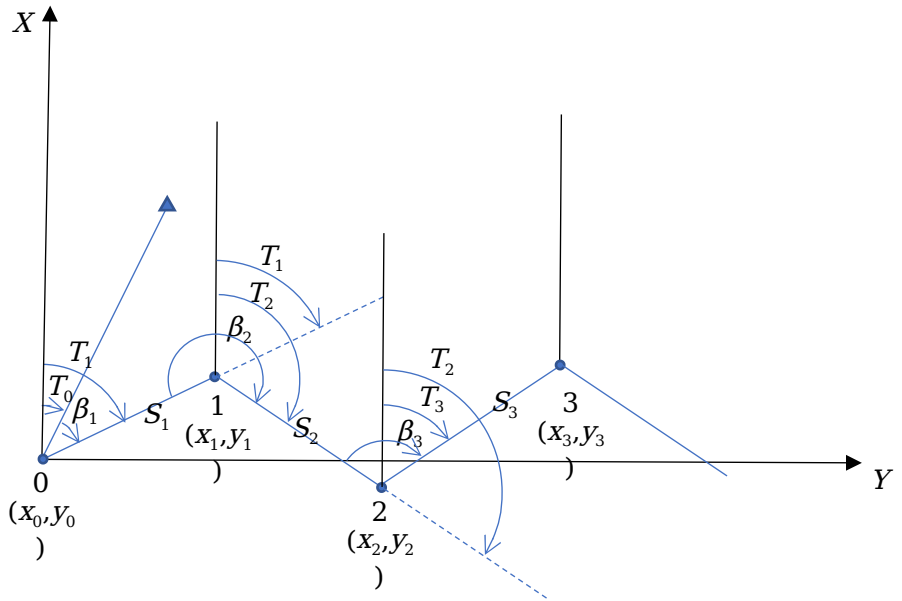
uncertainty of centering of reflector: 0.6 mm

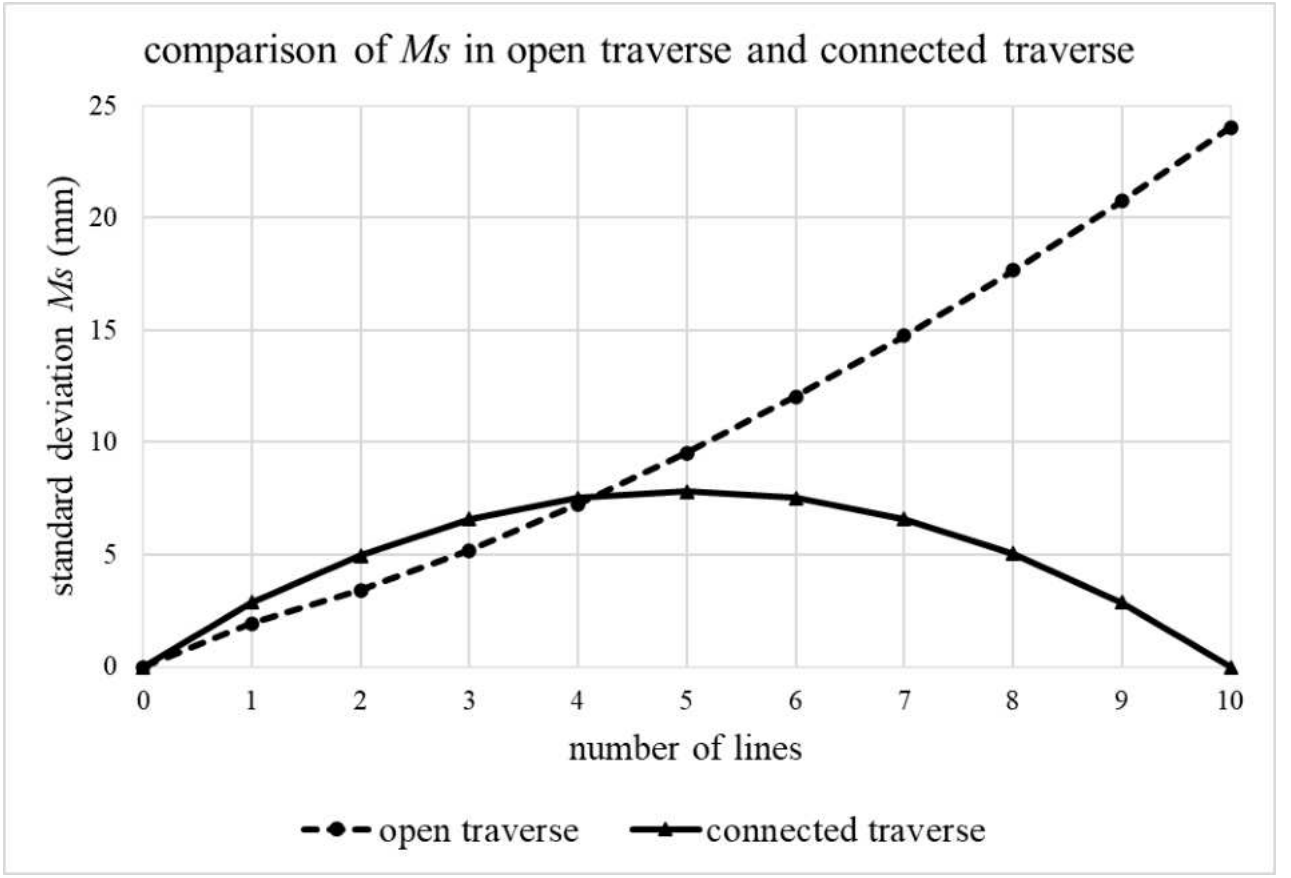
uncertainty of reflector constant: 0.3 mm

combined uncertainty of angle measurement: 3.5” ➔ 0.8 mm for a target 50 m away

combineduncertainty of distance measurement: 1.5 mm

Estimation of uncertainty in position along a single-route traverse using the combined measurement uncertainties of TS





