amsterdam
FIG WORKING WEEK 2020
10 – 14 MAY

SMART SURVEYORS FOR LAND AND WATER MANAGEMENT

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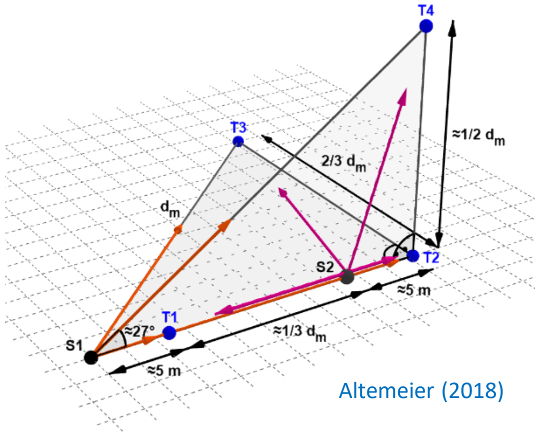
The New ISO Standard for a Field-Testing Procedure of Terrestrial Laser Scanners and its Practical Performance

The New ISO Standard for a Field-Testing Procedure of Terrestrial Laser Scanners and its Practical Performance



Altemeier (2018)

Ingo Neumann, Franziska Altemeier, Hamza Alkhatib (Leibniz University Hannover, Germany)

Bianca Gordon (Leica Geosystems AG, Heerbrugg, Switzerland)

Leibniz Universität Hannover
GIH
Leica Geosystems

General information

Focus of this collection of ideas / proposals

- Simple, fast, reliable checking of the instrument specifications
  - Within a few hours
  - (Measurement) Uncertainty
  - Detection of non acceptable (systematic) deviations
- The procedure(s) must be independent (manufacturer)
- No laboratory procedures
- No calibration
- Methods which fit into the testing philosophy of IS0 17123 (DIN 18723)
  - Simplified and full test procedure
  - Independent procedure with standard equipment

Agenda

1. **General Information**
2. Test procedure
   i. Simplified Test Procedure(s)
   ii. Full Test Procedure(s)
3. Sensitivity of the test procedure(s)
4. Measurement uncertainty (thresholds)
5. Conclusions

General information

2011 Proposal for a full/extended test procedure (Feldmann, Petersen, Staiger)

$\Rightarrow$ Reference distances (coordinates) for full procedure to consider the scale of the TLS measurements.

2012 - 2014: DVW - technical Bulletin for a test procedure:
(F. Neitzel; B. Gordon; D. Wujanz; WG 3 of DVW)

$\Rightarrow$ mainly following the ideas of Heister / Staiger (2009)

2014 - 2018 ISO WIP for a simple and full test procedure:
(17123-9; under the lead from the DIN Working group)

$\Rightarrow$ mainly following the ideas of the DVW - technical Bulletin

Future Extend and/or translate the ISO 17123-9 for DIN 18723

General information

DVW Bulletin

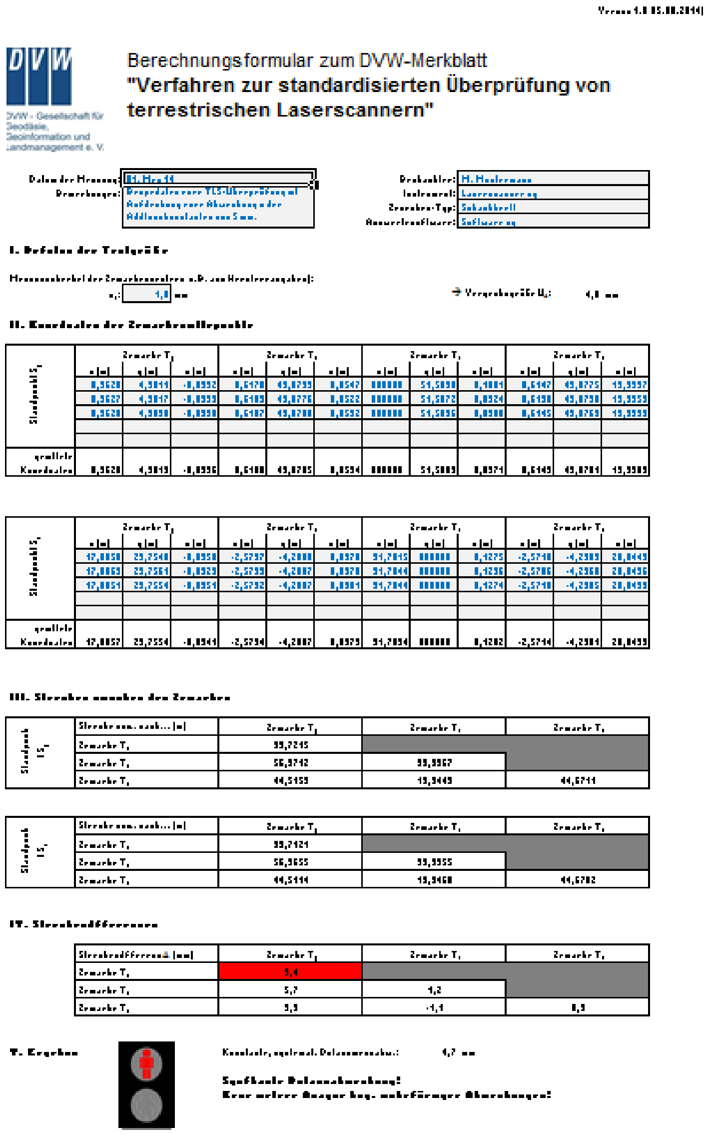
DVW-Merkblatt 7-2014

DVW

Verfahren zur standardisierten Überprüfung
von terrestrischen Laserscannern (TLS)

Fachautoren:	Frank Neitzel, TU Berlin Bianca Gordon, Leica Geosystems AG Daniel Wujanz, TU Berlin
Weitere Beteiligte:	DVW Arbeitskreis 3 DVW Arbeitskreis 4 Arbeitsgruppe Terrestrisches Laser Scanning – TLS Gesellschaft zur Kalibrierung geodätischer Messmittel e. V Technical Committee ISO/TC 172/SC 6
Beschlussfassung:	Beschlossen vom DVW Arbeitskreis 3 am 25.03.2014 Verabschiedet vom Präsidium des DVW am 16.05.2014

