# Testing of Terrestrial Laser Systems

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**Key words**: testing of terrestrial laser systems (TLS), testing of geometry affect of scanned object on, testing of TLS by reference standard, testing of TLS by reference entities, point accuracy by TLS.

## SUMMARY

Actual problem of investigation in area of laser scanner technology is testing of terrestrial laser systems (TLS) with aim of acquisition of supplementary information about TLS's properties. TLS producers describe the accuracy characteristics of TLS with one value only, without specification of measuring conditions.

This paper deals with the design of TLS testing, according to the geometry conditions, it means of shape, largeness, orientation, spatial position of the scanned objects and its influence on modelling. We are looking for answers on questions about quality determination of each point measured by TLS, its homogenity in whole measuring area, influence of non-homogenity on object modelling. To verify of this influence we choose two ways, carry out the test by reference measures and by reference entities.

For estimation of accuracy characteristics it is important to know the real conditions, created by correlation of measurement properties, the measured object and the TLS.

The main aim is to determine a complex accuracy characteristics of point determination and the surface model with concerning of important influences of the measurement and data processing.

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## 1. INTRODUCTION

TLS introduce modern technology, which is characterized spatial data acquisition and automation of measurement process. By application of TLS for concrete applications we come out from technical parameters given by producers. It is a new technology, which is not sufficient investigate from geodetic point of view, therefore it is necessary to consider new aspects and influences, which effect measurement process and interpretation.

One of the definitive criterions by application of laser scanner technology is accuracy of determination of point position, respectively area determination. Producers give these accuracy characteristics by one universal value without any factors, which influence accuracy.

We don't know how affect element properties of measurement process by various conditions, what is their magnitude, when it is necessary to consider, eventually neglect.
For obtaining of real vision about magnitude of their influence it is necessary to do testing of TLS.

Aim of testing is to determine complex accuracy characteristic of point determination and modelled area with including of all influences of whole measurement process. Obtained results will be a good contribution for practice especially by deciding of using technology in concrete applications.

## 2. TESTING CONDITIONS AND INVESTIGATION OF INFLUENCES OF MEASUREMENT PROCESS

Testing will be carried out in conditions of real measurement. Into measurement process enters measurement instrument, measured object and measuring area (Fig. 1).

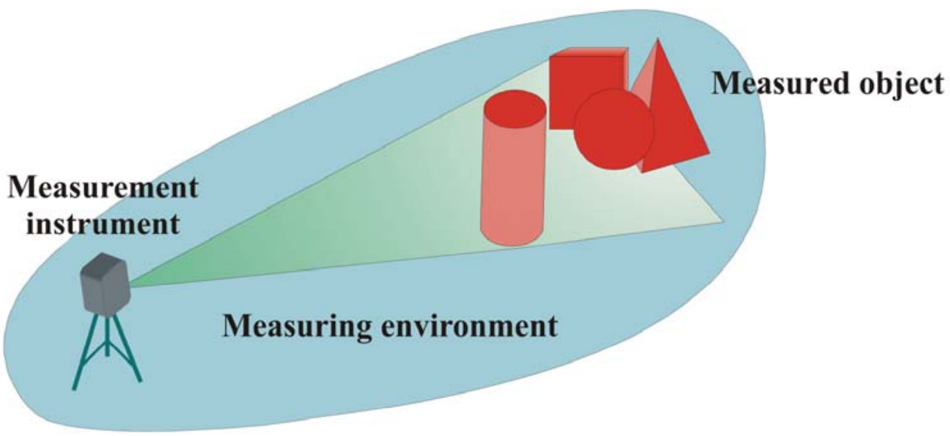


**Fig. 1:** Elements of Measurement process

They influence each other with their properties and by certain conditions also affect resultant accuracy of determination of point position (Fig. 2).

