

## SLOVENSKI STANDARD SIST ISO/TS 14253-2:2002

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Geometrical Product Specifications (GPS) -- Inspection by measurement of workpieces and measuring equipment -- Part 2: Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification iTeh STANDARD PREVIEW

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Spécification géométrique des produits (GPS) Vérification par la mesure des pièces et des équipements de mesure -- Partie 2 Guide pour l'estimation de l'incertitude dans les mesures GPS, dans l'étalonnage des équipements de mesure et dans la vérification des produits

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17.040.20 Lastnosti površin Properties of surfaces

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# TECHNICAL SPECIFICATION

ISO/TS 14253-2

First edition 1999-12-01

Geometrical Product Specifications (GPS) — Inspection by measurement of workpieces and measuring equipment —

### Part 2:

Guide to the estimation of uncertainty

iTeh gin GRS measurement, in calibration

of measuring equipment and in product

verification

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https://standards.iSpécification.géométrique des produits (GPS) — Vérification par la mesure des pièces et des équipements de mesure —

Partie 2: Guide pour l'estimation de l'incertitude dans les mesures GPS, dans l'étalonnage des équipements de mesure et dans la vérification des produits



Reference number ISO/TS 14253-2:1999(E)

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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

In other circumstances, particularly when there is an urgent market requirement for such documents, a technical committee may decide to publish other types of normative document:

- an ISO Publicly Available Specification (ISO/PAS) represents an agreement between technical experts in an ISO working group and is accepted for publication if it is approved by more than 50 % of the members of the parent committee casting a vote:
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- an ISO Technical Specification (ISO/TS) represents an agreement between the members of a technical committee and is accepted for publication if it is approved by 2/3 of the members of the committee casting a vote.

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An ISO/PAS or ISO/TS is reviewed every three years with adview to deciding whether it can be transformed into an International Standard. 980c22f2ed97/sist-iso-ts-14253-2-2002

Attention is drawn to the possibility that some of the elements of this Technical Specification may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO/TS 14253-2 was prepared by Technical Committee ISO/TC 213, *Dimensional and geometrical product specifications and verification*.

ISO 14253 consists of the following parts, under the general title *Geometrical product specifications (GPS)*—
Inspection by measurement of workpieces and measuring equipment:

- Part 1: Decision rules for proving conformance or non-conformance with specification
- Part 2: Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification [Technical Specification]
- Part 3: Procedures for evaluating the integrity of uncertainty in measurement values

Annexes A to D of this Technical Specification are for information only.

#### Introduction

This Technical Specification is a global GPS technical report (see ISO/TR 14638:1995). This global GPS Technical Report influences chain link 4, 5 and 6 in all chains of standards.

For more detailed information of the relation of this report to other standards and the GPS matrix model, see annex D.

This Technical Specification is developed to support ISO 14253-1. This Technical Specification establishes a simplified, iterative procedure of the concept and the way to evaluate and determine uncertainty (standard uncertainty and expanded uncertainty) of measurement, and the recommendations of the format to document and report the uncertainty of measurement information as given in "Guide to the expression of uncertainty in measurement" (GUM). In most cases only very limited resources are necessary to estimate uncertainty of measurement by this simplified, iterative procedure, but the procedure may lead to a slight overestimation of the uncertainty of measurement. If a more accurate estimation of the uncertainty of measurement is needed, the more elaborated procedures of the GUM must be applied.

This simplified, iterative procedure of the GUM methods is intended for GPS measurements, but may be used in other areas of industrial (applied) metrology.

Uncertainty of measurement and the concept of handling uncertainty of measurement being of importance to all the technical functions in a company, this Technical Specification relates to e.g. management function, design and development function, manufacture function, quality assurance function, metrology function, etc.

This Technical Specification is of special importance in relation to ISO 9000 quality assurance systems, where it is a requirement that the uncertainty of measurement is a requirement is a requirement that the uncertainty of measurement is a requirement in the uncertainty of measurement is a requirement that the uncertainty of measurement is a requirement in the uncertainty of measurement in the uncertainty of measurement is a requirement in the uncertainty of measurement is a requirement in the uncertainty of measurement in t

In this Technical Specification the uncertainty of the result of a process of calibration and a process of measurement is handled in the same way:

- calibration is treated as "measurement of metrological characteristics of a measuring equipment or a measurement standard";
- measurement is treated as "measurement of geometrical characteristics of a workpiece".

Therefore, in most cases no distinction is made in the text between measurement and calibration. The term "measurement" is used as a synonym for both.

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## Geometrical product specifications (GPS) — Inspection by measurement of workpieces and measuring equipment —

### Part 2:

Guide to the estimation of uncertainty in GPS measurement, in calibration of measuring equipment and in product verification

#### 1 Scope

This Technical Specification gives guidance on the implementation of the concept of "Guide to the estimation of uncertainty in measurement" (in short GUM) to be applied in industry for the calibration of (measurement) standards and measuring equipment in the field of GPS and the measurement of workpiece GPS-characteristics. The aim is to promote full information on how to achieve uncertainty statements and provide the basis for international comparison of results of measurements and their uncertainties (relationship between purchaser and supplier).

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This Technical Specification is intended to support ISO 14253-1. This Technical Specification and ISO 14253-1 are beneficial to all technical functions in a company in the interpretation of GPS specifications (i.e. tolerances of workpiece characteristics and values of maximum permissible errors (MPE) for metrological characteristics of measuring equipment).