Dokumentenstatus:
verabschiedet



https://www.dvw.de/veroeffentlichungen/merkblaetter → TLS

General information

ISO 17123-9

Optics and optical instruments — Field procedures for testing geodetic and surveying instruments

Part 9: Terrestrial laser scanners

Project leader: Ingo Neumann (DIN, Germany)

General information

Status : Published	**Publication date :** 2018-12
Edition : 1	**Number of pages :** 43
Technical Committee : ISO/TC 172/SC 6 Geodetic and surveying instruments	
ICS : 17.180.30 Optical measuring instruments	

https://www.iso.org/standard/68382.html

INTERNATIONAL STANDARD

ISO 17123-9

First edition
2018-12

Optics and optical instruments — Field procedures for testing geodetic and surveying instruments —

Part 9:
Terrestrial laser scanners

Optique et instruments d'optique — Méthodes d'essai sur site des instruments géodésiques et d'observation —

Partie 9: Scanners laser terrestres

Reference number
ISO 17123-9:2018(E)

Overview on the actual test procedure(s)

Procedure	DVW Bulletin	ISO-Group (ISO 17123-9)	DIN Working Group (DIN 18723)	Proposal of Feldmann et al. (2011)
Simple	---	Yes	Yes	(Yes)
Full	(Yes)	Yes	Yes	Yes
Extended (reference distances)	----	---	Under discussion	Yes (with fix installed targets)
Measurement Uncertainty	Partly	Yes	Yes	partly

Translation

fix installation

Simple: Red / Green decision without statistical treatment
Full: Repeated observations with statistical checking/judgement of the results
Extended: Introduction of reference distances

Agenda

1. General Information
2. **Test procedure**
    i. **Simplified Test Procedure(s)**
    ii. **Full Test Procedure(s)**
3. Sensitivity of the test procedure(s)
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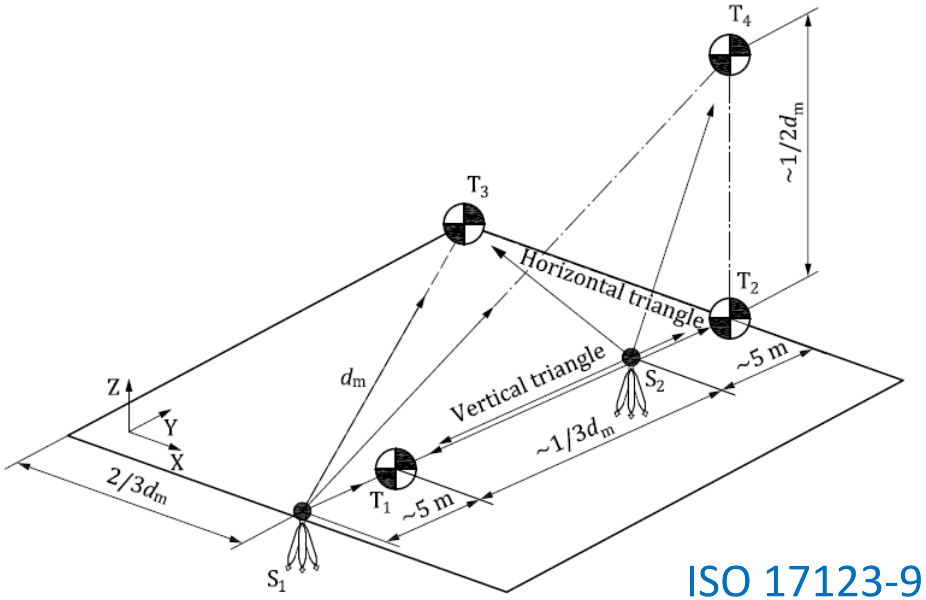
Test procedure

ISO 17123-9: Configuration of the „simplified and full test procedure”



ISO 17123-9

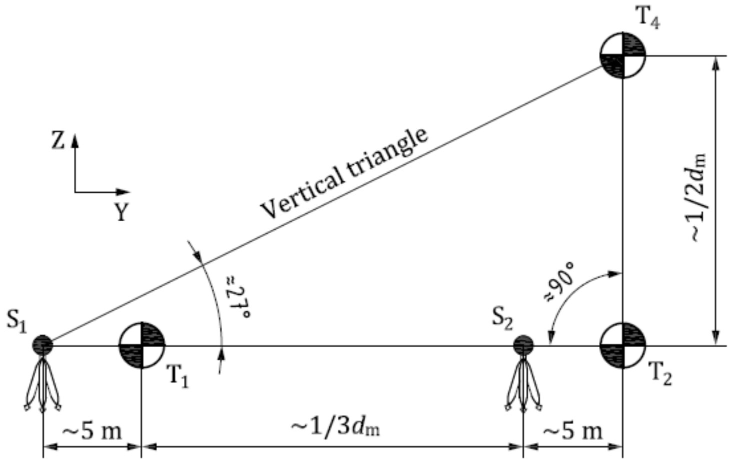
Key

S_1, S_2	instrument station
T_1, T_2, T_3, T_4	target point
d_m	maximum distance

- 4 Targets (T_j)
- 2 Instrument stations (S_i)