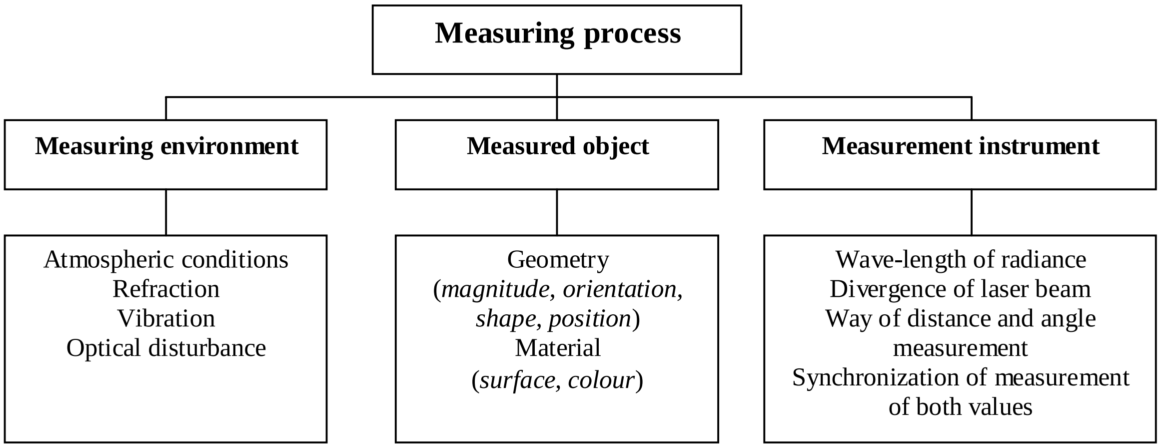


**Fig. 2:** Element properties of measurement process

For investigation of influences of measurement instrument, measured object and measuring area we will use a method of elimination of the rest affects according to Fig.3. Scheme presents investigated affect, which we will eliminate and which of measuring variants we will carry out.

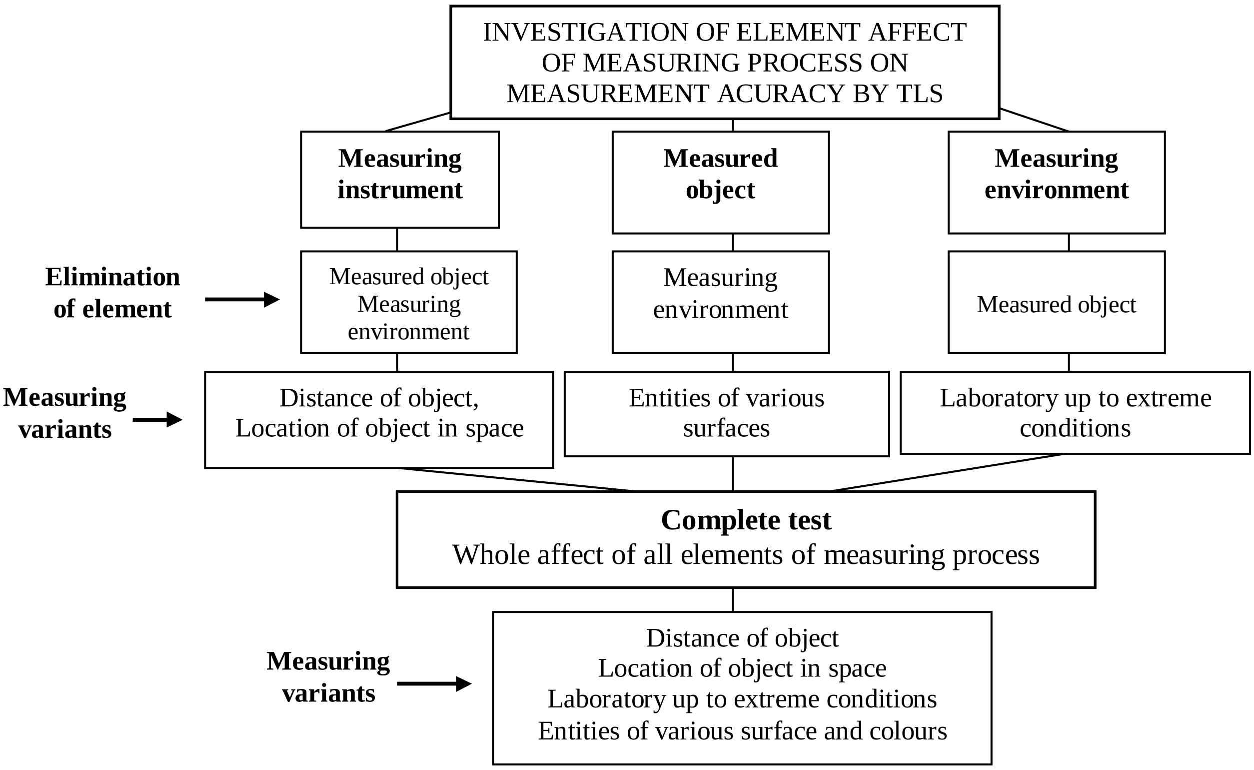


**Fig. 3:** Measurement variants for investigation of elements affect of measuring process at measuring accuracy

It means that e.g. when we investigate influence of geodetic instrument, we eliminate influence of measured object with object with as best object as it is possible, with the best properties and also environment influence with laboratory conditions. By influence investigation we will carry out measurement sets with distance variations between instrument and object and location of object in space.

Elimination of affect of measured object we will achieve by using of entities with such surface and colour, which are stabile and one-valued directional reflection. Afect of environment we will decrease at minimum by laboratory conditions (stabile temperature, pressure, damp).

Complete test involves co-effect of all elements of measuring process, Fig.3 presents its variants of measurement.

Up to this time realised tests is not involved testing of geometry characteristics of measured object, it means shape, magnitude, orientation, location in space and their affect on modelling. These geometric characteristics detect with help of scanned points of measured objects.

