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International Standard

# ISO/FDIS 17123-11

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

## Part 11: GNSS instruments

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

*Partie 11: Instruments GNSS*



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# Foreword

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This document was prepared by Technical Committee ISO/TC 172, *Optics and photonics*, Subcommittee SC 6, *Geodetic and surveying instruments*.

A list of all parts in the ISO 17123 series can be found on the ISO website.

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# Introduction

The ISO 17123 series 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.

These field procedures have been developed specifically for in situ applications without the need for special ancillary equipment and are purposely designed to minimize atmospheric influences.

ISO 17123-8[1] provides a standard which exclusively covers Global Navigation Satellite System (GNSS) test procedures for real-time kinematic applications. Since the creation of ISO 17123-8[1], GNSS-based geodetic measurement and instrumentation techniques have evolved in many ways:

— in addition to the classical real-time kinematic measurement procedures on which [1] is based, other GNSS-based geodetic measurement procedures have become established;

— complementary to classical base-rover measurement arrangements and the instrument morphology by means of separation of antenna and receiver, which was widely used at the time, versatile integrated measurement instrument types are currently available;

— correction data services play an essential role in the analysis.

This document therefore has the following objectives:

— provision of GNSS field test procedures to achieve the highest possible reliability in the use of GNSS-based geodetic measurement techniques;

— far-reaching consideration of technological advancements both in instrument technology and morphology as well as in data streams;

— extensive independence from the accuracy class of the measuring equipment;

— consideration of the measuring equipment as a complete system;

— qualitative and quantitative multistage nature of the field test procedure in order to be able to meet different requirement profiles;

— inclusion of the user's expertise.

The implementation of these objectives is limited by the following framework conditions:

— a GNSS measuring instrument is not a measuring device in the narrower sense that can be tested independently of external infrastructure on its own as well as without target specifications. Instead, GNSS measuring instruments are subcomponents of an overall system;

— GNSS measuring instruments are perceived as black box systems. A large group of these systems is designed by the manufacturer in such a way that no, or only little, influence can be exerted on important instrument parameters;

— another group of GNSS measuring instruments follows an open-box strategy and allows a large number of parameter settings in the positioning algorithm, the changes of which have a direct influence on the determined position;

— GNSS-based measurement techniques are always based on an estimation algorithm, the result of which depends on a very large number of possible influencing factors;

— the quality of satellite geodetic measurements and the positional accuracies that can be achieved with them depend directly on the measurement conditions on site;

— a metrologically correct, and at the same time, procedurally simple consideration of a multitude of the possible influencing factors on the achievable measurement accuracy is not possible according to the current state of the art, in contrast to other geodetic instruments and measurement principles.

The field test procedure presented in this document therefore focuses on the visualization of a three-dimensional coordinate, inherent to all GNSS measuring instruments, as the primary measurement result value, which is compared to a nominal value. It is a daily performance verification independent of this specific technique. More profound system verification requires the application of more specialized standards such as ISO 17123-8[1], which is not intended for high dynamic applications, e.g. autonomous driving, unmanned aerial vehicle (UAV) applications.

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

# Part 11:
# GNSS instruments

## 1 Scope

This document specifies a field procedure for the verification that a given Global Navigation Satellite System (GNSS)-based system and measurement procedure meets a required measurement uncertainty at the location and time of interest.

The field procedure uses three-dimensional coordinates which are compared to reference coordinates. It is designed to be applicable to the technically versatile geodetic and surveying GNSS systems on the market and can be used for any kind of GNSS-based applications to determine coordinates. It is independent of the technology used in the GNSS measuring instrument, the satellite data streams, and any correction data used.

The procedure is applicable to GNSS instruments under operating condition in the field in such a way that the main parameters affecting the determination of coordinates are included in the result of the test. This document defines several delimitation criteria, which allows for versatile applicability. As a result, the verification procedure can be regularly performed in the field with limited economic impact.



## 2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 9849, *Optics and optical instruments — Geodetic and surveying instruments — Vocabulary*

ISO 17123-1, *Optics and optical instruments — Field procedures for testing geodetic and surveying instruments — Part 1: Theory*

## 3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 9849 and ISO 17123-1 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

**3.1**
**coordinate**
one of a sequence of numbers designating the position of a point

Note 1 to entry: In a spatial *coordinate* (3.1) reference system, the *coordinate* (3.1) numbers are qualified by units.

Note 2 to entry: Coordinate in this document means a three-dimensional measured value in a coordinate system determined by a measurement.