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This Technical Specification introduces the Procedure for Uncertainty MAnagement (PUMA), which is a practical, iterative procedure based on the GUM for estimating uncertainty of measurement without changing the basic concepts of the GUM and is intended to be used generally for estimating uncertainty of measurement and giving statements of uncertainty for:

- single results of measurement;
- comparison of two or more results of measurement;
- comparison of results of measurement from one or more workpieces or pieces of measurement equipment
   with given specifications [i.e. maximum permissible errors (MPE) for a metrological characteristic of a measurement instrument or measurement standard, and tolerance limits for a workpiece characteristic, etc.], for proving conformance or non-conformance with the specification.

The iterative method is based basically on an upper bound strategy, i.e. overestimation of the uncertainty at all levels, but the iterations control the amount of overestimation. Intentional overestimation — and not underestimation — is necessary to prevent wrong decisions based on measurement results. The amount of overestimation shall be controlled by economical evaluation of the situation.

The iterative method is a tool to maximize profit and minimize cost in the metrological activities of a company. The iterative method/procedure is economically self-adjusting and is also a tool to change/reduce existing uncertainty in measurement with the aim of reducing cost in metrology (manufacture). The iterative method makes it possible to compromise between risk, effort and cost in uncertainty estimation and budgeting.

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#### 2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this Technical Specification. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this Technical Specification are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 1:1975, Standard reference temperature for industrial length measurements.

ISO 4288:1996, Geometrical Product Specifications (GPS) — Surface texture: Profile method — Rules and procedures for the assessment of surface texture.

ISO 9001:1994, Quality systems — Model for quality systems in design, development, production, installation and servicing.

ISO 9004-1:1994, Quality management and quality system elements — Part 1: Guidelines.

ISO 14253-1:1998, Geometrical Product Specification (GPS) — Inspection by measurement of workpieces and measuring instruments — Part 1: Decision rules for proving conformance or non-conformance with specifications.

ISO 14253-3:—<sup>1)</sup>, Geometrical Product Specification (GPS) — Inspection by measurement of workpieces and measuring instruments — Part 3: Procedures for evaluating the integrity of uncertainty of measurement values.

ISO 14660-1:1999, Geometrical Product Specification (GPS) — Geometric features — Part 1: General terms and definitions.

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Guide to the expression of uncertainty in measurement (GUM). BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1st edition, 1995.

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International Vocabulary of Basic and General Terms in Metrology (VIM), BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 2nd edition, 1993.

#### 3 Terms and definitions

For the purposes of this Technical Specification, the terms and definitions given in ISO 14253-1, ISO 14660-1, VIM, GUM and the following apply.

#### 3.1

#### black box model for uncertainty estimation

method of/model for uncertainty estimation in which the output value of a measurement is obtained in the same unit as the input (stimuli), rather than by measurement of other quantities functionally related to the measurand

NOTE 1 In the black box model — in this Technical Specification — the uncertainty components are assumed additive, the influence quantities is transformed to the unit of the measurand and the sensitivity coefficients are equal to 1.

NOTE 2 In many cases a complex method of measurement may be looked upon as one simple black box with stimulus in and result out from the black box. When a black box is opened, it may turn out to contain several "smaller" black boxes and/or several transparent boxes.

NOTE 3 The method of uncertainty estimation remains a black box method even if it is necessary to make supplementary measurements to determine the values of influence quantities in order to make corresponding corrections.

<sup>1)</sup> To be published.

#### 3.2

#### transparent box model for uncertainty estimation

method of/model for uncertainty estimation in which the value of a measurand is obtained by measurement of other quantities functionally related to the measurand

#### 3.3

#### measuring task

quantification of a measurand according to its definition

#### 3.4

#### basic measurement task (basic measurement)

measurement task(s) which form the basis for evaluation of more complicated characteristics of a workpiece or a measuring equipment

NOTE Examples of a basic measurement are:

- a) one of several individual measurements of the deviation from straightness of a feature of a workpiece;
- b) one of the individual measurements of error of indication of a micrometer when measuring the range of error of indication.

#### 3.5

#### overall measurement task

complicated measuring task, which is evaluated on the basis of several and maybe different basic measurements

NOTE Examples of an overall measuring task are:

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a) the measurement of straightness of a feature of a workpiece;

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b) the range of error of indication of a micrometer.

## **3.6** SIST ISO/TS 14253-2:2002

expanded uncertainty (of a measurement) (catalog/standards/sist/1e3fa4e9-0244-4324-9b10-

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[3.16 of ISO 14253-1:1998 and 2.3.5 of GUM:1995]

NOTE *U* (capital) always indicates expanded uncertainty of measurement.

#### 3.7

#### true uncertainty

 $U_{\mathsf{A}}$ 

uncertainty of measurement that would be obtained by a perfect uncertainty estimation

NOTE 1 True uncertainties are by nature indeterminate.

NOTE 2 See also 8.8.

#### 3.8

#### conventional true uncertainty — GUM uncertainty

 $U_{c}$ 

uncertainty of measurement estimated completely according to the more elaborate procedures of GUM

NOTE 1 The conventional true uncertainty of measurement may differ from an uncertainty of measurement estimated according to this Technical Specification.

NOTE 2 See also 8.8.

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#### 3.9

#### approximated uncertainty

 $U_{\mathsf{E}N}$ 

uncertainty of measurement estimated by the simplified, iterative method

NOTE 1 The index N indicates that  $U_{\mathsf{E}N}$  is assessed by iteration number N. The designation  $U_{\mathsf{E}}$  may be used without indication of the iteration number, when it is without importance to know the number of iterations.

NOTE 2 See also 8.8.

#### 3.10

#### target uncertainty (for a measurement or calibration)

 $U_{\mathsf{T}}$ 

uncertainty determined as the optimum for the measuring task

NOTE 1 Target uncertainty is the result of a management decision involving e.g. design, manufacturing, quality assurance, service, marketing, sales and distribution.

