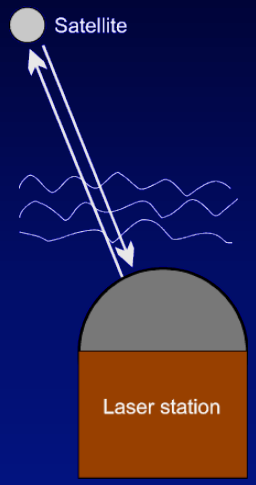
# How do we calibrate and how to get the most accurate data products What are the error sources to our ranging data?

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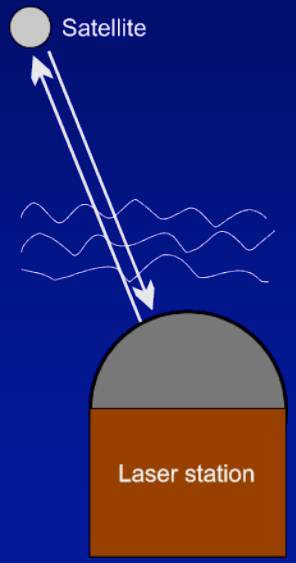
Czech Technical University in Prague, Czech Republic

# Accuracy - definition

- “A measure of the closeness of a measurement /average/ to the true value.”
- “Includes a combination of random error (precision) and systematic error (bias) components.”
- It is recommended to use the terms "precision" and "bias", rather than "accuracy," to convey the information usually associated with accuracy.




*definition according to USC Information Sciences Institute, Marina del Rey, CA*

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# Accuracy – biases check

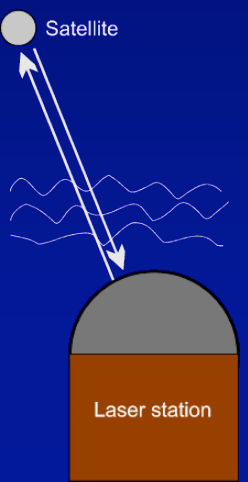
- Comparison to more accurate value
  HOWEVER - for SLR accuracy check such a value is not available

- SOLUTION
  characterizing ALL individual error budget contributors, their precision and BIASES
  (M. Pearlman, System characterization parameters, Herstmonceux, 1984)

- TWO KEY PROBLEMS

  - how to calibrate each contributor ?

  - is our contributors list complete ?

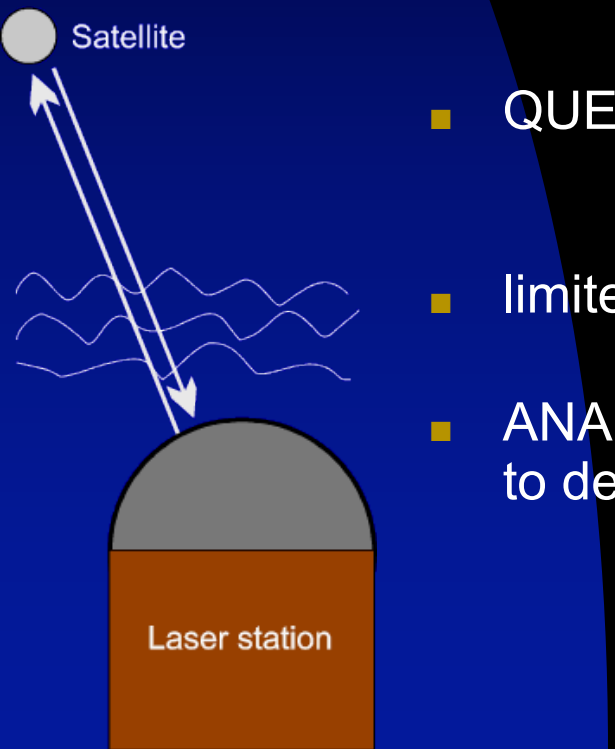


# Precision check

- High precision limit is prerequisite for high accuracy
- The precision of the mean value should increase

