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

**Part 1:  
Theory**

*Optique et instruments d'optique — Méthodes d'essai sur site pour les  
instruments géodésiques et d'observation —*

*Partie 1: Théorie*

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ISO copyright office  
Case postale 56 • CH-1211 Geneva 20  
Tel. + 41 22 749 01 11  
Fax + 41 22 749 09 47  
E-mail [copyright@iso.org](mailto:copyright@iso.org)  
Web [www.iso.org](http://www.iso.org)

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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 172, *Optics and photonics*, Subcommittee SC 6, *Geodetic and surveying instruments*.

This third edition cancels and replaces the second edition (ISO 17123-1:2010).

ISO 17123 consists of the following parts, under the general title *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments*:

- *Part 1: Theory*
- *Part 2: Levels*
- *Part 3: Theodolites*
- *Part 4: Electro-optical distance meters (EDM measurements to reflectors)*
- *Part 5: Total stations*
- *Part 6: Rotating lasers*
- *Part 7: Optical plumbing instruments*
- *Part 8: GNSS field measurement systems in real-time kinematic (RTK)*

## Introduction

This part of ISO 17123 specifies field procedures for adoption when determining and evaluating the uncertainty of measurement results obtained by geodetic instruments and their ancillary equipment, when used in building and surveying measuring tasks. Primarily, these tests are intended to be field verifications of suitability of a particular instrument for the immediate task. They are not proposed as tests for acceptance or performance evaluations that are more comprehensive in nature.

The definition and concept of uncertainty as a quantitative attribute to the final result of measurement was developed mainly in the last two decades, even though error analysis has already long been a part of all measurement sciences. After several stages, the CIPM (Comité Internationale des Poids et Mesures) referred the task of developing a detailed guide to ISO. Under the responsibility of the ISO Technical Advisory Group on Metrology (TAG 4), and in conjunction with six worldwide metrology organizations, a guidance document on the expression of measurement uncertainty was compiled with the objective of providing rules for use within standardization, calibration, laboratory, accreditation and metrology services. ISO/IEC Guide 98-3 was first published as an International Standard (ISO document) in 1995.

With the introduction of uncertainty in measurement in ISO 17123 (all parts), it is intended to finally provide a uniform, quantitative expression of measurement uncertainty in geodetic metrology with the aim of meeting the requirements of customers.

ISO 17123 (all parts) provides not only a means of evaluating the precision (experimental standard deviation) of an instrument, but also a tool for defining an uncertainty budget, which allows for the summation of all uncertainty components, whether they are random or systematic, to a representative measure of accuracy, i.e. the combined standard uncertainty.

ISO 17123 (all parts) therefore provides, for defining for each instrument investigated by the procedures, a proposal for additional, typical influence quantities, which can be expected during practical use. The customer can estimate, for a specific application, the relevant standard uncertainty components in order to derive and state the uncertainty of the measuring result.

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

## Part 1: Theory

### 1 Scope

This part of ISO 17123 gives guidance to provide general rules for evaluating and expressing uncertainty in measurement for use in the specifications of the test procedures of ISO 17123-2, ISO 17123-3, ISO 17123-4, ISO 17123-5, ISO 17123-6, ISO 17123-7 and ISO 17123-8.

ISO 17123-2, ISO 17123-3, ISO 17123-4, ISO 17123-5, ISO 17123-6, ISO 17123-7 and ISO 17123-8 specify only field test procedures for geodetic instruments without ensuring traceability in accordance with ISO/IEC Guide 99. For the purpose of ensuring traceability, it is intended that the instrument be calibrated in the testing laboratory in advance.

This part of ISO 17123 is a simplified version based on ISO/IEC Guide 98-3 and deals with the problems related to the specific field of geodetic test measurements.

### 2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC Guide 99, *International vocabulary of metrology — Basic and general concepts and associated terms (VIM)*

### 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC Guide 99 and the following apply.

#### 3.1 General metrological terms

##### 3.1.1

##### **(measurable) quantity**

property of a phenomenon, body or substance, where the property has a magnitude that can be expressed as a number and a reference

EXAMPLE 1 Quantities in a general sense: length, time, temperature.

EXAMPLE 2 Quantities in a particular sense: length of a rod.

##### 3.1.2

##### **value**

##### **value of a quantity**

##### **quantity value**

number and reference together expressing the magnitude of a quantity

EXAMPLE Length of a rod: 3,24 m.

### 3.1.3

#### **true value**

#### **true value of a quantity**

#### **true quantity value**

value consistent with the definition of a given quantity

Note 1 to entry: This is a value that would be obtained by perfect measurement. However, this value is in principle and in practice unknowable.