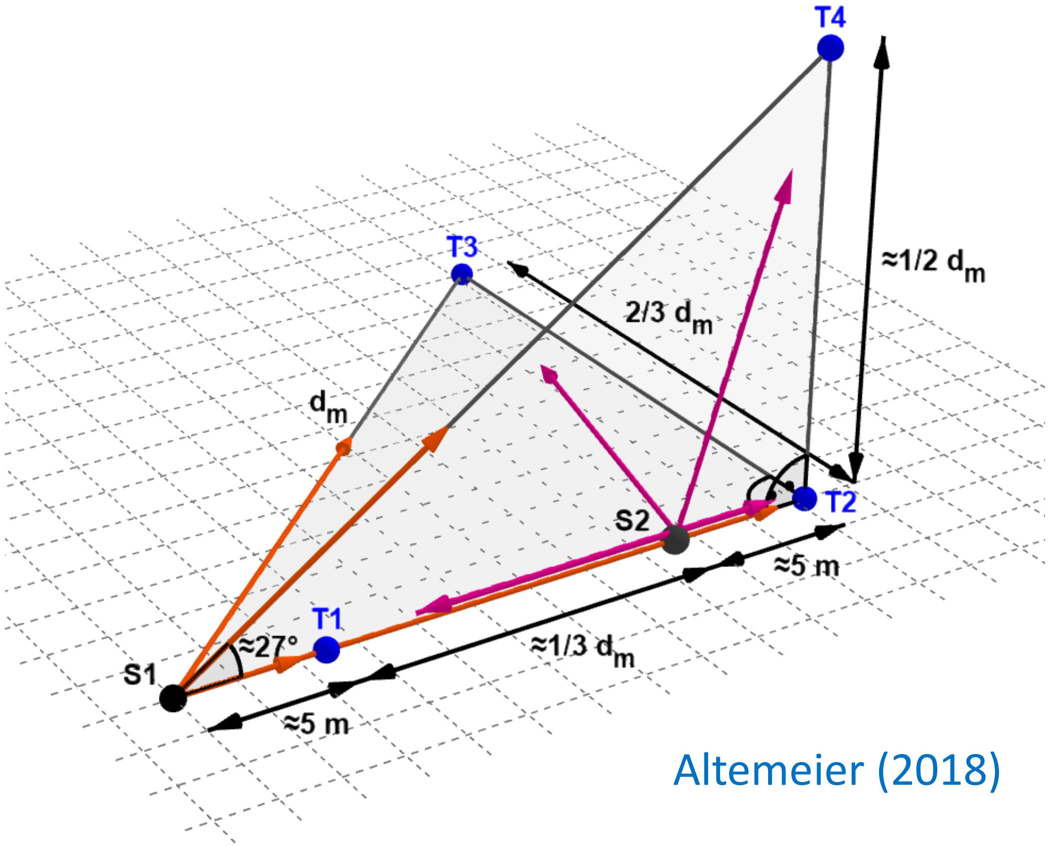
- 1 measurement on S_i (simple procedure)
- 3 independent measurement on S_i

→All 4 targets are determined 3 x 2 (full procedure)

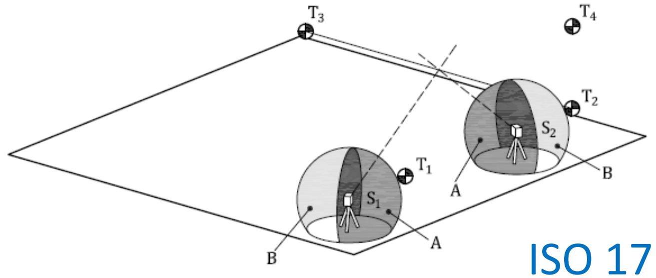


ISO 17123-9

ISO 17123-9: Configuration of the „simplified and full test procedure”



Altemeier (2018)

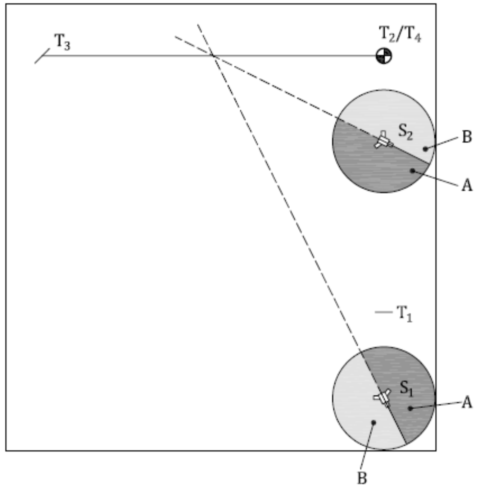


ISO 17123-9

Key

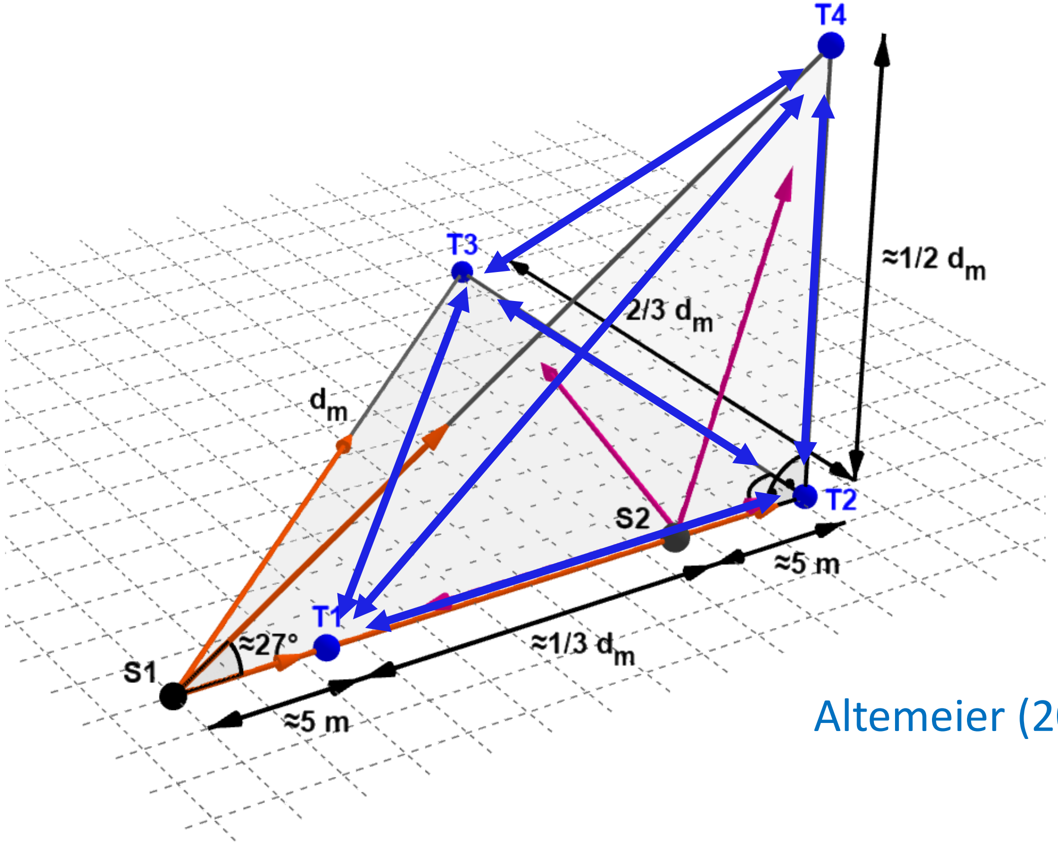
A	face I
B	face II
S_1, S_2	instrument station
T_1, T_2, T_3, T_4	target point