NOTE 2 Target uncertainty is determined (optimized) taking into account the specification [tolerance or maximum permissible error (MPE)], the process capability, cost, criticality and the requirements of 4.11.1, 4.11.2 of ISO 9001:1994, 13.1 of ISO 9004-1:1994 and ISO 14253-1.

NOTE 3 See also 8.8.

#### 3.11

## required uncertainty of measurement STANDARD PREVIEW

 $U_{\mathsf{R}}$ 

uncertainty required for a given measurement process and task teh.ai)

NOTE See also 6.2. The required uncertainty may be specified by, for example, a customer.

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#### 3.12 mups

using uncertainty budgeting techniques

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process of deriving an adequate measurement procedure from the measuring task and the target uncertainty by

#### 3.13

#### uncertainty budget (for a measurement or calibration)

statement summarizing the estimation of the uncertainty components that contributes to the uncertainty of a result of a measurement

NOTE 1 The uncertainty of the result of the measurement is unambiguous only when the measurement procedure (including the measurement object, measurand, measurement method and conditions) is defined.

NOTE 2 The term "budget" is used for the assignment of numerical values to the uncertainty components, their combination and expansion, based on the measurement procedure, measurement conditions and assumptions.

#### 3.14

#### uncertainty contributor

хx

source of uncertainty of measurement for a measuring process

#### 3.15

#### limit value (variation limit) for an uncertainty contributor

 $a_{xx}$ 

absolute value of the extreme value(s) of the uncertainty contributor, xx

#### 3.16

#### uncertainty component

 $u_{r}$ 

standard uncertainty of the uncertainty contributor, xx

NOTE The iteration method uses the designation  $u_{xx}$  for all uncertainty components. This is not consistent with the present version of GUM which sometimes uses the designation  $s_{xx}$  for uncertainty components evaluated by A evaluation and the designation  $u_{xx}$  for uncertainty components evaluated by B evaluation.

#### 3.17

#### influence quantity of a measurement instrument

characteristic of a measuring instrument that affects the result of a measurement performed by the instrument

#### 3.18

#### influence quantity of a workpiece

characteristic of a workpiece that affects the result of a measurement performed on that workpiece

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## 4 Symbols

For the purposes of this Technical Specification, the generic symbols given in Table 1 apply.