From these facts result that it is necessary to answer on these following questions

- With how quality are determined each points measured by TLS?
- Is this quality homogenous in whole range of measurement (space)?
- Does contingent non-homogeneity an affect on model quality of measured objects?

Aim is to suggest testing processes of TLS, which would come to answers at above mentioned questions not only in bipolar version but also in version of detail information about quantitative parameters of investigated effects.

## 3. TESTING OF GEOMETRY AFFECT OF SCANNED OBJECT ON

Geometry affect of scanned objects on TLS we detect by two various ways, by using of reference standard or reference entity.

### 3.1 Testing of TLS by Reference Standard

Result of each measurement with TLS are spatial coordinates of points $x$, $y$, $z$, where we don't know measured values $d$, $\omega$, $\xi$. For accuracy determination of spatial point position we have to verify variances of determining values.

By calibration of geodetic measurement instruments we compare measured value with nominal value, which magnitude is fast determined (stabilized, signalized), e.g. measured distance with nominal distance of baseline, measured directions with nominal plan of directions.

This verifying way of measured distance and angle is not possible to apply for TLS because TLS is not possible to measure distance at signalized point not even plan of directions. Reason is area acquisition of data, by which are TLS defined.

Area acquisition of data with TLS is characterised by raster ordering of measured points for certain distance of measured object *d* and regularly or regularly changing separation of points *s*. To this separation between measured points belongs increase of horizontal $\Delta\omega$ and vertical angle $\Delta\xi$ (Fig. *4*).

From this reason we suggest verifying of determining values (distance *d*, horizontal angle $\omega$ and vertical angle $\xi$) by comparison of reference values of raster (set up values – parameters of scanning $d_r$, $\Delta\omega_r$, $\Delta\xi_r$) and values measured on scanned points, e.g. in CAD software ($d_m$, $\Delta\omega_m$, $\Delta\xi_m$).

For testing we have to create conditions for scanning of regular raster, which is given by parameters of scanning. Ordering of measured points into shape of regular raster is reachable by scanning of spherical surface with radius of fillet *r* and with identifying of projective centre of TLS with the centre of spherical surface. Projective centre is defined as fictive origin of determining of laser beam.

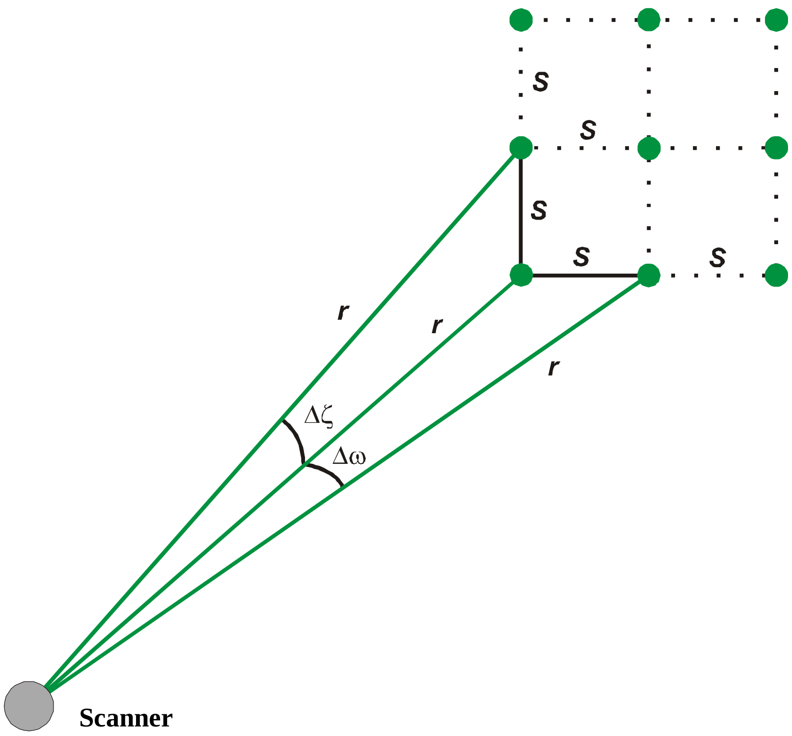


**Fig. 4:** Testing of TLS with help of reference standard

We have to locate TLS in distance *r* from testing spherical surface ($d = r$) to respond all points of scanned spherical surface to measured distance *r* (Fig. 4). Spherical surface (section) has to be oriented in that manner that vertical line leaded to it in arbitrary point has to go through projective centre of TLS.

Surface and colour of spherical surface is elected on a base of test results, which have to be carried out for given wave-length of laser beam of testing instruments. Magnitude of spherical surface section depends on its radius *r*. Spherical surface has to be produced with minimally about one accuracy higher order as it is given by producer of TLS.

