# Geodetic Surveying Tasks for Establishing a National Long Length Standard Baseline

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**Key words**: metrology, geodesy, distance, calibration, measuring standard

## SUMMARY

The article informs about the Czech National Long Length Standard Baseline, which consists of two components of the Geodetic baseline Kostice, in Northern Bohemia and the electronic distance meter integrated in Leica TCA 2003.

Metrological traceability is documented according to EN ISO/IEC 17025:2005 and EA-4/02 Expressions of the Uncertainty of Measuring and Test Equipment and according to National Standards, NOV 1995. The article gives recommendations for the co-operation of land surveying institutes within the framework of metrological traceability certification and the processing of interlaboratory comparisons.

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## 1. INTRODUCTION

In the Czech Republic each land surveying engineer is bound to observe all Acts, especially the Act on Land Surveying and the related Act on Metrology and all related regulations.

Some results of the geodetic surveying activities must be validated by a public appointed geodetic survey engineer. Validation is finished by putting down the following text: "essentials and accuracy comply with legal standards and with requirements agreed with the customer."

Each public appointed survey engineer has to act professionally, observe all requirements which are agreed with the customer and comply with legal standards.

One of the requirements is to use calibrated measuring instruments. This means using measuring instruments with metrological traceability (the Act on Land Surveying and the Act on Metrology). The metrological traceability of measuring equipment is defined as the possibility of placing the measuring equipment into an uninterrupted sequence of measured quantity. This sequence begins by the measuring standard of the highest metrological quality.

The Act on Metrology establishes the following classification of measuring instruments:

– measuring standards,
– legally verified working measuring standards,
– working measuring standards,
– referential materials.

All measuring equipments used in geodetic surveying are classified as measuring standards.

The Act on Metrology defines rights and duties of persons and companies for ensuring correct and uniform measurements.

According to item no. 11, paragraph 5 of the Act on Metrology, each user of measuring equipment is responsible for its calibration if there is no other more suitable special method.

In the Czech Republic there are generally two independent ways of calibrations: according to National standards or according to EN ISO standards.

Original Czech legislation in this branch is set down by the following acts: the Act on Metrology No. 505/1990, as amended by Acts Nos. 119/2000 and 137/2002, and by Act. No.

13/2002 and also by Decree No. 262/2000 that defines correct and uniform measuring equipment and measuring procedures. This decree has been amended by decree No. 344/2002. The Decree No. 345/2002 establishes measuring equipment for legal control, measuring equipment which must be approved for use and fundamental measuring quantities and their symbols.

The quality system is regulated by standards CSN EN ISO 9000 and 9001 and by some other related standards.
Both ways are aimed to provide right and accurate measurements. This is ensured most frequently by calibrations of measuring equipment.
There are several technical and economic difficulties in providing the metrological traceability.

The organization that is preparing a measuring standard should carefully consider all technical and economic possibilities to decide whether the establishment of the standard is cost effective or if it would be better to have the measuring standard established by an authorized or accredited subject.

In the 80` of the 20th century electronic distance meters started to play an important role in distance measurement. High accuracy of measurements can be checked by two basic procedures:

– determination of physical quantities of the electronic distance meter in the laboratory (measuring the stability of radiation frequency),
– comparison with a reliable measuring standard.

Long-term experience has taught us that the majority of customers prefer calibration, which is analogical to common use of the measuring equipment. This was one of the reasons for establishing the National Long Length Standard Baseline.

The National Long Length measuring resolution of presently manufactured measuring instruments is in tenths of a millimeter.

This fact and the request of the Czech Government for ensuring the equivalence of metrology with EU countries, i.e. right and uniform measuring, was the reason for establishing the national standard of long distances. Right measuring of distances is important especially in road building.

The National Standard of Long Distances was established as a system consisting of the following parts:

– 12 pillars tightly fixed in the terrain which are parts of Kostice geodetic baseline,
– 12 plugs for an accurate centering of geodetic equipment on pillars,
– Leica TCA 2003 Total Station with integrated electronic distance meter with instruments for the measuring of the air temperature and barometric pressure.

## 2. DESCRIPTION OF THE MEASURING STANDARD

The principle of the Measuring Standard is quite simple: it is the realization of distances where the shortest one is about 25 meters and the longest one is about 1450 meters. Each distance is represented by a combination of two pillars. The position of each pillar is fixed.

**Figure 2-1:** Pillar with the prism

Distance parameters of the measuring standard are in table 2-1. These parameters were the result of measurements of the measuring by EDM Leica TCA 2003 which has had metrological traceability on the laser interferometer HP 5519A. Distance parameters were checked by other methods with less accuracy. An international comparison has also been carried out by a team of the Laboratory of Geodesy of the Bundeswehr University in Munich, Germany.

The National Long Length Standard Base Line is situated about 60 km north-west of Prague. It is a set of 12 pillars, which are arranged in one line along a road between villages Kostice and Libceves. The pillars are numbered from 1 to 12.

The pillars are vertical steel piles which are hammered in the ground from 3 to 11 meter deep. The top of each pillar is about 1 meter above the ground and there is a round steel plate on each pillar. The plate is designed for the fixing of standard geodetic instruments. For each pillar, an accurate plug is necessary.

Although all pillars are fixed deep in the ground, there are some residual movements. The values of these movements are usually in the range of tenths of a millimeter per year. The largest movement that has ever been measured, is 2 millimetres between years 2006 and 2007. These residual movements cause drift of the Standard Base Line, so that it needs to be periodically recalibrated.