### 3.1.4

#### **reference value**

#### **reference quantity value**

quantity value used as a basis for comparison with values of quantities of the same kind

Note 1 to entry: A reference quantity value can be a true quantity value of the measurand, in which case it is normally unknown. A reference quantity value with associated measurement uncertainty is usually provided by a reference measurement procedure.

### 3.1.5

#### **measurement**

process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity

Note 1 to entry: Measurement implies comparison of quantities and includes counting of entities.

### 3.1.6

#### **measurement principle**

phenomenon serving as the basis of a measurement (scientific basis of measurement)

Note 1 to entry: The measurement principle can be a physical phenomenon like the Doppler effect applied for length measurements.

### 3.1.7

#### **measurement method**

generic description of a logical organization of operations used in a measurement

Note 1 to entry: Methods of measurement can be qualified in various ways, such as “differential method” and “direct measurement method”.

### 3.1.8

#### **measurand**

quantity intended to be measured

EXAMPLE Coordinate  $x$  determined by an electronic tacheometer.

### 3.1.9

#### **indication**

quantity value provided by a measuring instrument or measuring system

Note 1 to entry: An indication and a corresponding value of the quantity being measured are not necessarily values of quantities of the same kind.

### 3.1.10

#### **measurement result**

#### **result of measurement**

set of quantity values attributed to a measurand together with any other available relevant information

Note 1 to entry: A measuring result can refer to

- the indication,
- the uncorrected result, or



— the corrected result.

A measurement result is generally expressed as a single measured quantity value and a measurement uncertainty.

### 3.1.11

#### **measured quantity value**

quantity value representing a measurement result

### 3.1.12

#### **error**

#### **error of measurement**

#### **measurement error**

measured quantity value minus a reference quantity value

### 3.1.13

#### **random measurement error**

#### **random error**

component of measurement error that in replicate measurements varies in an unpredictable manner

Note 1 to entry: Random measurement errors of a set of replicate measurements form a distribution that can be summarized by its expectation, which is generally assumed to be zero, and its variance.

### 3.1.14

#### **systematic error**

#### **systematic error of measurement**

component of measurement error that in replicate measurements remains constant or varies in a predictable manner

Note 1 to entry: Systematic error, and its causes, can be known or unknown. A correction can be applied to compensate for a known systematic measurement error.

## 3.2 Terms specific to this part of ISO 17123

### 3.2.1

#### **accuracy of measurement**

closeness of agreement between a measured quantity value and the true value of the measurand

Note 1 to entry: "Accuracy" is a qualitative concept and cannot be expressed in a numerical value.

Note 2 to entry: "Accuracy" is inversely related to both systematic error and random error.

### 3.2.2

#### **experimental standard deviation**

estimate of the standard deviation of the relevant distribution of the measurements

Note 1 to entry: The experimental standard deviation is a measure of the uncertainty due to random effects.

Note 2 to entry: The exact value arising in these effects cannot be known. The value of the experimental standard deviation is normally estimated by statistical methods.

### 3.2.3

#### **precision**

#### **measurement precision**

closeness of agreement between measured quantity values obtained by replicate measurements on the same or similar objects under specified conditions

Note 1 to entry: Measurement precision is usually expressed by measures of imprecision, such as experimental standard deviation under specified conditions of measurement.

### 3.2.4

#### **repeatability condition**

#### **repeatability condition of measurement**

condition of measurement, out of a set of conditions

Note 1 to entry: Conditions of measurement include

- the same measurement procedure,
- the same observer(s),
- the same measuring system,
- the same meteorological conditions,
- the same location, and
- replicate measurements on the same or similar objects over a short period of time.

### 3.2.5

#### **repeatability**

#### **measurement repeatability**

measurement precision under a set of repeatability conditions of measurement

### 3.2.6

#### **reproducibility conditions of measurement**

condition of measurement, out of a set of conditions

Note 1 to entry: Conditions of measurement include

- different locations,
- different observers,
- different measuring systems, and
- replicate measurements on the same or similar objects.

### 3.2.7

#### **reproducibility**

#### **measurement reproducibility**

measurement precision under reproducibility conditions of measurement

### 3.2.8

#### **influence quantity**

quantity, which in a direct measurement does not affect the quantity that is actually measured, but affects the relation between the indication of a measuring system and the measurement result

EXAMPLE Temperature during the length measurement by an electronic tacheometer.