Figure 3 — Instrument orientations on both positions (side view)



ISO 17123-9

ISO 17123-9: Configuration of the „simplified and full test procedure"

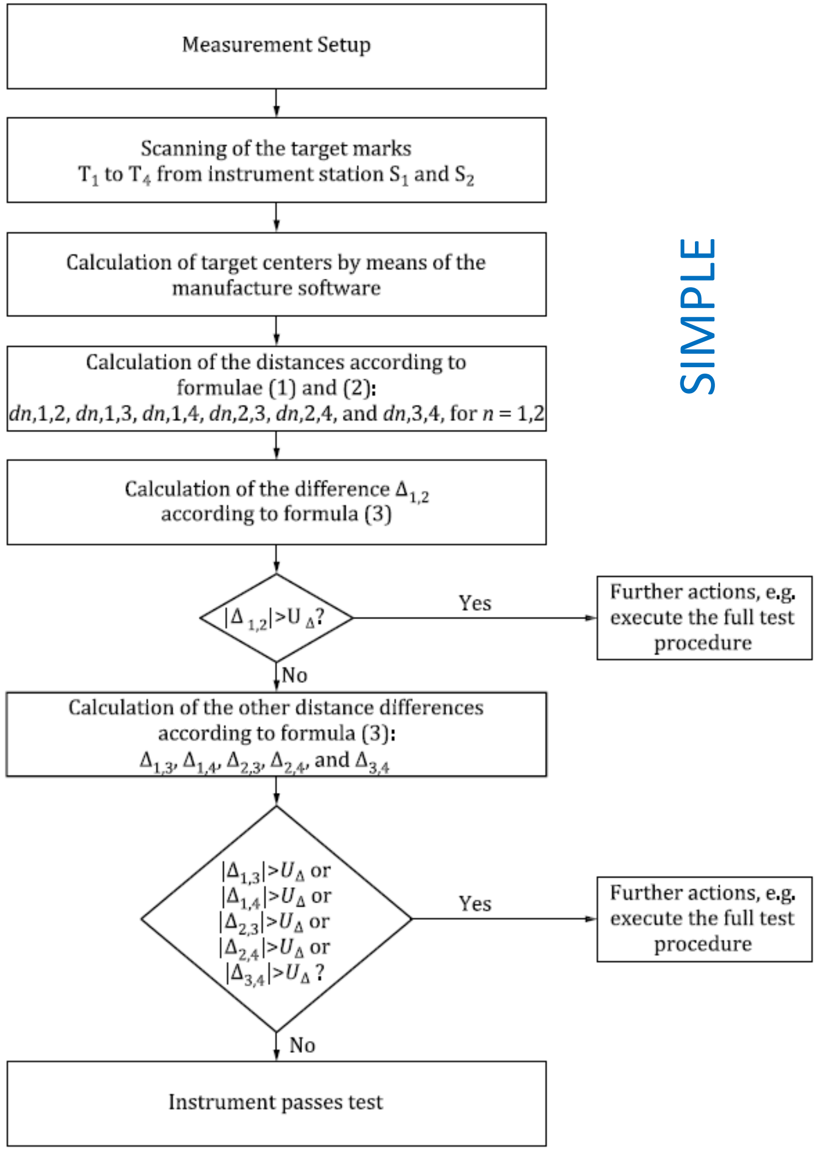


Altemeier (2018)