Table 1 — Generic symbols

a         limit value for a distribution           a <sub>xx</sub> limit value for an error or uncertainty contributor (in the unit of the result of measurement, of the measurand)           a*xxx         limit value for an error or uncertainty contributor (in the unit of the influence quantity)           a         linear coefficient of thermal expansion           b         coefficient for transformation of a <sub>xx</sub> to u <sub>xx</sub> .           C         correction (value)           d         resolution of a measurement equipment           E         Young's modulus           ER         error (value of a measurement)           G         function of several measurement values [G(X <sub>1</sub> , X <sub>2</sub> ,, X <sub>i</sub> ,)]           h         hysteresis value           k         coverage factor           m         number of standard deviations in the half of a confidence interval           MR         measurement result (value)           n         number of standard deviations in the half of a confidence interval           MR         measurement result (value)           n         number of standard deviations and the half of a confidence interval           MR         measurement result (value)           n         number of tentations the half of a confidence interval           n         number of confidence result (value)           n<	Symbol	Description
a*xx       limit value for an error or uncertainty contributor (in the unit of the influence quantity)         α       linear coefficient of thermal expansion         b       coefficient for transformation of axx to axx         C       correction (value)         d       resolution of a measurement equipment         E       Young's modulus         ER       error (value of a measurement)         G       function of several measurement values [G(X₁, X₂, Xρ,)]         h       hysteresis value         k       coverage factor         m       number of standard deviations in the half of a confidence interval         MR       measurement result (value)         n       number of standard deviations in the half of a confidence interval         N       number of standard stand	а	limit value for a distribution
$\begin{array}{c} a^*_{xx} & \text{limit value for an error or uncertainty contributor (in the unit of the influence quantity)} \\ a & \text{linear coefficient of thermal expansion} \\ b & \text{coefficient for transformation of } a_{xx} \text{ to } u_{xx} \\ C & \text{correction (value)} \\ d & \text{resolution of a measurement equipment} \\ E & \text{Young's modulus} \\ ER & \text{error (value of a measurement)} \\ G & \text{function of several measurement values} [G(X_1, X_2, \dots, X_i, \dots)] \\ h & \text{hysteresis value} \\ k & \text{coverage factor} \\ m & \text{number of standard deviations in the half of a confidence interval} \\ MR & \text{measurement result (value)} \\ n & \text{number of iterations} \\ V & \text{Poisson's number} \\ p & \text{number of iterations} \\ V & \text{Poisson's number} \\ r & \text{number of total uncorrelated uncertainty contributors} \\ r & \text{number of total orrelated uncertainty contributors} \\ r & \text{number of total uncorrelated uncertainty contributors} \\ r & \text{number of total uncorrelated uncertainty contributors} \\ r & \text{number of total uncorrelated uncertainty contributors} \\ r & \text{number of total uncorrelated uncertainty contributors} \\ r & \text{number of total uncorrelated uncertainty contributors} \\ r & \text{number of total uncertainty (standard deviation)} \\ s_{x} & \text{standard duncertainty (standard deviation)} \\ s_{x} & \text{standard deviation of a sample} \\ s_{\overline{x}} & \text{standard deviation of a nean value of a sample} \\ u_{c} & \text{combined standard uncertainty of measurement} \\ U & \text{expanded uncertainty of measurement} \\ U & \text{expanded uncertainty of measurement} \\ U_{c} & \text{conventional true uncertainty of measurement} \\ U_{E} & \text{approximated uncertainty of measurement} \\ U_{E} & \text{approximated uncertainty of measurement} \\ U_{T} & \text{target uncertainty} \\ U_{$	$a_{xx}$	limit value for an error or uncertainty contributor (in the unit of the result of measurement, of the measurand)
b coefficient for transformation of $a_{xx}$ to $u_{xx}$ C correction (value)  d resolution of a measurement equipment  E Young's modulus  ER error (value of a measurement)  G function of several measurement values [ $G(X_1, X_2, X_p,)$ ]  h hysteresis value  k coverage factor  m number of standard deviations in the half of a confidence interval  MR measurement result (value)  n number of  N number of iterations  P number of total uncorrelated uncertainty contributors  p number of total ourcrelated uncertainty contributors  p correlation coefficient  TV true value of a measurement $a_{xx} = a_{xx} = a_{xx$		limit value for an error or uncertainty contributor (in the unit of the influence quantity)
C correction (value)  d resolution of a measurement equipment  E Young's modulus  ER error (value of a measurement)  G function of several measurement values [G(X1, X2, Xp,)]  h hysteresis value  k coverage factor  m number of standard deviations in the half of a confidence interval  MR measurement result (value)  n number of  N number of iterations CL STANDARD PREVIEW  v Poisson's number  p number of total correlated uncertainty contributors  r number of total correlated uncertainty contributors  r number of total correlated uncertainty contributors  p correlation coefficient  u, u, u, standard uncertainty (standard deviation)  s²x standard deviation of a sample  s³x standard deviation of a mean value of a sample  uc combined standard uncertainty contributor .xx — uncertainty component  U expanded uncertainty of measurement  UA true uncertainty of measurement  UC conventional true uncertainty of measurement  UC conventional true uncertainty of measurement  UE approximated uncertainty  UR required uncertainty  UR approximated uncertainty  UR measurement result (uncorrected)  Xi measurement result (uncorrected)	α	linear coefficient of thermal expansion
d	b	coefficient for transformation of $a_{xx}$ to $u_{xx}$
ER error (value of a measurement)  G function of several measurement values [G(X <sub>1</sub> , X <sub>2</sub> ,X <sub>i</sub> ,)]  h hysteresis value  k coverage factor  m number of standard deviations in the half of a confidence interval  MR measurement result (value)  n number of  N number of iterations Ch STANDARD PREVYEW  v Poisson's number  p number of total uncorrelated uncertainty contributors  r number of total uncorrelated uncertainty contributors  r number of total correlated uncertainty contributors  r number of total correlated uncertainty contributors  γ correlation coefficient  TV true value of a measurement (standard deviation)  s <sub>X</sub> standard uncertainty (standard deviation)  s <sub>X</sub> standard deviation of a sample  v <sub>c</sub> combined standard uncertainty  u <sub>XX</sub> standard deviation of an ean value of a sample  u <sub>C</sub> combined standard uncertainty contributor xx — uncertainty component  U expanded uncertainty of measurement  U <sub>A</sub> true uncertainty of measurement  U <sub>C</sub> conventional true uncertainty of measurement  U <sub>E</sub> approximated uncertainty of measurement (number of iteration not stated)  U <sub>E</sub> approximated uncertainty  U <sub>R</sub> required uncertainty  U <sub>Y</sub> uncertainty  U <sub>Y</sub> uncertainty  uncertainty value (not estimated according to GUM or this Technical Specification)  X measurement result (in the transparent box model of uncertainty estimation)	С	correction (value)
