Introduction

Why are we measuring?

History of the Instruments

Geodetic Measurements today
  User’s view
  Manufacturer’s view
  Metrologist’s view

Ageless principles in surveying

The Art of Measurement
  yesterday - today
  phases of a surveying project

Conclusions
Metrology – the science of measurement

Why are we measuring?

- more knowledge and cognition
- astronomy, astrophysics, chemistry, biology, medicine, physics, ... geodesy

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4 phases of surveying instruments

Antiquity | Optical | Electro Optical | Multi-Sensors

- Egyptian Surveyors
- Roman Agrimensor with Groma
- ZEISS TH II designed by Heinrich WILD
- ZEISS RegElra 14 Registering Total Station
- GEOCORDER 4000 1-person-station
- TRIMBLE GPS-Receiver
- WILD NA 2000 Digital Level

- 1590
- 1924
- 1990
- 2009

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Technical progress since 1990

The actual surveying equipment

- Laser scanner
- terrestrial tacheometry
- total station
- GNSS
- Rotating laser
- Digital level
- laser tracker
- laser radar
- camera
- airborne
- Binoculars + EDM + compass
Measurement – the Customer’s View

**80% of our measurements are not controlled!**

The user is convinced that his results are true!
He does not care for a regular check of the entire equipment!

Product life cycles (3 – 5 years) are too short!

The customer is using the instrument like a Black box
... and like an Office-software

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Measurement – the Manufacturer’s view

**Surveying is easy**

**Market concentration**

**Product piracy!**

Reasons for a new product...?
• New or improved functionality
• Non-availability of electronic components
• Reduction of manufacturing costs

Not every product, which could be developed technically appears ... on the market!

1. Fully automated leveling system
2. Highprecision-distance-measurement-device
All instruments are fulfilling their specifications!

The traceability of geodetic measurements to national standards is not always given!

The measurements are not always carried out with sufficient care!

Geometrical Quality of our measurements?

Measurement system

Accuracy of distances E and DH
The limits of accuracy - yesterday

- multiple measurements
- observer was directly involved in the measurement

The limits of accuracy - today

1. Distances
   Speed of propagation of light in the atmosphere
   refraction index $n$

   \[
   \Delta T = \pm 1 \text{ K} \quad \pm 1 \times 10^{-6}n
   \]
   \[
   \Delta p = \pm 1 \text{ hPa} \quad \pm 0.3 \times 10^{-6}n
   \]
   \[
   \Delta e = \pm 1 \text{ hPa} \quad \pm 0.04 \times 10^{-6}n
   \]

2. Heights
   vertical refraction
   vertical temperature gradient
   desired acquisition: 0.01 K/m

3. Angles
   Horizontal refraction
   horizontal temperature gradient

   \[
   \delta(T)[\text{mgon}] = 0.033 \cdot D[\text{m}] \cdot \text{grd} T[K/m]
   \]

   example \(\text{grd} T = 0.5 \text{ K/m}, D = 500 \text{m} \rightarrow \delta = 8.2 \text{ mgon}\)
The limits of accuracy – today 2

Measurements

Leveling & centering

Influenced by:
• optical plumet (well adjusted?)
• tripod
• Spirit level
• experience of the operator

The quality of GNSS-measurements?

Accuracy and reliability are depending on a lot of factors:
- satellite constellation
- observation time
- visibility
- quality of orbit parameters
- influence of the ionosphere

The following accuracy, indicated as RMS, is based on calculation with….(name of the software-package) …

Extracted from the specifications of GNSS-manufacturer

Accuracy and reliability may be subject to anomalies due to multipath, obstructions, and satellite geometry. Always follow recommended survey practices.

Extracted from the specifications of GNSS-manufacturer
1. First, consider the whole
2. Know the tools
3. Consider contributing errors
4. Record defining parameters
5. Beware the bounds of Convention
6. Build proof into the process
7. Engage the user

"The ABC of x, y, z - 21 Principles for Consideration by Surveyors and other Geospatial Professionals"
P. M. Byrne and G. Kelly, FIG Working week, Hong Kong 2007

Cause for the loss
A sub-contractor (Martin-Marietta) designed and manufactured the steering system (jet engines)...and programmed it in imperial pounds!

NASA "thought" that the system is working in metric pounds!

Factor = 4.45!!

The problem could have been detected and fixed during the 9-months-flight!

This example is not specific to Aerospace-industry

Similar errors occur in a lot of complex technical projects
The art of measurement in the past

- Capabilities for carrying out precision mechanical work
- Skills in calculating
- Sharp-sighted eyes

John Wayne and Oliver Hardy as surveyors, in „the Fighting Kentuckian” (1947)

The surveying tasks – in the past and today

- Points
- Measurement Objects
- Measurement Data
- Data Treatment
- Numerical Analysis and Calculations
- 2D Map (contour lines) fixed scales
- Points, Surfaces, Bodies, 3D Objects
- Coordinates, Distances (Deviations), Control of shape & Dimension, Data for technical processes
- Numerical Analysis and Calculations, Cax Models, Visualization, Interactive models, Process guidance
The different phases of a surveying project

In the past

- Data Acquisition
- Field Work
- Data Treatment

Time

Presence

Several decisions

Planning & Design

step 1 define the final product

Data format

- Measurement data
- Reference Data
- Final product

Latency

Time delay
0.1 s ... several months

Refreshment period?

Actuality

LOD

 LOD = Level of Detail
 Density of information

Geometrical quality

Trueness, Accuracy, Repeatability, uncertainty...

Step 2

Product types

- Map
- Numerical analysis
- visualization
- 3D model
- interactive model
- Process data for machine guidance

Definition of the final product(s)
Requirements fulfilled?

No

Yes

Step 2
Define the data acquisition and the data processing.

Choice of...

Data processing strategy

Data acquisition strategy

Software for data processing

Instruments...

...types and models

Dependencies

Time frame

Object size

Environmental conditions

Vibrations, refraction, object sensitivity, obstacles, security aspects...

Requirements fulfilled?

The planning phase today 2

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Conclusions

- Know potential perturbations
- Evaluate the uncertainty budget with respect to the entire measurement system
- Validate the measurements and the final results
- Implement independent checks of the entire system

Instruments with increased performance & efficiency

Push the button... but, there are still manual operations!

Different types of instruments for 1 task, for example DEM=Digital Elevation Model

Choice of the best measurement procedure

Mastering the chosen procedure

- Know potential perturbations
- Evaluate the uncertainty budget with respect to the entire measurement system
- Validate the measurements and the final results
- Implement independent checks of the entire system

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Conclusions

The art of measurement - today

Master the entire process

Planification
Validation
Uncertainty budget
Proof building
Data treatment
Master the instrument
Visualization
Data analysis
Presentation

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Screenshot from _Dersu Uzala_ by Akira Kurosawa, 1975