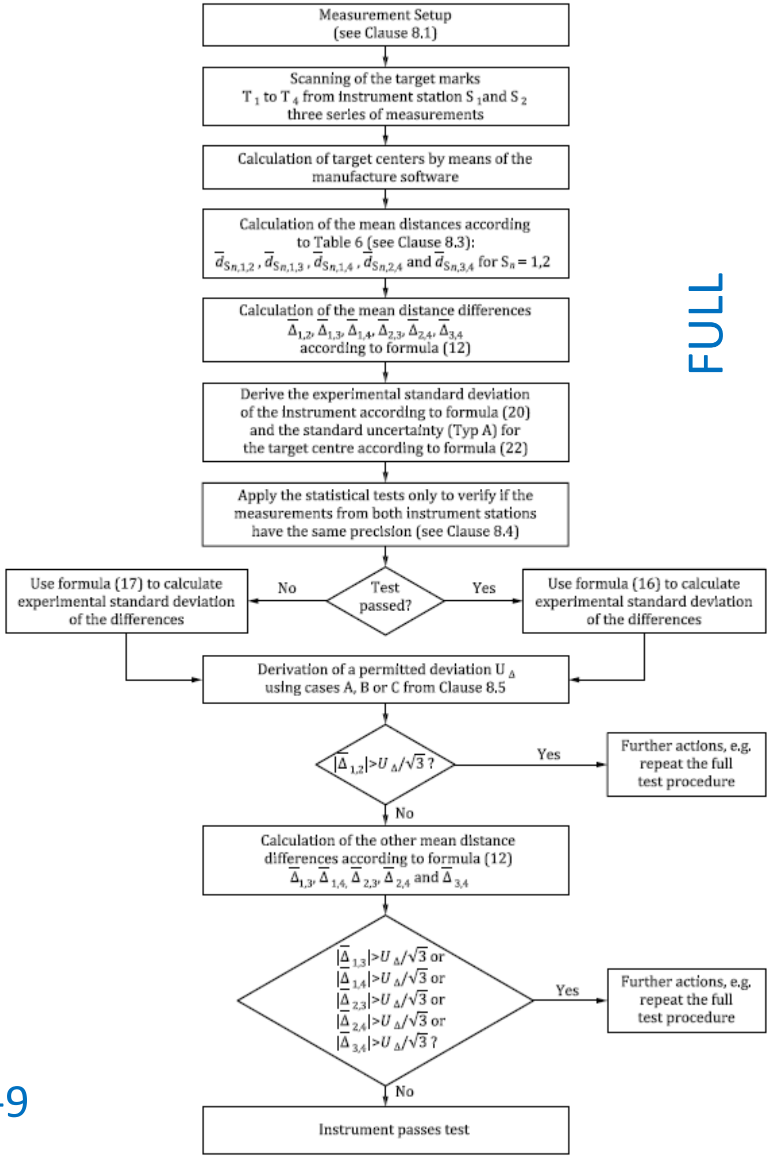
Station 1 (S_1)		Station 2 (S_2)
(T1 – T2)(1)	⇨ Δ_1 ⇩ 2 x additional constant	(T1 – T2)(2)
(T1 – T3)(1)	⇨ Δ_2	(T1 – T3)(2)
(T1 – T4)(1)	⇨ Δ_3	(T1 – T4)(2)
(T2 – T3)(1)	⇨ Δ_4	(T2 – T3)(2)
(T2 – T4)(1)	⇨ Δ_5	(T2 – T4)(2)
(T3 – T4)(1)	⇨ Δ_6	(T3 – T4)(2)

Most important for angle errors

Test procedure – summary



SIMPLE



FULL

ISO 17123-9

Agenda

1. General Information
2. Test procedure
   i. Simplified Test Procedure(s)
   ii. Full Test Procedure(s)
3. **Sensitivity of the test procedure(s)**
4. Measurement uncertainty (thresholds)
5. Conclusions

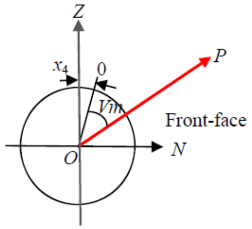
Sensitivity of the procedure

Simulation of most important calibration parameters (Altemeier, 2018)

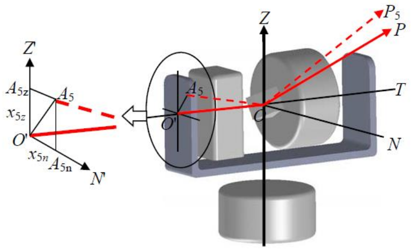
Geometric model according to Muralikrishnan et al. (2015) (selected parameters)

Parameter	Description	Influence on
x_4	Vertical index offset	ΔVm
x_{5n}	Beam tilt component along n	$\Delta Hm, \Delta Vm$
x_{5z}	Beam tilt component along z	$\Delta Hm, \Delta Vm$
x_6	Mirror tilt	ΔHm
x_7	Transit tilt	ΔHm
x_{10}	Zero-offset (Bird-bath error)	ΔRm

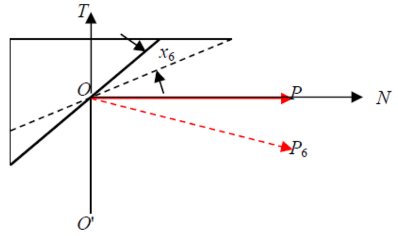
x_4



x_5



x_6



Muralikrishnan et al. (2015)

Sensitivity of the procedure

Simulation of most important calibration parameters (Altemeier, 2018)

Selection of the simulation parameters	• Selected instrument • Configuration of the test field • Magnitude of the systematic deviations ($x_4, x_{5n}, x_{5z}, x_6, x_7, x_{10}$)
Simulation of reference values	• Polar elements: Distance (R), Horizontal direction (H), Vertical angle (V)
Adding the systematic error	• Geometric model after Muralikrishnan et al. (2015): $\Delta Rm, \Delta Hm, \Delta Vm$
Randomize the observations	• Generate random deviations (according to the instruments data sheet) • → 3 observation sets: measurement values Rm, Hm, Vm
Apply testing procedure ISO 17123-9	• Transformation to the cartesian coordinates of the target centers: X, Y, Z • Calculation and testing of the distance deviations: $\lvert\bar{\Delta}_{i,j}\rvert > U_\Delta/\sqrt{3}$