Note 3 to entry: Without limiting generality, the form of expression of coordinates in this document is by the designation *E* (east), *N* (north), *H* (height).

[SOURCE: ISO 19111:2019[2], 3.1.5, modified — Notes 2 and 3 to entry have been added.]

**3.2**
**coordinate system**
three-dimensional set of coordinates in which the *global navigation satellite system (GNSS)* (3.5) measuring instrument calculates and displays the measured variables

**3.3**
**position component**
two-dimensional sub-system of the global navigation satellite system (GNSS) three-dimensional *coordinate system* (3.2) comprising East and North *coordinate* (3.1)

Note 1 to entry: The GNSS *coordinate* (3.1) determined in perpendicular direction to the *position component* (3.3) is the *height component* (3.4).

**3.4**
**height component**
*global navigation satellite system (GNSS)* (3.5) coordinate determined in perpendicular direction to the local GNSS geoid surface

**3.5**
**global navigation satellite system**
GNSS
system consisting of several satellites in different orbital planes, which allow absolute navigation solutions as well as highly precise (e.g. differential) positioning and broadcasting of time due to the global coverage

EXAMPLE 1 Global Positioning System (GPS) or Navigational Satellite Timing and Ranging – Global Positioning System (NAVSTAR-GPS) - U.S. Department of Defense navigation system based on the constellation of usually more than 24 satellites at an altitude of 20 200 km above the earth's surface.

EXAMPLE 2 GLObal'naya NAvigationnaya Sputnikovaya Sistema (GLONASS) - Russia's GNSS based on the constellation of approximately 24 satellites at an altitude of 19 100 km above the earth's surface.

EXAMPLE 3 Galileo - GNSS organized by the EU and the European Space Agency. The system is planned to consist of 30 satellites at an altitude of 23 200 km above the earth's surface.

EXAMPLE 4 Beidou - Satellite Navigation System operated by China. Satellites in medium earth orbit (22 000 km above the earth's surface) as well as in geosynchronous orbit (35 790 km above the earth's surface) are used, where the latter include satellites in both geostationary orbit and in inclined geosynchronous orbit.

EXAMPLE 5 Quasi-Zenith Satellite System (QZSS) – Satellite navigation system operated by Japan. The system is compatible with GPS.

Note 1 to entry: GNSS includes all operating global navigation systems by satellite.

[SOURCE: ISO 9849]

**3.6**
**global navigation satellite system measuring equipment**
**GNSS measuring equipment**
sum of all devices and software applications required for the realization of a *measuring point* (3.11) and for the determination of coordinates by means of satellite-based positioning

EXAMPLE *GNSS measuring instrument* (3.7), tripod, centring devices, data reception and communication modules.

**3.7**
**GNSS measuring instrument**
global navigation satellite system measuring instrument
measuring equipment for the determination of coordinates on the basis of satellite-supported positioning

Note 1 to entry: A *GNSS measuring instrument* (3.7) consists, e.g. of GNSS antenna, GNSS receiver, and field computer.

**3.8**
**GNSS measurement procedure**
global navigation satellite system measurement procedure
procedure including all satellite-based position determinations for the determination of coordinates in a geodetic reference system

Note 1 to entry: Typical *GNSS measurement procedures* (3.8) are: Single Point Positioning (SPS), Precise Point Positioning (PPP), Real-Time Kinematic (RTK), Network Real-Time Kinematic (NRTK).

**3.9**
**dilution of precision**
DOP
measure of the quality of the satellite geometry in a global navigation satellite system (GNSS) measurement

Note 1 to entry: The DOP value reflects the spatial distribution of the GNSS satellites during the measurement.

Note 2 to entry: Depending on the dimension of interest, the DOP value can be given as, e.g. vertical dilution of position (VDOP, accuracy degradation in vertical direction), horizontal dilution of precision (HDOP, accuracy degradation in horizontal direction), positional dilution of precision (PDOP, accuracy degradation in 3D), time dilution of precision (TDOP, accuracy degradation in time), or geometric dilution of precision (GDOP, accuracy degradation in 3D and time).



**3.10**
**antenna height**
vertical distance of the antenna reference point to the point to be measured

**3.11**
**measuring point**
point from which or towards which a measurement is carried out

[SOURCE: ISO 7078:2020[3], 3.6.50.]



