NATIONAL TECHNICAL UNIVERSITY OF ATHENS

SCHOOL OF RURAL AND SURVEYING ENGINEERING
DEPARTMENT OF TOPOGRAPHY
LABORATORY OF GENERAL GEODESY

# A NEW METHOD TO CHECK THE ANGLE PRECISION OF TOTAL STATIONS

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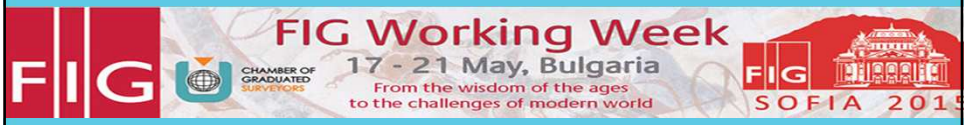



*Sofia, Bulgaria 17- 21 May 2015*

## OUTLINE

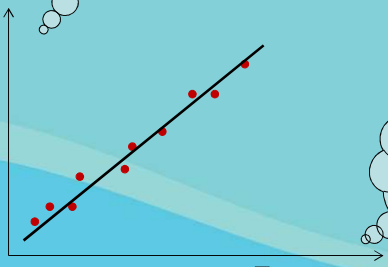
1. THE MAIN IDEA
2. THE PARAMETERS OF THE CONTROL FIELD
3. THE UNCERTAINTY EQUATION
4. EXPERIMENTAL APPLICATION
5. THE CONCLUDING REMARKS

## THE MAIN IDEA

The *fundamental idea* f… majority of the metrological tests … of a measured value with an i… st with the "true" value from a firs… instrument

Axis y: measurements

CONTROL FIELD



Axis x: "true" values

*Least Squares adjustments*

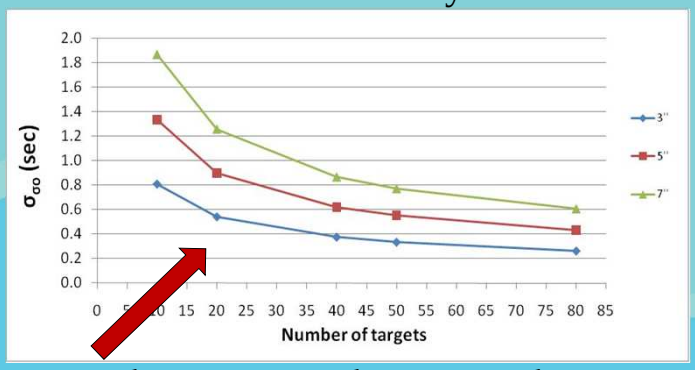
$$y = a \cdot x + b$$

## THE PARAMETERS OF THE CONTROL FIELD

### 1. *The number of targets*

**Monte Carlo Simulations** ⇒ **The uncertainty equation**

$$y = a \cdot x + b$$




The first critical curvature change is shown **at twenty targets** while the next change which occurs at forty targets provides a little improvement in the error about ±0.2″

## THE PARAMETERS OF THE CONTROL FIELD

### 2. The type of target

The apparent size of the target, at a distance D, is equal to its real size multiplied by the factor k

$$k = \frac{L_{tel}}{D}$$

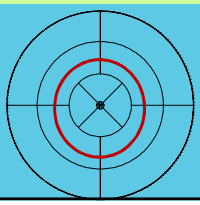
$L_{tel}$: is the focal length of the telescope,
D: distance

**The apparent width of the targets' lines at different distances.**

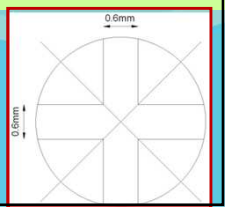
| D \ Real target Line width | 1mm | 5mm | 10mm |
|---|---|---|---|
| 10m | 15μm | 75μm | 150μm |
| 30m | 5μm | 25μm | 50μm |
| 50m | 3μm | 15μm | 30μm |

The apparent width of the lines that define its center should be greater or equal to the TS's crosshairs width.

The designed target



**the magnification of its center**



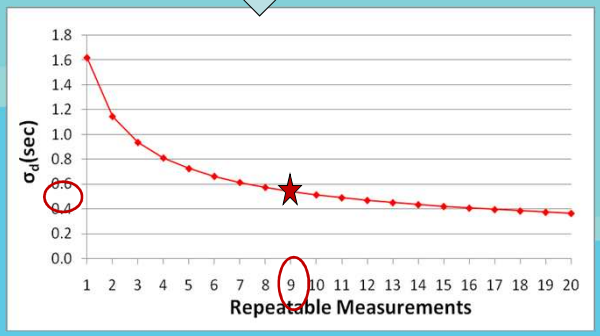

## THE PARAMETERS OF THE CONTROL FIELD

### 3. The number of sightings

$$\sigma_m \approx 45''/M \qquad \sigma_d = \frac{\sigma_m}{\sqrt{n}}$$

M: Magnification

n: repeatable measurements




The error of direction reading in relation to the number of measurements for TSs of magnification 30x