Analysis of 10000 Monte-Carlo-Runs

Sensitivity of the procedure

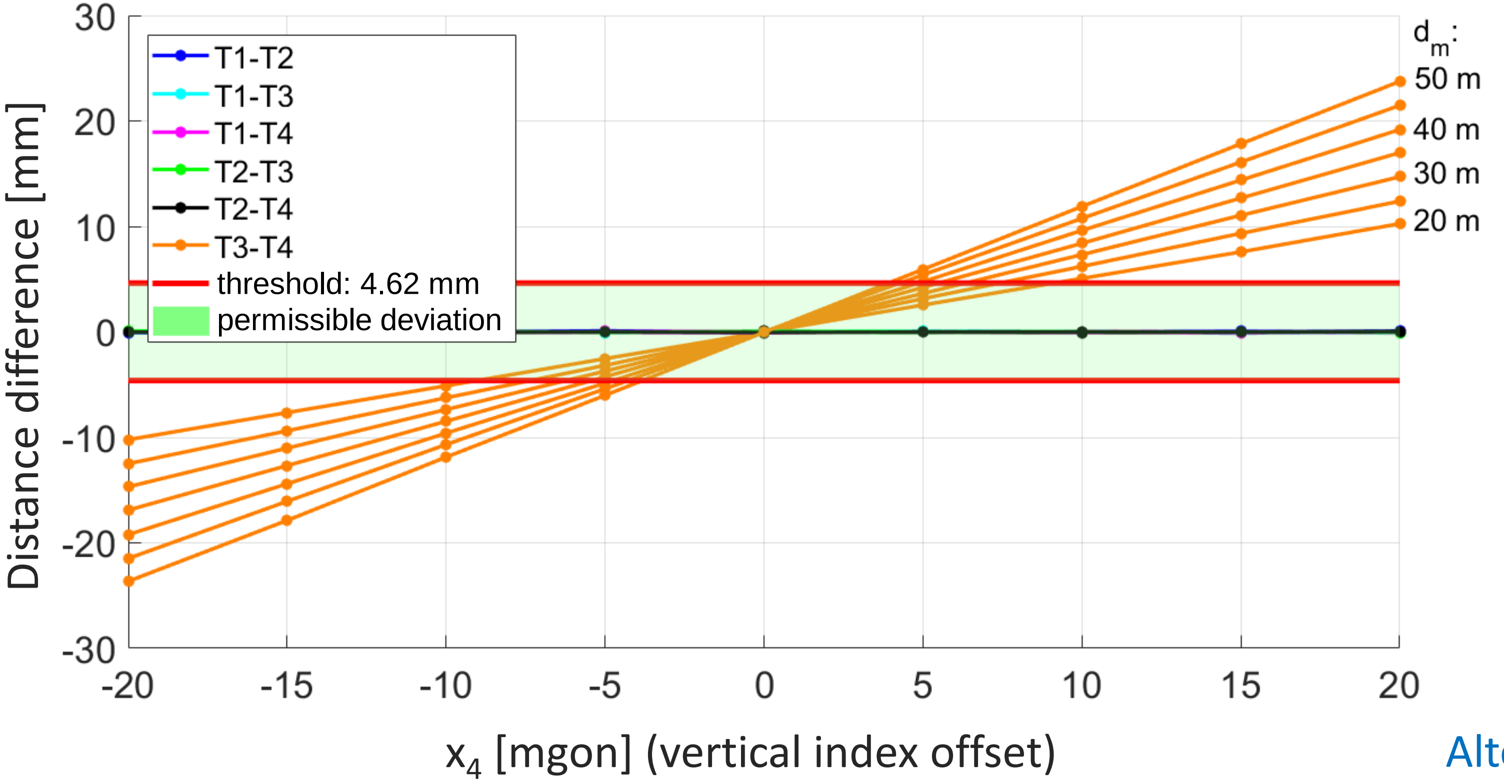
Simulation of most important calibration parameters (Altemeier, 2018)

- Influence of the measurement configuration
  - Variation of the test field size (d_m) } See next slides
  - Variation of the height of target T4 } See next slides
  - Violation of the test field configuration (X and Y) → Small influence
  - Deviation of other criteria (Perpendicularity, 5 m, …) → Small influence
- Influence of the systematic deviations under
  - Variation of individual parameters } See next slides
  - Combination of minimum two parameters } See next slides
- Determination of the threshold for the judgement of the TLS

  → Not treated in this presentation

Simulation of most important calibration parameters (Altemeier, 2018)