Measurement will be realised by producing of scan sets with various parameters of scanning ($\Delta\omega$, $\Delta\xi$) for given radius r. Scanning results will be for each parameter set up a regular raster of measured points on spherical surface.

Evaluation of test consists in calculation of differences between determining parameters ($d_m$, $\Delta\omega_m$, $\Delta\xi_m$) with reference values ($d_r$, $\Delta\omega_r$, $\Delta\xi_r$).

Test results will be:

- accuracy characteristics of determining values (variance of distance, horizontal and vertical angle),
- mean coordinate error and mean positioning error of point (application of Error Theory),
- raster characteristics (calculation of point separation of raster as chord between points on a base of $d_m$, $\Delta\omega_m$, $\Delta\xi_m$),
- accuracy characteristics of surface modelling, which will be determined from differences of measured and references values.

Obtained values of accuracy characteristics give us more real information about TLS's accuracy as well as about stability of these parameters in a whole range of measurement by TLS.

### 3.2 Testing of TLS by Reference Entities

Idea of testing of TLS by reference entities comes out from existing global method of coordinate measuring system testing (CMS) (Kopáčik, 1989).

Both types of 3D automated measuring systems – TLS and CMS enable an automated measurement process of spatial coordinates, indirect determination of magnitudes and geometric properties of measured object.

By global testing are CMS verified by reification of measures (angles and distances), geometric shapes (standards). Standard for CMS testing is solid entity, which is resistant towards elastic deformations and is able to preserve its measures and shape without measurable changes in a long time interval. By comparison of calculated and nominal measures, geometric properties are obtained global accuracy characteristics.

TLS introduce transition from measurement of individual points to area measurements. Result of one measurement is set of points. From this results that for TLS testing we use set of points, which create surface, area of reference entity, it means standard with known nominal measures and geometric characteristics.

Because it is a pilot suggestion of TLS testing with help of reference entities, we will use simple geometric entities, which main advantage is their simple mathematical formulation, respectively quick and responsible analysis. As reference entities we suggest to use:

- sphere, cone, cylinder, pinnacle, cube,
- characterized by nominal measures (their election given by sufficient point amount form modelling, minimal resolution of instrument, instrument range, laser beam divergence).

Reference entities should fulfil the following properties:

- consisting of solid stabile material (metal, brick, concrete, wood, ...),
- various colour expression,
- produced minimally about one accuracy higher order as is accuracy of TLS.

Measuring process is influenced by relationships between measuring environment, measuring instrument and reference entities. To be these influences allowed for we have to know character and magnitude of their influence on complete accuracy characteristic of point determination, respectively surface.

For fixation of spatial reference entities we will execute scans of area of interest from various standpoints with various parameters of scanning. Suggestion of its number and locations has to fulfil the most appropriate configuration. Scans will be connected with help of identical points by method of spatial transformation.

In order to be compared spatial posit position of reference entities determined by laser scanning with other independent method it is necessary to carry out terrestrial measurements of reference points of entities with exploitation of classical measurements processes and instruments corresponding accuracy.

Geometry of reference entities we know from "production" with accuracy of 0,03 mm (accuracy of machine treatment).

From point clouds obtained from scanning process we produce reference entity models. Consequently we will analyse determination accuracy of measured points, surfaces and entities. Entities enable us to verify not only nominal values but also their geometric properties (alignment of entity surfaces, perpendicularity of planes, reciprocal angle between surfaces, alignment of cylinder pedestals, symmetry of planes, planarity, etc.).

## 4. CONCLUSION

Complete test introduces very serious and difficult process, which demands detail solution of many procedures from the physical, constructional, mathematical, statistical point of view. With successful realisation of test we obtained complete accuracy characteristics of TLS, which will be important contribution especially for TLS's users as well as for wide geodetic public, which will be "consumer" of measuring results realised by TLS.

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## BIOGRAPHICAL NOTES

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Study Geodesy and Cartography SUT Bratislava 1977-82. Doctoral study at the Department of Surveying at SUT Bratislava in 1982-85. Senior lecturer at the Department of Surveying – lectures and seminars from Geodesy for CE, Geodesy for Water Managers and Construction Engineers, the Underground and Mine Surveying and Engineering Surveying, Measurement Systems in Engineering Surveying and Surveying in Civil Engineering (the study program in English). From 1990 - 1992 lectures and seminars at the TU Vienna from Geodesy and Engineering Surveying. Chairman and member of State Exam and Diploma Commissions at TU Brno, Uni Žilina and at SUT Bratislava and the Slovak Chamber of Surveyors and Cartographers. Member of the European project EEGCES, WG1. Delegate national of the Com.2 (Education) of the FIG. Member of the board of Geodetski list (Croatia) and the WG's of FIG and IAG, which activity is oriented to implementation of laser technology in geodesy.

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