## THE UNCERTAINTY EQUATION

$$y = a \cdot x + b$$

y: are the measurements from TS under test

x: are the corresponding standard (true) measurements from the reference TS

***Least Squares*** ⇓ ***are calculated***

**b:** is the systematic error of TS under test.

**a:** is the scale of TS (mathematically expresses the slope of the adjustment line).

and their uncertainties $\sigma_a$ and $\sigma_b$

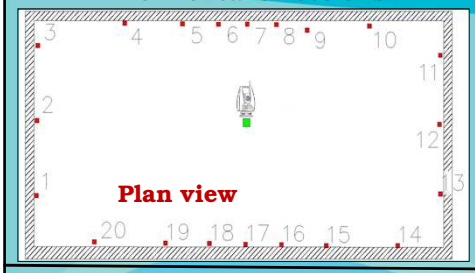
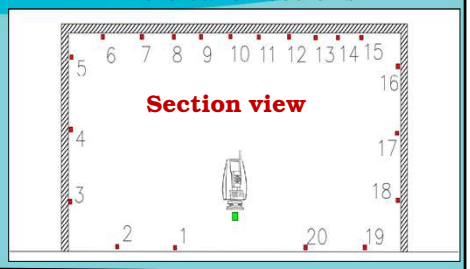
the standard error $\sigma_o$ **(random error)** of the adjustment

**It is considered that random errors follow the same distribution at the entire range of the control field**

The TS may be used in applications when the demanded accuracy $\sigma_\varepsilon$ is greater than the total error, which consists of the systematic and the random part, namely $\sigma_\varepsilon \geq \pm\sqrt{\sigma_o^2 + b^2}$

## THE EXPERIMENTAL APPLICATION

### *The control fields*

| **Horizontal directions** | **Vertical directions** |
|---|---|
|   |   |
| •**20 targets – all around (per 18°)** | * **20 targets - all around (per 15°) – except the area under the TS** |

* **True values: 9 measurements – Leica TM30**

•**4 others TSs were checked – nominal accuracy ranging from ±3″ to ±6″**

**The measurements were carried out in 2 periods within 30 min for each TS**

# THE EXPERIMENTAL APPLICATION

*The results of the adjustments*

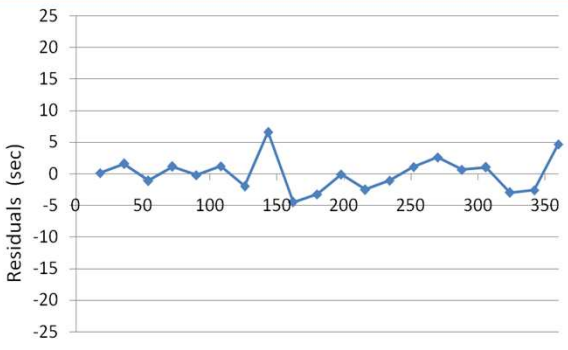
## Horizontal directions

| Total Station | Nominal Uncertainty | a | $\sigma_a$ | b (arcsec) | $\sigma_b$ (arcsec) | $\sigma_o$ (arcsec) |
|---|---|---|---|---|---|---|
| A | ±5" | 1.0000008 | $\pm1.5\cdot10^{-6}$ | 0.4" | ±1.3" | ±2.5" |
| B | ±5" | 0.9999823 | $\pm3.6\cdot10^{-5}$ | 64.5" | ±3.0" | ±6.3" |
| C | ±3" | 1.0000251 | $\pm8.2\cdot10^{-5}$ | -29.3" | ±7.1" | ±15.2" |
| D | ±6" | 0.9999993 | $\pm2.3\cdot10^{-6}$ | 2.4" | ±2.0" | ±4.2" |

## Vertical directions

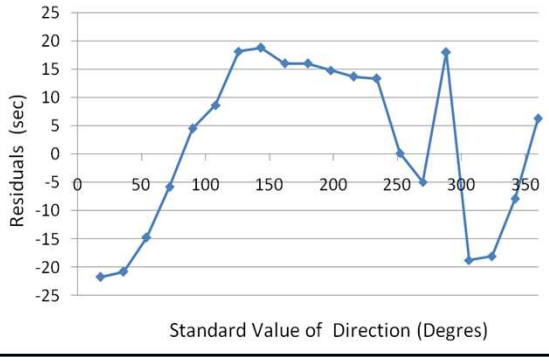
| Total Station | Nominal Uncertainty | a | $\sigma_a$ | b (arcsec) | $\sigma_b$ (arcsec) | $\sigma_o$ (arcsec) |
|---|---|---|---|---|---|---|
| A | ±5" | 1.0000001 | $\pm6.1\cdot10^{-6}$ | 1.5" | ±2.4" | ±3.9" |
| B | ±5" | 1.0000298 | $\pm3.8\cdot10^{-5}$ | 18.3" | ±4.2" | ±7.2" |
| C | ±3" | 1.0000373 | $\pm5.0\cdot10^{-5}$ | 4.9" | ±4.1" | ±8.9" |
| D | ±6" | 1.0000009 | $\pm4.2\cdot10^{-6}$ | 2.1" | ±1.3" | ±3.6" |

***The above results were confirmed by the official distributor of these TSs in Greece***




- **The residual for horizontal directions of TS A.**

**The residual for horizontal directions of TS C.**



## DISCUSSION

As the ISO 17123-3 prescribes separate measurements at different control fields and different separate mathematical procedures for the horizontal and the vertical directions test respectively ,the main advantage of the proposed method is that requires simultaneous measurements at an indoor control field.

ISO 17123-3 only certifies the internal precision of TS by using repeatable measurements to targets without any comparison to standard values.

The field work needs about 1 hour for the measurements with the standard TS and about half an hour for any TS under check, while the ISO procedure demands at least double or triple this time.

## CONCLUSION

The control field installation is convenient, cost effective and quick organized

The "true" values which are indispensable for the procedure could be easily acquired by several periodical measurements using a reference TS of ±0.5″or a Laser Tracker

The proposed method requires the same method of measurements' analysis by using the least squares method adjustment of the simple first degree equation y=ax+b (for both horizontal and vertical directions)

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## Thanks For Your Attention!!!

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