ER error (value of a measurement)  G function of several measurement values [G(X1, X2, Xμ,)]  h hysteresis value  k coverage factor  number of standard deviations in the half of a confidence interval  MR measurement result (value)  n number of  N number of iterations TEN STANDARD PREVIEW  γ Poisson's number  ρ number of total uncorrelated uncertainty contributors  γ number of total correlated uncertainty contributors  γ number of total correlated uncertainty contributors  γ correlation coefficient  TV true value of a measurement γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ γ	d	resolution of a measurement equipment
G       function of several measurement values [G(X1, X2, Xp,)]         h       hysteresis value         k       coverage factor         m       number of standard deviations in the half of a confidence interval         MR       measurement result (value)         n       number of         N       number of iterations Ten STANDARD PREVIEW         ν       Poisson's number         p       number of total uncorrelated uncertainty contributors         r       number of total uncorrelated uncertainty contributors         r       number of total correlated uncertainty contributors         ρ       correlation coefficient       Standard standard uncertainty (standard deviation)         true value of a measurement       standard standard uncertainty (standard deviation)         s <sub>x</sub> standard deviation of a sample         u <sub>c</sub> combined standard uncertainty         u <sub>xx</sub> standard deviation of a mean value of a sample         u <sub>c</sub> combined standard uncertainty         u <sub>xx</sub> standard deviation of uncertainty contributor xx — uncertainty component         U <sub>x</sub> true uncertainty of measurement         U <sub>x</sub> conventional true uncertainty of measurement (number of iteration not stated)         U <sub>E</sub> approximated uncertainty<	E	Young's modulus
h         hysteresis value           k         coverage factor           m         number of standard deviations in the half of a confidence interval           MR         measurement result (value)           n         number of           N         number of iterations           V         Poisson's number           p         number of total uncorrelated uncertainty contributors           r         number of total correlated uncertainty contributors           r         number of total correlated uncertainty contributors           r         number of total correlated uncertainty contributors           ρ         correlation coefficient           TV         true value of a measurement           u, u, u         standard of a measurement is standard deviation of a measurement (standard deviation)           s̄x         standard deviation of a mean value of a sample           ūc         combined standard uncertainty contributor xx — uncertainty component           Ūc         expanded uncertainty of measurement           Ūc         conventional true uncertainty of measurement           Ūc         conventional true uncertainty of measurement           Ūc         approximated uncertainty of measurement (number of iteration not stated)           Ūc         approximated uncertainty	ER	error (value of a measurement)
k         coverage factor           m         number of standard deviations in the half of a confidence interval           MR         measurement result (value)           n         number of           N         number of iterations         Ten of total control tent of total uncorrelated uncertainty contributors           p         number of total correlated uncertainty contributors           r         number of total correlated uncertainty contributors           ρ         correlation coefficient         Stall 18/15/15/14253-2-2002           p         correlation coefficient         Stall 18/15/15/14253-2-2002           u, u, u, or alunder of a measurement of the interval of a measurement of the interval of a measurement of a sample         standard uncertainty (standard deviation)           s <sub>x</sub> standard deviation of a sample           u <sub>c</sub> combined standard uncertainty           u <sub>x</sub> standard deviation of uncertainty contributor xx — uncertainty component           U         expanded uncertainty of measurement           U <sub>A</sub> true uncertainty of measurement           U <sub>C</sub> conventional true uncertainty of measurement           U <sub>E</sub> approximated uncertainty of measurement (number of iteration number N           U <sub>E</sub> approximated uncertainty           U <sub>T</sub> target uncerta	G	function of several measurement values $[G(X_1, X_2,, X_i,)]$
m number of standard deviations in the half of a confidence interval  MR measurement result (value)  n number of  N number of iterations  v Poisson's number  p number of total uncorrelated uncertainty contributors  r number of total correlated uncertainty contributors  r number of total correlated uncertainty contributors  r number of total correlated uncertainty contributors  p correlation coefficient  TV true value of a measurement 000.229.0407/sixt. iso ts. 14253-2.2002  u, u <sub>i</sub> standard uncertainty (standard deviation)  s <sub>x</sub> standard deviation of a sample  s <sub>x</sub> standard deviation of a mean value of a sample  u <sub>c</sub> combined standard uncertainty  u <sub>xx</sub> standard deviation of uncertainty contributor xx — uncertainty component  U expanded uncertainty of measurement  U <sub>A</sub> true uncertainty of measurement  U <sub>C</sub> conventional true uncertainty of measurement  U <sub>E</sub> approximated uncertainty of measurement (number of iteration not stated)  U <sub>EN</sub> approximated uncertainty  U <sub>R</sub> required uncertainty  U <sub>R</sub> required uncertainty  U <sub>V</sub> uncertainty value (not estimated according to GUM or this Technical Specification)  X measurement result (in the transparent box model of uncertainty estimation)	h	hysteresis value
MR number of  N number of iterations  V Poisson's number  p number of total correlated uncertainty contributors  r number of total correlated uncertainty contributors  p correlation coefficient	k	coverage factor
n       number of         N       number of iterations         ν       Poisson's number         ρ       number of total uncorrelated uncertainty contributors         r       number of total correlated uncertainty contributors         ρ       correlation coefficient         TV       true value of a measurement         u, u₁       standard uncertainty (standard deviation)         s₂x       standard deviation of a sample         s₂x       standard deviation of a mean value of a sample         uc       combined standard uncertainty         uxx       standard deviation of uncertainty contributor xx — uncertainty component         U       expanded uncertainty of measurement         UA       true uncertainty of measurement         UC       conventional true uncertainty of measurement         UE       approximated uncertainty of measurement (number of iteration not stated)         UEN       approximated uncertainty         UR       required uncertainty         UR       required uncertainty         UV       uncertainty         UV       uncertainty         Ux       uncertainty value (not estimated according to GUM or this Technical Specification)         X       measurement result (uncorrected)	m	number of standard deviations in the half of a confidence interval