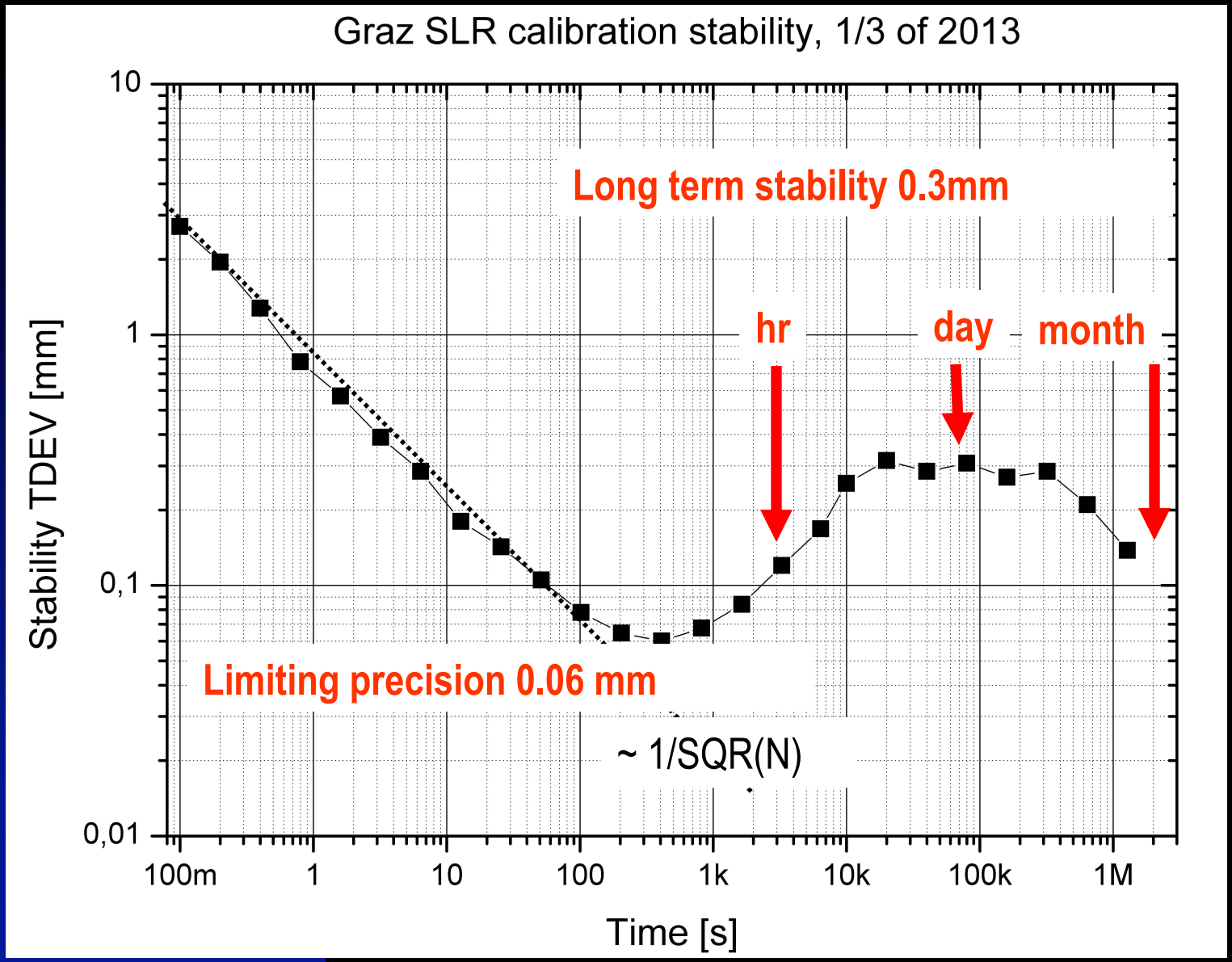
  s ~ 1 / SQR(N) … N is a number of averaged values