Influence of the measurement configuration

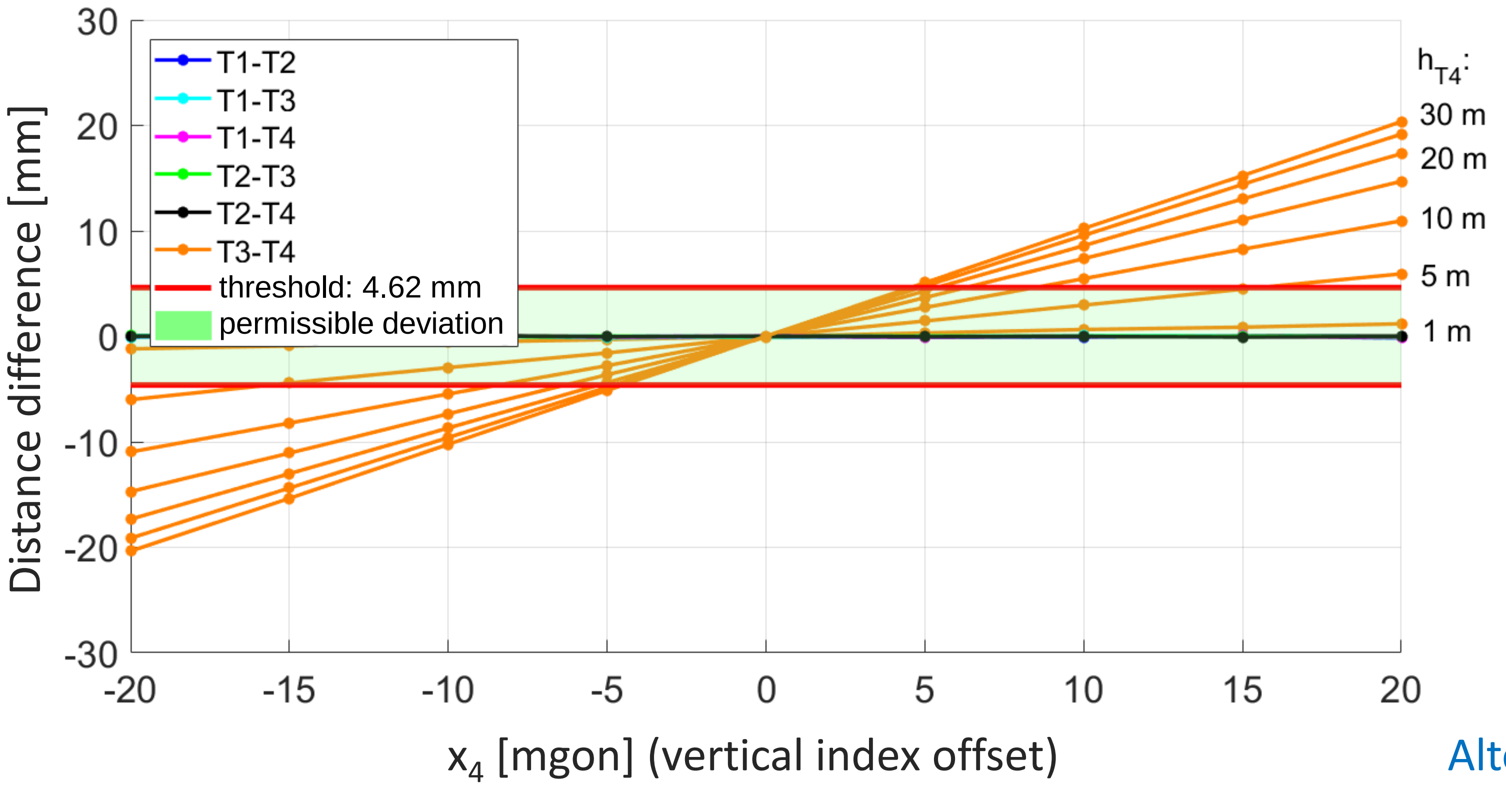


Altemeier (2018)

Sensitivity of the procedure

Simulation of most important calibration parameters (Altemeier, 2018)

Influence of the measurement configuration



Altemeier (2018)

Sensitivity of the procedure

Simulation of most important calibration parameters (Altemeier, 2018)

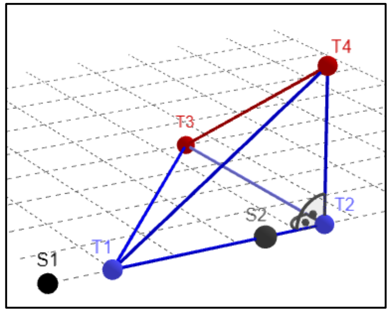
Identification of sensitive distances

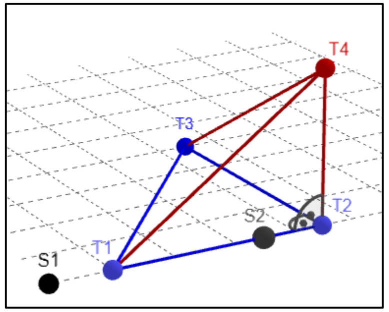
	x_4	x_{5n}	x_{5z}	x_6	x_7	x_{10}
T1-T2	-	-	-	-	-	+
T1-T3	-	-	-	-	-	+
T1-T4	-	+	+	-	-	+
T2-T3	-	-	-	-	-	+
T2-T4	-	+	-	-	-	+
T3-T4	+	+	+	+	-	+
legend:	Influence of the parameters: - no / + significant / + dominant					

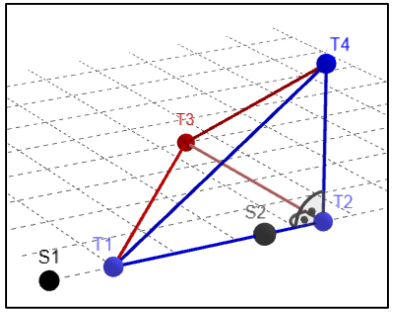
Negligence of the test field configuration (X,Y):

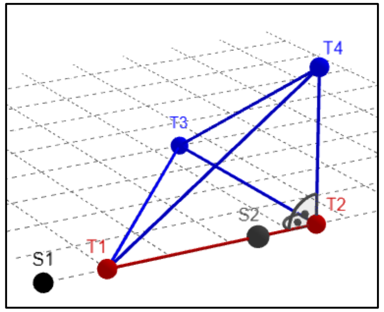
- less sensitive
- less specific
- x_{10} not influenced