N       number of iterations         ν       Poisson's number         ρ       number of total uncorrelated uncertainty contributors         r       number of total correlated uncertainty contributors         ρ       correlation coefficient         TV       true value of a measurement       operation of the incomplex standard variety (estandard deviation)         s <sub>x</sub> standard uncertainty (standard deviation)         s <sub>x</sub> standard deviation of a sample         σ <sub>x</sub> standard deviation of a mean value of a sample         u <sub>c</sub> combined standard uncertainty         u <sub>xx</sub> standard deviation of uncertainty contributor xx — uncertainty component         U       expanded uncertainty of measurement         U <sub>A</sub> true uncertainty of measurement         U <sub>C</sub> conventional true uncertainty of measurement         U <sub>E</sub> approximated uncertainty of measurement (number of iteration not stated)         U <sub>EN</sub> approximated uncertainty         U <sub>R</sub> required uncertainty         U <sub>T</sub> target uncertainty         U <sub>V</sub> uncertainty value (not estimated according to GUM or this Technical Specification)         X       measurement result (uncorrected)         X <sub>i</sub> measurement result (in the transparent box model of uncertainty esti	MR	measurement result (value)
ν       Poisson's number         p       number of total uncorrelated uncertainty contributors         r       number of total correlated uncertainty contributors         ρ       correlation coefficient         ITV       true value of a measurement       SIST ISO IS 14233-2-2002         u, u, u, and it is standard uncertainty (standard deviation)       standard uncertainty (standard deviation)         s̄x and standard deviation of a sample         v <sub>x</sub> and standard deviation of a mean value of a sample         u <sub>c</sub> combined standard uncertainty         u <sub>xx</sub> and deviation of uncertainty contributor xx — uncertainty component         U expanded uncertainty of measurement         U <sub>A</sub> true uncertainty of measurement         U <sub>C</sub> conventional true uncertainty of measurement         U <sub>E</sub> approximated uncertainty of measurement (number of iteration not stated)         U <sub>EN</sub> approximated uncertainty         U <sub>R</sub> required uncertainty         U <sub>R</sub> target uncertainty         U <sub>V</sub> uncertainty value (not estimated according to GUM or this Technical Specification)         X measurement result (uncorrected)         X <sub>i</sub> measurement result (in the transparent box model of uncertainty estimation)	n	number of
$\begin{array}{c} r \\ \rho \\ correlation coefficient \\ TV \\ true value of a measurement \\ QSDC27Dcd07/sist iso to 14253-2-2002 \\ U, u_i \\ istandard uncertainty (standard deviation) \\ \hline s_x \\ standard deviation of a sample \\ \hline s_{\overline{x}} \\ standard deviation of a mean value of a sample \\ u_c \\ combined standard uncertainty \\ u_{xx} \\ standard deviation of uncertainty contributor xx — uncertainty component \\ U \\ expanded uncertainty of measurement \\ U_A \\ true uncertainty of measurement \\ U_C \\ conventional true uncertainty of measurement (number of iteration not stated) \\ U_{EN} \\ approximated uncertainty of measurement of iteration number N U_R \\ required uncertainty \\ U_T \\ target uncertainty \\ U_V \\ uncertainty value (not estimated according to GUM or this Technical Specification) \\ X \\ measurement result (in the transparent box model of uncertainty estimation) \\ \hline \end{array}$	N	
$\begin{array}{c} r \\ \rho \\ correlation coefficient \\ TV \\ true value of a measurement \\ QSDC27Dcd07/sist iso to 14253-2-2002 \\ U, u_i \\ istandard uncertainty (standard deviation) \\ \hline s_x \\ standard deviation of a sample \\ \hline s_{\overline{x}} \\ standard deviation of a mean value of a sample \\ u_c \\ combined standard uncertainty \\ u_{xx} \\ standard deviation of uncertainty contributor xx — uncertainty component \\ U \\ expanded uncertainty of measurement \\ U_A \\ true uncertainty of measurement \\ U_C \\ conventional true uncertainty of measurement (number of iteration not stated) \\ U_{EN} \\ approximated uncertainty of measurement of iteration number N U_R \\ required uncertainty \\ U_T \\ target uncertainty \\ U_V \\ uncertainty value (not estimated according to GUM or this Technical Specification) \\ X \\ measurement result (in the transparent box model of uncertainty estimation) \\ \hline \end{array}$	ν	Poisson's number (standards itch ai)
ρ       correlation coefficient       SIST ISO/IS 1423-2-2002         TV       true value of a measurement 080-229-2007/sist-iso-ts-14253-2-2002         u, u <sub>i</sub> standard uncertainty (standard deviation)         s <sub>x</sub> standard deviation of a sample         u <sub>c</sub> combined standard uncertainty         u <sub>xx</sub> standard deviation of uncertainty contributor xx — uncertainty component         U       expanded uncertainty of measurement         U <sub>A</sub> true uncertainty of measurement         U <sub>C</sub> conventional true uncertainty of measurement         U <sub>E</sub> approximated uncertainty of measurement (number of iteration not stated)         U <sub>EN</sub> approximated uncertainty of measurement of iteration number N         U <sub>R</sub> required uncertainty         U <sub>T</sub> target uncertainty         U <sub>V</sub> uncertainty value (not estimated according to GUM or this Technical Specification)         X       measurement result (uncorrected)         X <sub>i</sub> measurement result (in the transparent box model of uncertainty estimation)	p	
TV true value of a measurement $\frac{1}{0}$ standard or $\frac{1}{0}$ standard uncertainty (standard deviation) $\frac{1}{0}$ standard deviation of a sample $\frac{1}{0}$ standard deviation of a mean value of a sample $\frac{1}{0}$ combined standard uncertainty $\frac{1}{0}$ uncertainty of measurement $\frac{1}{0}$ true uncertainty of measurement $\frac{1}{0}$ conventional true uncertainty of measurement $\frac{1}{0}$ approximated uncertainty of measurement (number of iteration not stated) $\frac{1}{0}$ approximated uncertainty $\frac{1}{0}$ approximated uncertainty $\frac{1}{0}$ true uncertainty of measurement of iteration number $\frac{1}{0}$ uncertainty $\frac{1}{0}$ true uncertainty $\frac{1}{0}$ approximated uncertainty $\frac{1}{0}$ uncertainty $\frac{1}{0}$ uncertainty $\frac{1}{0}$ uncertainty value (not estimated according to GUM or this Technical Specification) $\frac{1}{0}$ measurement result (uncorrected) $\frac{1}{0}$ measurement result (in the transparent box model of uncertainty estimation)	r	SIST ISO/TS 14253_22002
$u_i$ standard uncertainty (standard deviation) $s_x$ standard deviation of a mean value of a sample $u_c$ combined standard uncertainty $u_{xx}$ standard deviation of uncertainty contributor $xx$ — uncertainty component $U$ expanded uncertainty of measurement $U_A$ true uncertainty of measurement $U_C$ conventional true uncertainty of measurement $U_E$ approximated uncertainty of measurement (number of iteration not stated) $U_{EN}$ approximated uncertainty of measurement of iteration number $N$ $U_R$ required uncertainty $U_T$ target uncertainty $U_V$ uncertainty value (not estimated according to GUM or this Technical Specification) $X$ measurement result (uncorrected) $X_i$ measurement result (in the transparent box model of uncertainty estimation)		https://standards.itah.gu/ontalog/standards/gst/163ta/60.0044.4304.0h10