  normal distribution, Gaussian statistics, white noise

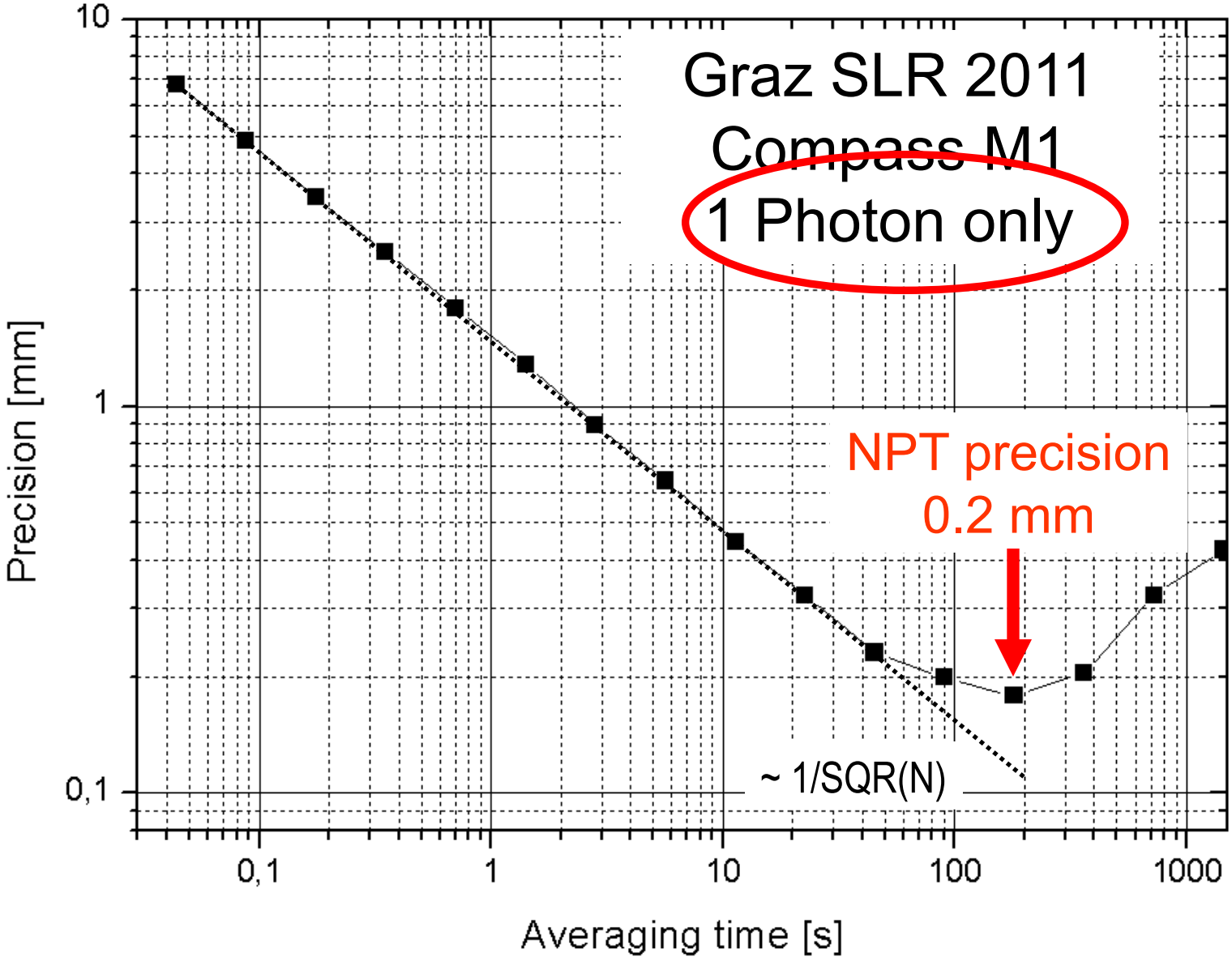



- QUESTION - how long (up to what N) one can average to increase the precision ?
- limited by the system STABILITY
- ANALYSIS – evaluate the “Time variance” TDEV to determine limiting precision and system stability

# Precision check – time variance “Stable 32”



# Precision check – time variance “Stable 32”



# “Ranging machine” error budget contributors
# Ground target calibration

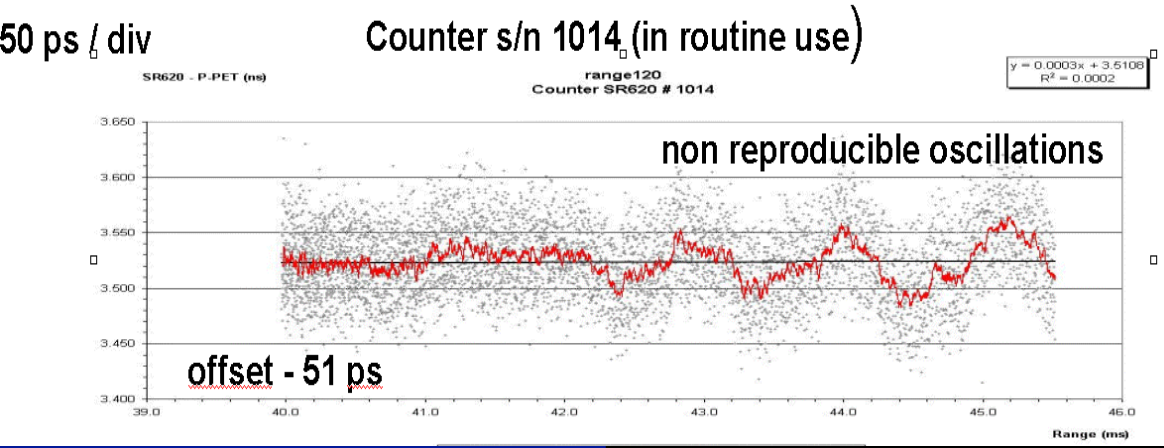
| | |
|---|---|
| Calibration & target setup | T/R optics configuration |
| Optical arrangement | near field, 1 Photon |
| Target distance | range accuracy |
| Laser wavefront | near / far field pattern |
| RF interference | for short distances |
| Timing system linearity | for short intervals |
| Meteo sensors | calibration, stability |
| Time and frequency | offsets, stability,.. |
| SPAD detector | gating, echo rate |

# Portable Calibration Standard for SLR

- To identify the SLR system mm biases
- Ultra-stable Pico Event Timer based on ETM modules by Thales-Dassault
- Epoch and frequency reference
- date analysis SW, set of meteo sensors, ...