50 m interval

Performance of GNSS static observations and its dependance on baseline length

- Previous study presented at WW2023

  $\sigma_{NS} = \sigma_{EW} = 6$ mm, $\sigma_{UD} = 26$ mm for 10 km baseline

- This study (preliminary: need further scrutiny of data and collection of data for long base line)

  $\sigma_{NS} \sim \sigma_{EW} \sim 2$ mm + 0.3 ppm x D, $\sigma_{UD} \sim 5$ mm + 1 ppm x D (under no magnetic storm)

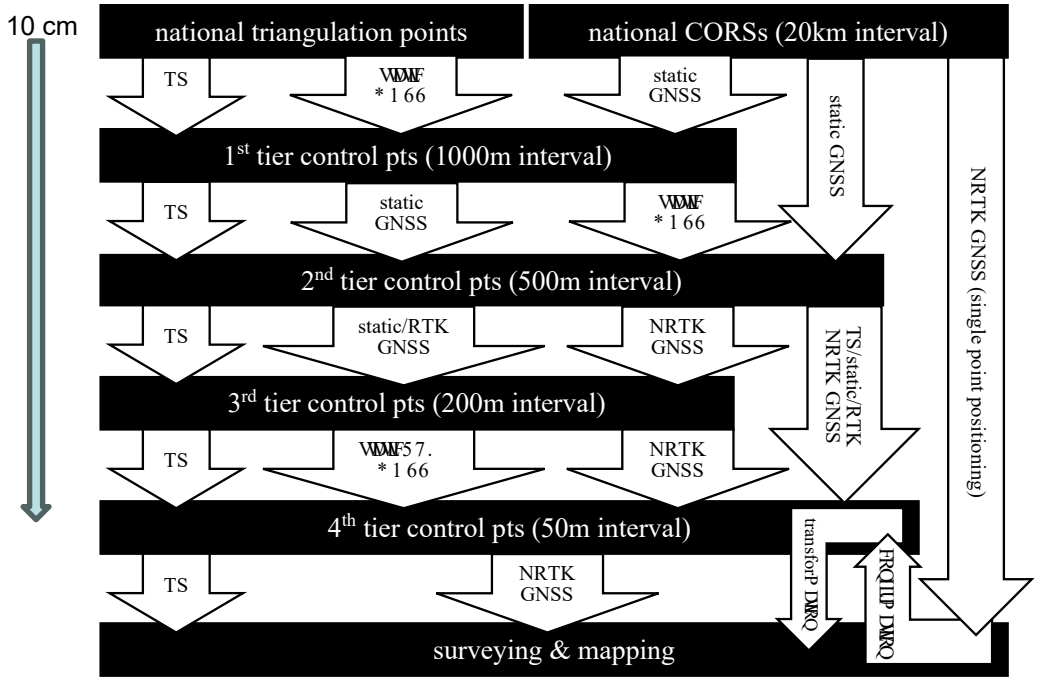
  - compared with manufacturers' nominal accuracy

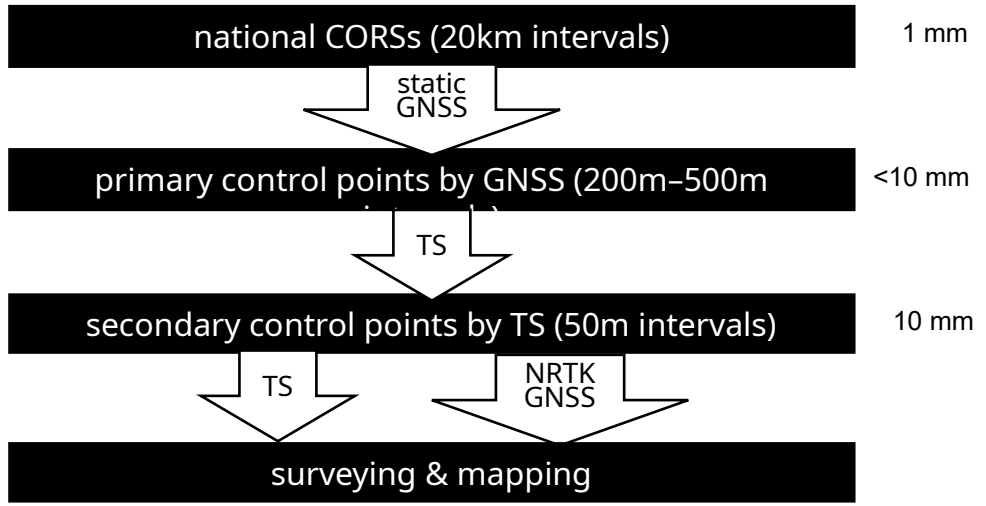
    $\sigma_{NS} \sim \sigma_{EW} \sim 3$ mm + 0.5 ppm x D, $\sigma_{UD} \sim 5$ mm + 0.5 ppm x D

  - applied to 10 km baseline

    $\sigma_{NS} \sim \sigma_{EW} \sim 5$ mm, $\sigma_{UD} \sim 15$ mm

Complicated and less accurate control surveys ➔ Simple and more accurate ones with CORS-GNSS for the primary and TS traverse for the secondary control surveys





SUSTAINABLE DEVELOPMENT GOALS | International Federation of Surveyors supports the Sustainable Development Goals

Commission #6

Engineering Surveys

Serving Society for the Benefit of People and Planet