$\begin{array}{c} s_x \\ s_{\overline{x}} \\ \end{array}  \text{standard deviation of a sample} \\ u_c \\ u_c \\ \end{array}  \text{combined standard uncertainty} \\ u_{xx} \\ \end{array}  \text{standard deviation of uncertainty contributor } xx - \text{uncertainty component} \\ U \\ \text{expanded uncertainty of measurement} \\ U_A \\ \text{true uncertainty of measurement} \\ U_C \\ \text{conventional true uncertainty of measurement} \\ U_E \\ \text{approximated uncertainty of measurement (number of iteration not stated)} \\ U_{EN} \\ \text{approximated uncertainty of measurement of iteration number } N \\ U_R \\ \text{required uncertainty} \\ U_T \\ \text{target uncertainty} \\ U_V \\ \text{uncertainty value (not estimated according to GUM or this Technical Specification)} \\ X \\ \text{measurement result (uncorrected)} \\ X_i \\ \text{measurement result (in the transparent box model of uncertainty estimation)} \\ \end{array}$	TV	true value of a measurement 980c22f2ed97/sist-iso-ts-14253-2-2002
$ \begin{array}{c} s_{\overline{x}} \\ u_{c} \\ combined standard uncertainty \\ u_{xx} \\ standard deviation of uncertainty contributor xx — uncertainty component \\ U \\ expanded uncertainty of measurement \\ U_{A} \\ true uncertainty of measurement \\ U_{C} \\ conventional true uncertainty of measurement \\ U_{E} \\ approximated uncertainty of measurement (number of iteration not stated) \\ U_{EN} \\ approximated uncertainty of measurement of iteration number N N N N N N N N N N$	u, u <sub>i</sub>	standard uncertainty (standard deviation)
$\begin{array}{c} u_{\rm c} \\ \\ u_{xx} \\ \\ \end{array}  \text{standard deviation of uncertainty contributor } xx - \text{uncertainty component} \\ \\ U \\ \\ U \\ \\ \end{array}  \text{expanded uncertainty of measurement} \\ \\ U_{\rm A} \\ \\ \end{aligned}  \text{true uncertainty of measurement} \\ \\ U_{\rm C} \\ \\ \end{aligned}  \text{conventional true uncertainty of measurement} \\ \\ U_{\rm E} \\ \end{aligned}  \text{approximated uncertainty of measurement (number of iteration not stated)} \\ U_{\rm EN} \\ \end{aligned}  \text{approximated uncertainty of measurement of iteration number } N \\ U_{\rm R} \\ \end{aligned}  \text{required uncertainty} \\ U_{\rm T} \\ \end{aligned}  \text{target uncertainty} \\ U_{\rm V} \\ \end{aligned}  \text{uncertainty value (not estimated according to GUM or this Technical Specification)} \\ X \\ \end{aligned}  \text{measurement result (uncorrected)} \\ X_i \\ \end{aligned}  \text{measurement result (in the transparent box model of uncertainty estimation)} \\ \end{aligned}$	$S_{\chi}$	standard deviation of a sample
$\begin{array}{c} u_{xx} & \text{standard deviation of uncertainty contributor } xx - \text{uncertainty component} \\ U & \text{expanded uncertainty of measurement} \\ U_{A} & \text{true uncertainty of measurement} \\ U_{C} & \text{conventional true uncertainty of measurement} \\ U_{E} & \text{approximated uncertainty of measurement (number of iteration not stated)} \\ U_{EN} & \text{approximated uncertainty of measurement of iteration number } N \\ U_{R} & \text{required uncertainty} \\ U_{T} & \text{target uncertainty} \\ U_{V} & \text{uncertainty value (not estimated according to GUM or this Technical Specification)} \\ X & \text{measurement result (uncorrected)} \\ X_{i} & \text{measurement result (in the transparent box model of uncertainty estimation)} \\ \end{array}$	$S_{\overline{X}}$	standard deviation of a mean value of a sample
$ \begin{array}{c} U \\ U_{\rm A} \\ \end{array} \\ \begin{array}{c} \text{true uncertainty of measurement} \\ \\ U_{\rm C} \\ \end{array} \\ \begin{array}{c} \text{conventional true uncertainty of measurement} \\ \\ U_{\rm E} \\ \end{array} \\ \begin{array}{c} \text{approximated uncertainty of measurement (number of iteration not stated)} \\ \\ U_{\rm EN} \\ \end{array} \\ \begin{array}{c} \text{approximated uncertainty of measurement of iteration number } N \\ \\ U_{\rm R} \\ \end{array} \\ \begin{array}{c} \text{required uncertainty} \\ \\ U_{\rm T} \\ \end{array} \\ \begin{array}{c} \text{target uncertainty} \\ \\ U_{\rm V} \\ \end{array} \\ \begin{array}{c} \text{uncertainty value (not estimated according to GUM or this Technical Specification)} \\ \\ X \\ \end{array} \\ \begin{array}{c} \text{measurement result (uncorrected)} \\ \\ X_i \\ \end{array} \\ \begin{array}{c} \text{measurement result (in the transparent box model of uncertainty estimation)} \\ \end{array}$	$u_{c}$	combined standard uncertainty
$U_{\rm C}$ true uncertainty of measurement $U_{\rm C}$ conventional true uncertainty of measurement $U_{\rm E}$ approximated uncertainty of measurement (number of iteration not stated) $U_{\rm EN}$ approximated uncertainty of measurement of iteration number $N$ $U_{\rm R}$ required uncertainty $U_{\rm T}$ target uncertainty $U_{\rm V}$ uncertainty value (not estimated according to GUM or this Technical Specification) $X$ measurement result (uncorrected) $X_i$ measurement result (in the transparent box model of uncertainty estimation)	$u_{xx}$	standard deviation of uncertainty contributor $xx$ — uncertainty component
$U_{\rm C}$ conventional true uncertainty of measurement $U_{\rm E}$ approximated uncertainty of measurement (number of iteration not stated) $U_{\rm EN}$ approximated uncertainty of measurement of iteration number $N$ $U_{\rm R}$ required uncertainty $U_{\rm T}$ target uncertainty $U_{\rm T}$ target uncertainty $U_{\rm T}$ uncertainty value (not estimated according to GUM or this Technical Specification) $U_{\rm T}$ measurement result (uncorrected) $U_{\rm T}$ measurement result (in the transparent box model of uncertainty estimation)	U	expanded uncertainty of measurement
$U_{\rm E}$ approximated uncertainty of measurement (number of iteration not stated) $U_{\rm EN}$ approximated uncertainty of measurement of iteration number $N$ $U_{\rm R}$ required uncertainty $U_{\rm T}$ target uncertainty $U_{\rm V}$ uncertainty value (not estimated according to GUM or this Technical Specification) $X$ measurement result (uncorrected) $X_i$ measurement result (in the transparent box model of uncertainty estimation)	$U_{A}$	true uncertainty of measurement
$U_{EN}$ approximated uncertainty of measurement of iteration number $N$ $U_{R}$ required uncertainty $U_{T}$ target uncertainty $U_{V}$ uncertainty value (not estimated according to GUM or this Technical Specification) $X$ measurement result (uncorrected) $X_i$ measurement result (in the transparent box model of uncertainty estimation)	$U_{C}$	conventional true uncertainty of measurement
$U_{\rm R}$ required uncertainty $U_{\rm T}$ target uncertainty $U_{\rm V}$ uncertainty value (not estimated according to GUM or this Technical Specification) $X$ measurement result (uncorrected) $X_i$ measurement result (in the transparent box model of uncertainty estimation)	$U_{E}$	approximated uncertainty of measurement (number of iteration not stated)
$U_{ m R}$ required uncertainty $U_{ m T}$ target uncertainty $U_{ m V}$ uncertainty value (not estimated according to GUM or this Technical Specification) $X$ measurement result (uncorrected) $X_i$ measurement result (in the transparent box model of uncertainty estimation)	$U_{EN}$	approximated uncertainty of measurement of iteration number N
$U_{T}$ target uncertainty $U_{V}$ uncertainty value (not estimated according to GUM or this Technical Specification) $X$ measurement result (uncorrected) $X_i$ measurement result (in the transparent box model of uncertainty estimation)		required uncertainty
$U_{ m V}$ uncertainty value (not estimated according to GUM or this Technical Specification) $X$ measurement result (uncorrected) $X_i$ measurement result (in the transparent box model of uncertainty estimation)		target uncertainty
<ul> <li>X measurement result (uncorrected)</li> <li>X<sub>i</sub> measurement result (in the transparent box model of uncertainty estimation)</li> </ul>		uncertainty value (not estimated according to GUM or this Technical Specification)
$X_i$ measurement result (in the transparent box model of uncertainty estimation)		measurement result (uncorrected)
Y   measurement result (corrected)	Y	measurement result (corrected)