T_4 height dependent





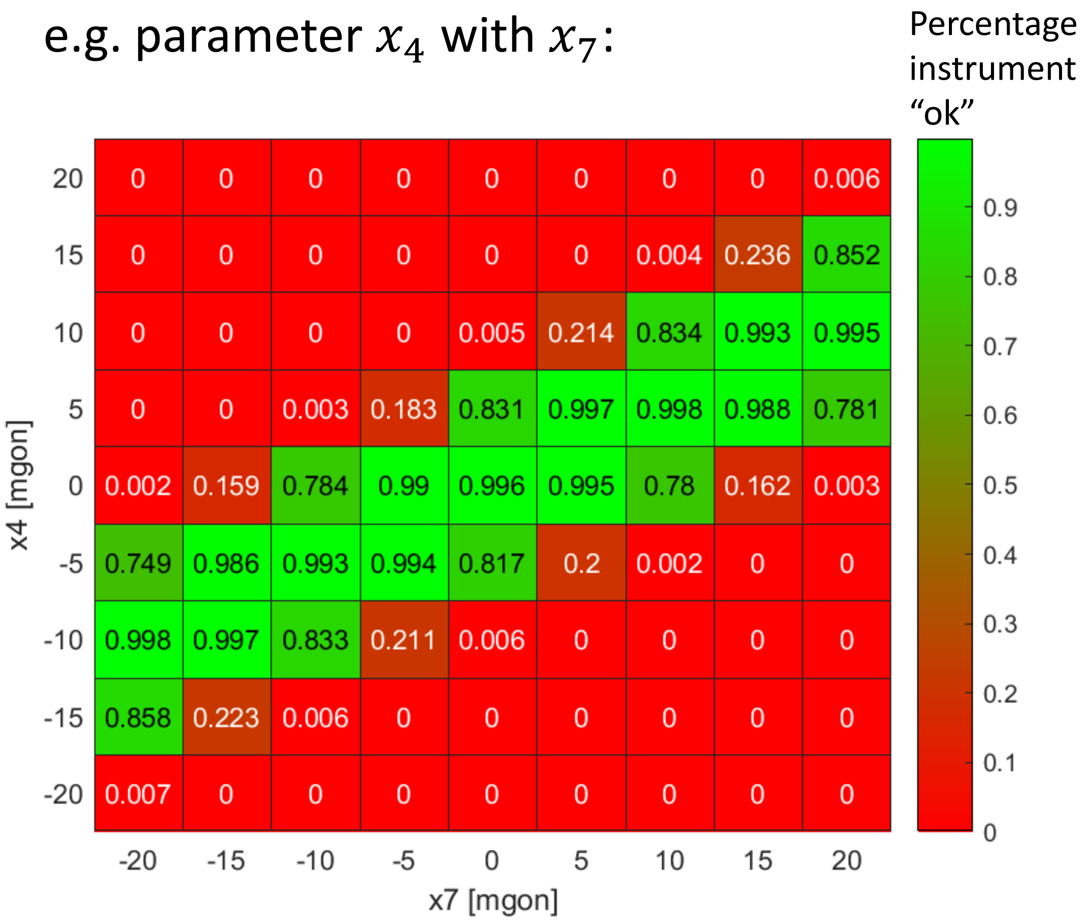




Simulation of most important calibration parameters (Altemeier, 2018)

Combination of parameters

e.g. parameter x_4 with x_7:



Result:

- Compensation/ amplification of the influences
- Sensitivity of distance differences changes
- Depending on the magnitude and sign of the parameters

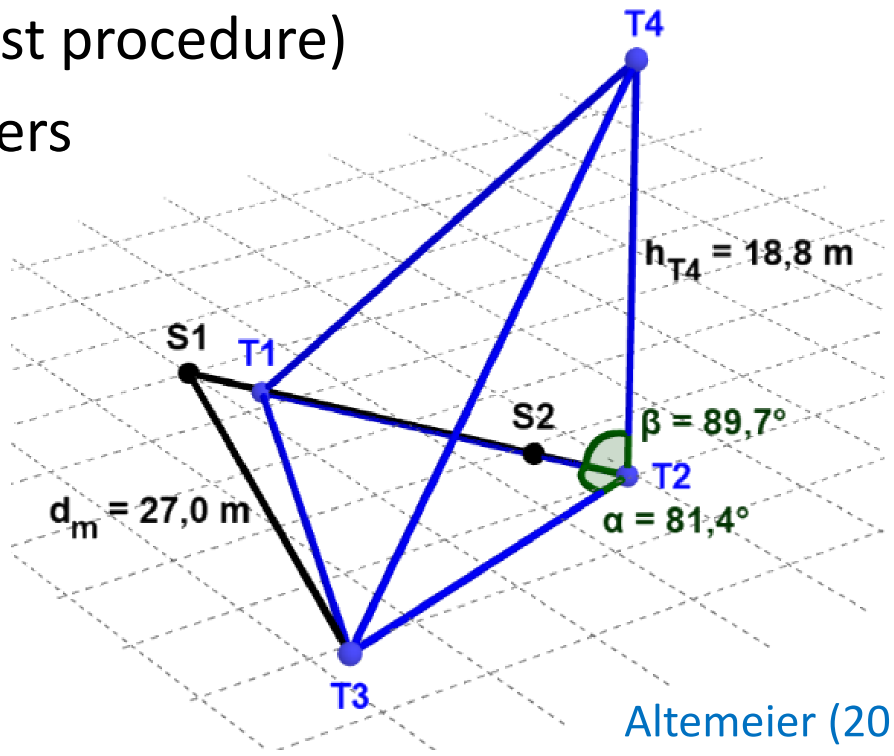
→ **Inference difficult**

Sensitivity of the procedure

Empiricial evaluation and validation of the results

Evaluation of real measurements (Leica Geosystems AG)

- Measurements according to ISO 17123-9 (full test procedure)
- Systematically manipulated calibration parameters ($x_4, x_{5n}, x_{5z}, x_6, x_7$)



Altemeier (2018)

Results:

- Sensitivity proofed
- Inference on manipulated parameters possible (for individual parameters)

Agenda

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4. **Measurement uncertainty (thresholds)**
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(Measurement) uncertainty

Quantification for the measurement uncertainty (MU)

Guide to the Expression of Uncertainty in Measurements (GUM)

- ISO [1995]: Evaluation of Measurement Data - Guide to the Expression of Uncertainty in Measurement (GUM). Eds: BIPM, IEC, IFCC, ILAC, ISO, IUPAC, IUPAP and OIML.
- Detection of all significant influence factors on the MU is requested
- For random, systematic (and non modelled) effects
- Consideration of type „A“ and type „B“ uncertainties

Thresholds for the comparison of the distance differences

- A) Based on manufacturer / project requirements
- B) Based on the measurements itself (only if no other information is available)
- C) Combination of B) and numerical calculation of MU

(Measurement) uncertainty

Quantification for the measurement uncertainty

Characteristics of type „A“ and type „B“ uncertainties

- Type A:
  - Uncertainties that can be obtained from repeated measurements with the aid of statistical methods
  - Approximation of the distribution
  - Often a simple mean and the standard deviation of a measurand
- Type B:
  - Uncertainty that is obtained by other methods (as statistical analysis)
  - e.g. values from previous measurements, expert knowledge, manufacturer information, calibration certificates, books, ….
  - The consideration of this type of uncertainty need a (very) good knowledge about the sensors and the underlying measurement process

$$u = \sqrt{u_A^2 + u_B^2}$$ ➡ **Simple case:** From manufacturer

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Conclusions

- Summary
  - Reversal of the burden of proof → **high relevance**
  - ISO 17123-9 is recommended (but DVW Bulletin still ok)
    - DVW only uses 3 important distances as decision criterion
    - DVW has not a detailed uncertainty treatment
  - **Very high sensitivity with respect to typical calibration models**
  - **Very fast measurements and analysis procedure (2h – 3h)**

- Further comments:
  - DIN and ISO will maybe have different content of the documents
    → difference lies mainly only in the “extended” version
  - The collaboration between the different institutions is beneficial
  - DVW Bulletin will most probably be updated

Thanks a lot for the attention and contributions!

References

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The New ISO Standard for a Field-Testing Procedure of Terrestrial Laser Scanners and its Practical Performance

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