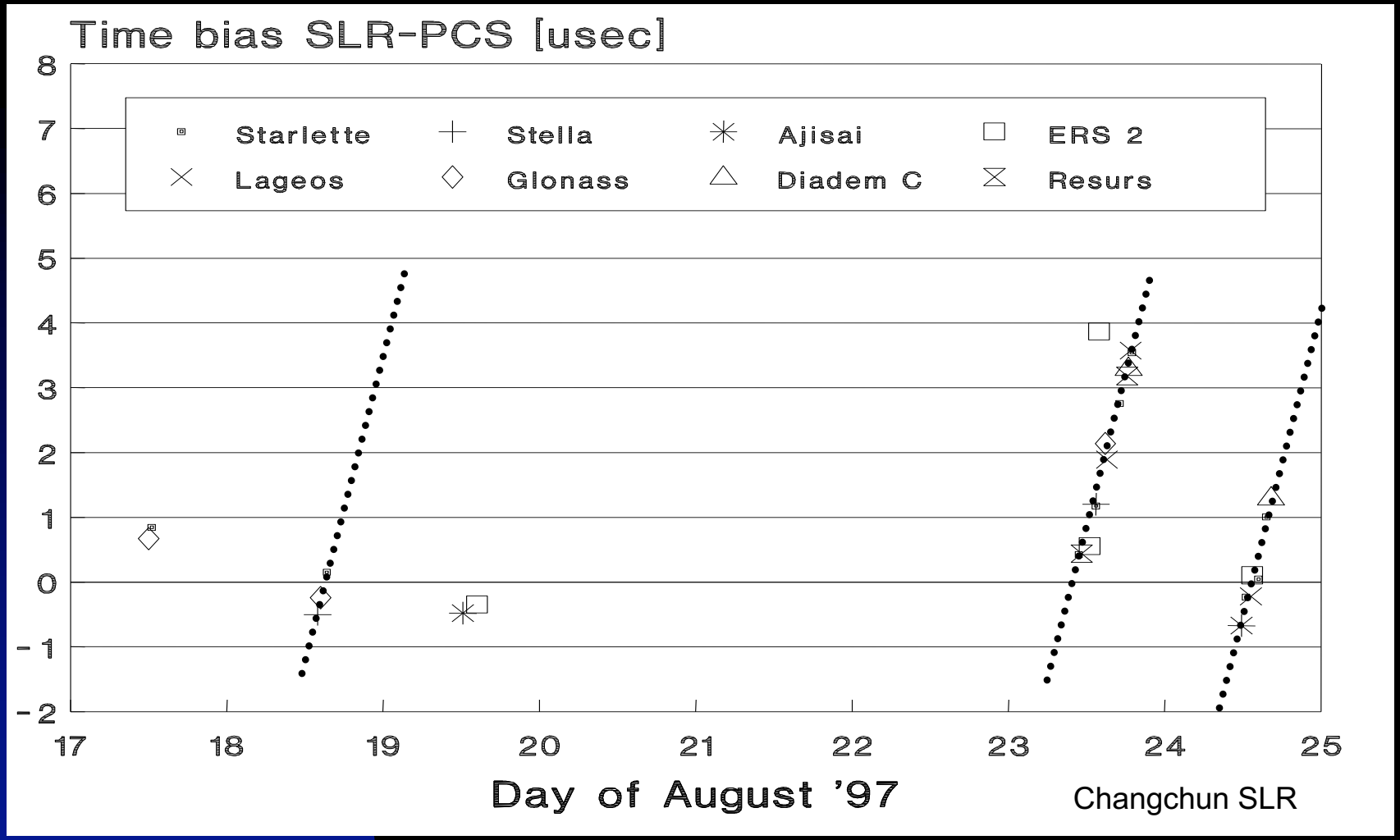
## SR620 / P-PET Counter Linearity

### Potsdam, 2001, LAGEOS pass




| | |
|---|---|
| Graz | 1997, ‘98, ‘99 |
| Tokyo | 1997 |
| Changchun | 1997 |
| WLRS Wettzell | 1997 / 99 |
| TIGO Wettzell | 1998 |
| Zimmerwald | 1998 |
| Herstmonceux | 1998 |
| Potsdam | 2001 |
| Shanghai | 2001,’04,’06 |