### 3.3 The term “uncertainty”

#### 3.3.1

##### **uncertainty**

##### **uncertainty of measurement**

##### **measurement uncertainty**

non-negative parameter characterizing the dispersion of quantity values attributed to a measurand, based on the information used

Note 1 to entry: Measurement uncertainty comprises, in general, many components. Some of these components can be evaluated by a Type A evaluation of measurement uncertainty from the statistical distribution of the quantity values from series of measurements and can be characterized by an experimental standard deviation. The other components, which can be evaluated by a Type B evaluation of measurement uncertainty, can also be characterized by an approximation to the corresponding standard deviations, evaluated from assumed probability distributions based on experience or other information.

#### 3.3.2

##### **Type A evaluation**

##### **Type A evaluation of measurement uncertainty**

evaluation of a component of measurement uncertainty (standard uncertainty) by a statistical analysis of quantity values obtained by measurements under defined measurement conditions

Note 1 to entry: For information about statistical analysis, see [4.1](#) and ISO/IEC Guide 98-3.

#### 3.3.3

##### **Type B evaluation of measurement uncertainty**

evaluation of a component of measurement uncertainty (standard uncertainty) determined by means other than a Type A evaluation of measurement uncertainty

EXAMPLE The component of measurement uncertainty can be based on

- previous measurement data,
- experience with, or general knowledge of, the behaviour and property of relevant instruments or materials,
- manufacturer’s specifications,
- data provided in calibration and other reports,
- uncertainties assigned to reference data taken from handbooks, and
- limits deduced through personal experiences.

Note 1 to entry: For more information see [4.3](#) and ISO/IEC Guide 98-3.

#### 3.3.4

##### **standard uncertainty**

##### **standard uncertainty of measurement**

##### **standard measurement uncertainty**

measurement uncertainty expressed as a standard deviation

Note 1 to entry: Standard uncertainty can be estimated either by a Type A evaluation or by a Type B evaluation.

#### 3.3.5

##### **combined standard uncertainty**

##### **combined standard measurement uncertainty**

standard (measurement) uncertainty, obtained by using the individual standard uncertainties (and covariances as appropriate), associated with the input quantities in a measurement model

Note 1 to entry: The procedure for combining standard uncertainties is often called the “law of propagation of uncertainties” and in common parlance the “root-sum-of-squares” (RSS) method.

**3.3.6**

**coverage factor**

numerical factor larger than one, used as a multiplier of the (combined) standard uncertainty in order to obtain the expanded uncertainty

Note 1 to entry: The coverage factor, which is typically in the range of 2 to 3, is based on the coverage probability or level of confidence required of the interval.

**3.3.7**

**expanded uncertainty**

**expanded measurement uncertainty**

half-width of a symmetric coverage interval, centred around the estimate of a quantity with a specific coverage probability

Note 1 to entry: A fraction can be viewed as the coverage probability or level of confidence of the interval.

**3.3.8**

**coverage interval**

interval containing the set of true quantity values of a measurand with a stated probability, based on the information available

Note 1 to entry: It is intended that a coverage interval not be termed “confidence interval” in order to avoid confusion with the statistical concept. To associate an interval with a specific level of confidence requires explicit or implicit assumptions regarding the probability distribution, characterized by the measurement result.

**3.3.9**

**coverage probability**

probability that the set of true quantity values of a measurand is contained within a specific coverage interval

Note 1 to entry: The probability is sometimes termed “level of confidence” (see ISO/IEC Guide 98-3).

**3.3.10**

**uncertainty budget**

statement of a measurement uncertainty, of the components of that measurement uncertainty, and of their calculation and combination

Note 1 to entry: It is intended that an uncertainty budget include the measurement model, estimates, measurement uncertainties associated with the quantities in the measurement model, type of applied probability density functions and type of evaluation of measurement uncertainty.

**3.3.11**

**measurement model**

mathematical relation among all quantities known to be involved in a measurement

**3.4 Symbols**

**Table 1 — Symbols and definitions**

$a$	Half-width of a rectangular distribution of possible values of input quantity $X_i$ ; $a = (a_+ - a_-)/2$
$a_+$	Upper bound or upper limit of input quantity $X_i$
$a_-$	Lower bound or lower limit of input quantity $X_i$
$A$	Design or Jacobian matrix ( $N \times n$ )
$c_i$	Partial derivatives or sensitive coefficient: $c_i = \frac{\partial f}{\partial x_i}$ ( $i = 1, 2, \dots, N$ )
$c$	Vector of sensitive coefficients $c_i$ ( $i = 1, 2, \dots, N$ )
$e$	Unit vector