**3.12**
**reference point**
*measuring point* (3.11) for which a reference value is known

## 4 Symbols and abbreviations

### 4.1 Symbols

| Symbol | Quantity | Unit |
|---|---|---|
| $U$ | expanded measurement uncertainty | m |
| $x, y, z$ | Cartesian coordinates | m |
| $E$ | East coordinate in the GNSS three-dimensional coordinate system | m |
| $N$ | North coordinate in the GNSS three-dimensional coordinate system | m |
| $H$ | Height coordinate in the GNSS three-dimensional coordinate system | m |
| $L$ | position component | m |
| $i, j$ | running indices for measurement and measurement set number | - |
| $k$ | running index for various antenna heights | - |
| $\phi$ | horizontal antenna orientation | gon |
| $h$ | antenna height | m |

| Symbol | Quantity | Unit |
|---|---|---|
| [$a$, $b$] | closed interval from $a$ included to $b$ included ISO 80000-2[4] | - |
| ($a$, $b$] | left half-open interval from $a$ excluded to $b$ included ISO 80000-2[4] | - |

## 4.2 Abbreviated terms

max maximum

A, B, C, D measurement uncertainty classes

DOP dilution of precision

EPN European Permanent Network

IGS International GNSS Service

ITRF International Terrestrial Reference Frame

MPE Maximum Permissible Error

RINEX Receiver Independent Exchange Format

RTK Real-Time Kinematic

R Reference

$\overline{X}$ mean value of quantity $X$ ($X$=$E$, $N$, $H$, ...)



# 5 Delimitation

## 5.1 Reason for delimitation



GNSS measurement procedures depend on a large number of influencing factors and prerequisites. For a GNSS field test procedure to be standardised, the following delimitations are therefore to be made.

## 5.2 Quantitative delimitation by measurement uncertainty classes

The GNSS field test procedure includes:

— GNSS measuring instruments for determining coordinates with measurement uncertainties better than 5 m. The measurement uncertainties are classified according to Table 1.

**Table 1 — Classification of measurement uncertainties in position ($U_{\mathrm{position}}$) and height coordinates ($U_{\mathrm{height}}$)**

Dimensions in millimetres

| Class | $U_{\mathrm{position}}$ | $U_{\mathrm{height}}$ |
|---|---|---|
| A | <10 | <20 |
| B | [10; 30] | [20; 50] |
| C | (30; 200] | (50; 200] |
| D | (200; 5 000] | (200; 5 000] |

NOTE Exemplary assignment of applications to the measurement uncertainty classes are provided in Annex D.

The GNSS field test procedure excludes:

— GNSS measuring instruments for the determination of exclusively one- or two-dimensional coordinates;

— GNSS measuring instruments for the determination of exclusively non-static coordinate measuring, e.g. velocity only.

## 5.3 Qualitative delimitation through multistage test procedure

The GNSS field test procedure includes a multistage GNSS field test procedure. It takes into account the area of application of the GNSS measuring instrument, the test periodicity, and the measurement uncertainty classes. It is subdivided according to Table 2, analogous to the structure of the ISO 17123 series.

**Table 2 — Procedure stages of the GNSS field test procedure**

| Procedure stage | Description | Measurement uncertainty class (see Table 1) | | | |
|---|---|---|---|---|---|
| | | A | B | C | D |
| 1 | Simple coordinate comparison (see 6.2) | | x | x | x |
| 2 | Qualified coordinate comparison (see 6.3) | | x | x | |
| 3 | Extended qualified comparison with concentration on selected system parts (e.g. verification of antenna calibration values). See 6.4. | x | | | |

The multistage nature of the GNSS field test procedure results as follows:

Procedure stage 1

— simplified test procedure with an evaluation of whether the measurement uncertainty of a coordinate is within the selected measurement uncertainty class;

— without determination of standard uncertainties (according to [5]; and [6])

— without restriction to a predefined GNSS measurement procedure.



Procedure stage 2

— complete test procedure with specification of defined measurement conditions;

— with references to influencing factors and preconditions to be observed (e.g. settings on the measuring instrument, satellite visibility, DOP values, multipath effects);

— without restriction to a predefined GNSS measurement procedure.

Procedure stage 3 (diagnostic - not for conformance)

— extended test procedure for the best possible determination of the the magnitude of uncertainty contributions from various components of the GNSS measuring instrument;

— with determination of standard uncertainties (according to [5] and [6]);

— with restriction to a predefined GNSS measurement procedure;

— with instructions for improving the measurement uncertainties.

## 5.4 Functional delimitation related to GNSS measuring instrument

The GNSS field test procedure includes:

— the integral testing of the GNSS measuring equipment from measurement to portrayal of the coordinate as depicted in Figure 1, including the GNSS measuring instrument used, accessories, measuring