# ”Ranging machine” biases identification




The SLR used a wrong frequency source (the slope),
the SLR time base has been synchronized only once per day
the time bias is target independent

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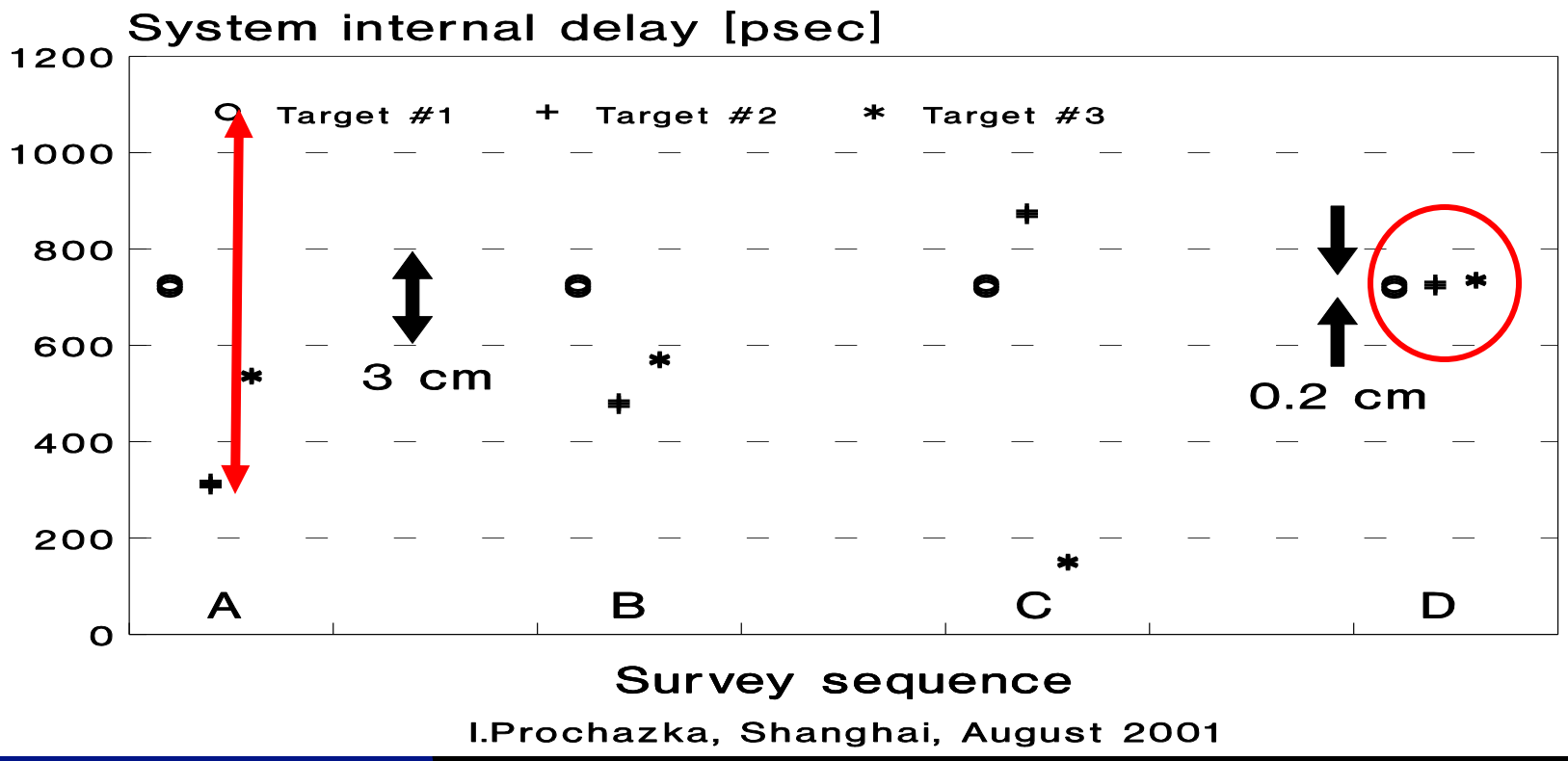
# ”Ranging machine” biases identification




The 3 cal. targets /hollow 2D retros/ have been re-surveyed and the calibration procedure tuned until the the system internal delay value consistency of 2 mm has been achieved.
The 2mm level was a precision limit for the system

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