The National Long Length Standard Baseline Kostice is used for EDM calibrations. EDMs are usually calibrated together with reflecting prisms. The calibration process results in determination of the index and scale constants that are necessary for determination of corrections of results obtained by the instrument. Accuracy of these corrections is also determined.

The set of 12 pillars can make 66 twins which represents 66 various lengths from 25 meters to 1450 meters. All distances are linear slope distances. There are several reasons for converting these distances into horizontal ones and for reducing them into a uniform surface. Particularly a reference surface the sphere with the radius of 6,370,201.887 meters has been chosen.

**Figure 2-2:** The view of the top of the pillar with fixed geodetic tripod

One of advantages of parameters determined in this manner is that only 11 values of horizontal distances between neighboring pillars are necessary for knowing all 66 distances. Other distances can be obtained simply by summing up appropriate values.

Basic 11 values and their uncertainties are given in the table 2-1 below.

| Pillars | Results – Research Institute of Geodesy, Topography and Cartography (2007) | | Results – Bundeswehr University in Munich (2006) | | Difference |
|---|---|---|---|---|---|
| | Distance (m) | Standard uncertainty (mm) | Distance (m) | Standard uncertainty (mm) | (mm) |
| 1 - 2 | 25,0892 | 0,5 | 25,0881 | 0,4 | 1,1 |
| 1 - 3 | 58,0519 | 0,5 | 58,0500 | 0,4 | 1,9 |
| 1 - 4 | 133,8831 | 0,6 | 133,8810 | 0,4 | 2,1 |
| 1 - 5 | 228,9825 | 0,8 | 228,9811 | 0,4 | 1,4 |
| 1 - 6 | 332,9594 | 1,1 | 332,9586 | 0,4 | 0,8 |
| 1 - 7 | 459,8596 | 1,5 | 459,8584 | 0,4 | 1,2 |
| 1 - 8 | 608,8432 | 1,9 | 608,8415 | 0,4 | 1,7 |
| 1 - 9 | 787,0671 | 2,4 | 787,0651 | 0,4 | 2,0 |
| 1 - 10 | 977,8891 | 3,0 | 977,8827 | 0,5 | 6,4 |
| 1 - 11 | 1199,9900 | 3,6 | 1199,9907 | 0,5 | -0,7 |
| 1 - 12 | 1450,0077 | 4,4 | 1450,0112 | 0,5 | -3,5 |

**Table 2-1:** Actual Parameters of the measuring standard

## 3. TECHNOLOGIES OF DISTANCE DETERMINATION

The National Long Length Standard Baseline Kostice was measured by the following methods:

– by electronic distance meter with accurate metrological traceability,
– by invar tapes,
– by methods of measuring horizontal parallax angles to a solid invar rod.

The first method listed above is the most accurate method based on precise calibration of the electronic distance meter Leica TCA 2003.

This precise calibration is possible in the range of the laser interferometer, which is from 0 to 30 meters. The only distance of the baseline which is in this range is the distance between pillars 1 and 2. For making benefit of the accurate calibration it was necessary to split other distances. The smallest possible number of measured sub-distances and the possibility of metrological traceability on the laser interferometer are the simple conditions for this splitting.

**Figure 3-1:** Measuring of the distance from the pillar no. 6 by invar tape

Hereby 10 distances were split into 10 various sub-distances. These sub-distances were roughly marked out and then measured with at least 10 repetitions. The measuring function of the EDM in the short range of each sub-distance was calibrated. The standard uncertainty of the calibration is about 0.08 millimeter.

Laser interferometer is traced on the laser interferometer IK-1 of the Czech Metrology Institute. This is how the National Long Distance Standard Baseline Kostice was traced on the SI realization of the meter unit.

Accuracy of distances between pillars can be determined by the following formula:

$$u_{[mm]} = Q\left(0{,}5;3{,}0 \cdot L_{[km]}\right),$$

where $L$ is the value of distance in kilometers and $u$ is standard uncertainty according to EA 4/02 document.

One of the most important sources of uncertainty in the field of measurement is uncertainty of the air temperature and barometric pressure. This was the reason why measurements were carried out early in the morning before sunrise when the temperature was more stable.

## 4. INTERNATIONAL COMPARISON OF MEASUREMENT

In the table mentioned above there are results of measurements which were carried out by the University of Bundeswehr Munich, Germany. All $E_n$ coefficients except the distance 1 – 3 comply with the demands of the comparison. This laboratory has sophisticated methods of distance measuring and thanks to it also big authority in Germany, however their methods have no metrological traceability on the SI meter realization.

In the EU there are only two laboratories with accreditation for measurement of long distances. A Finnish laboratory and an Austrian laboratory have accreditation for measurement of distances up to 100 meters.

## 5. CONCLUSIONS

Today's accuracy of distances between pillars does not respond to the actual need. There is a possibility of improvements based on parallel measurement of the radiation frequency. This is important for better determination of the most important source of uncertainty.

Desired accuracy is standard uncertainty of 2 millimeters for the 1 kilometer distance.

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## BIOGRAPHICAL NOTES

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– developing and manufacturing automated measuring systems for deformation monitoring which are installed at the nuclear power plant in Temelin, Czech Republic,
– application of metrology in land surveying (metrological tracing of new measuring standards of angle and distance, managing of accredited calibration laboratory and authorized centre of metrology),
– creating new standards in land surveying and geoinformatics.

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