### 5 Concept of the iterative GUM-method for estimation of uncertainty of measurement

Applying the GUM method completely one will find a conventional true uncertainty of measurement,  $U_{\mathbb{C}}$ .

The simplified, iterative method/procedure of this Technical Specification is to achieve estimated uncertainties of measurements,  $U_{\rm E}$  by overestimating the influencing uncertainty components/contributors ( $U_{\rm E} \geqslant U_{\rm C}$ ). The process of overestimating provides "worst-case-contributions" at the upper bound from each known or predictable uncertainty contributor, thus ensuring results of estimations "on the safe side", i.e. not underestimating the uncertainty of measurement. The simplified, iterative method of this Technical Specification is based on the following:

- all uncertainty contributors are identified;
- it is decided which of the possible corrections shall be made (see 8.4.6);
- the influence on the uncertainty of the result of measurement from each contributor is evaluated as a standard uncertainty  $u_{xx}$ , called the uncertainty component;

NOTE As a convention in the iterative method the influence of each contributor must be converted into the unit of the measurand — using relevant physical equations/formulae and sensibility coefficients.

- an iteration process, PUMA (see clause 6);
- the evaluation of each of the uncertainty components (standard uncertainties)  $u_{xx}$  can take place either by type A-evaluation or by type B-evaluation;  $ANDARD\ PREVIEW$
- type B-evaluation is preferred if possible in the first iteration in order to get a rough uncertainty estimate
  to establish an overview and to save cost;
- the total effect of all contributors (called the combined standard uncertainty) is calculated by the formula:

$$u_{\rm C} = \sqrt{u_{x1}^2 + u_{x2}^2 + u_{x3}^2 + \dots + u_{xn}^2}$$
 980c22f2ed97/sist-iso-ts-14253-2-2002 (1)

- the formula (1) is only valid for a black box model of the uncertainty estimation and when the components  $u_{xx}$  are all uncorrelated (for more details and other formulas see 8.6 and 8.7);
- for simplification the only correlation coefficients between contributors considered are

$$\rho = 1, -1, 0 \tag{2}$$

if the uncertainty components are not known to be uncorrelated, full correlation is assumed, either  $\rho = 1$  or -1. Correlated components are added arithmetically before put into the formula above (see 8.5 and 8.6);

— the expanded uncertainty *U* is calculated by the formula:

$$U = k \times u_{\mathbf{C}} \tag{3}$$

where k = 2; k is the coverage factor (see also 8.8);

The simplified, iterative method normally will consist of at least two iterations of estimating the components of uncertainty.

- a) The first very rough, quick and cheap iteration has the purpose of identifying the largest components of uncertainty (see Figure 1);
- b) The following iterations if any only deal with making more accurate "upper bound" estimates of the largest components to lower the estimate of the uncertainty ( $u_c$  and U) to a possible acceptable magnitude.