Maintaining Length and Angle Standards in The Republic of Serbia within the Geodetic Metrological Laboratory

Sinisa DELČEV, Violeta VASILIĆ, Vukan OGRIZOVIĆ and Jelena GUČEVIĆ, Serbia

Keywords: metrology, quality assurance, standard, metrological laboratory

SUMMARY

Comparing and maintaining standards represent a foundation for establishing and maintaining a quality system of a scientific technical field of study. The role of a standard, as a materialised measure, reference material or a measuring system is to define, establish, keep or reproduce a unit or one or more measurement values as well as to serve as a reference. Within the Metrological Laboratory of the Belgrade Faculty of Civil Engineering (ML-160), there are current standards regularly used for probing or verifying length and angle measurement instruments. According to the quality assurance system, current ML-160 standards are periodically controlled by the laboratory staffs who continuously work on advancing both equipment and the methods of work. This paper provides a review of former activities and the current state in maintaining quality assurance in geodesy in the Republic of Serbia. Historical review of geodetic metrology in Serbia, as well as, metrological standards on theodolites, total stations, levels, and GPS receivers calibration procedures are given in the paper.

Maintaining Length and Angle Standards in The Republic of Serbia within the Geodetic Metrological Laboratory

Sinisa DELČEV, Violeta VASILIĆ, Vukan OGRIZOVIĆ and Jelena GUČEVIĆ, Serbia

1 INTRODUCTION

Measuring represents a basic part of geodetic works, whether it is related to determining dimensions and shape of the Earth, state survey, both classical and photogrammetric or engineering geodesy. In all the cases, measuring results that meet the requirements of unity and accuracy are expected since they are applicable only as such. Such results have been obtained on the basis of theory and practice of geodetic measuring developed within the long history of geodesy

.

Metrology is the scientific study of measurements. Basically, it is dealing with reproduction and establishing of measuring units, their primary, secondary, working standards, the methods of measuring physical quantities, development and creation of measuring devices, improving measuring procedures and quality of measuring performance, as well as all other issues related to measuring regardless of their accuracy (Federal Institute for Measures and Precious Metals, 1998). Metrological quality assurance is a set of rules, technical means and necessary measures taken to provide the required accuracy of measuring.

Geodetic metrology is a science on geodetic measuring, above all their basic quantities - length and angle, as well as all accompanying quantities (time, frequency, temperature, pressure, surface, gravity acceleration, electric dimensions, etc.) (Mrkić, 1991)

The allowed tolerances in contemporary geodetic measuring are considerably lower that they used to be. Therefore, the requests for precise measuring and considerably higher level of geodetic control have been increased for a good reason. Fulfilment of such requests is possible only if sufficient attention is paid to the issue of testing and verification of geodetic measuring instruments.

Such a system of metrological quality assurance cannot be imagined without a well organised and equipped geodetic laboratory. The metrological laboratory of the Department for Geodesy (ML-160) started its work in 1985. This is the first laboratory in this region that performed and still performs probing of all geodetic measuring tools - instruments, measuring rods and tapes...

The laboratory’s accreditation ensures the product, material or tools to be tested, inspected and calibrated in an appropriate way and according to prescribed legislation and standards. This accreditation also ensures formal acknowledgment of the laboratory’s competence and validity of results abroad, by concluding international contracts on mutual acknowledgment and entering relevant international organisations (ILAC - International Laboratory Accreditation Cooperation, ECA - European Cooperation for Accreditation).

As a basic document for accreditation of their laboratories, the majority of organisations used ISO/IEC Instruction 25, and EN 45001. As a result of a comprehensive experience in implementation of these two standards, a new standard ISO/IEC 17025 has been created instead of the previous two.

A standard defines, establishes, keeps or reproduces a unit or one or more measurement values. It also can serve as a reference. For a quality assurance system existence, current standards of a laboratory have to be periodically controlled by the laboratory staffs.

2 HISTORICAL FACTS

All the geodetic networks in the territory of the Republic of Serbia have been developed as integral parts of the networks of the former SFR of Yugoslavia. Thus the reference position networks in two epochs, First Order Triangulation Network (TM1) and Astro-Geodetic Network (AGM) have been developed, as well as reference altitude networks in two epochs First Order Levelling Network (NVT I) and Second Order Levelling Network (NVT II), gravimetrical network and local reference networks as separate entities. With the disintegration of SFRY, reference 3D networks were developed with the use of GPS technology for each new state.

2.1. Metrological Quality Assurance of Geodetic Reference Position Networks

The entire region of the former SFRY is covered with the State Trigonometric Network of 1st order (TM1) comprised of 595 triangles. This network **has never been adjusted as a whole**, and individual adjustments were carried out by connecting to MGI points (*Militar Geogräphischen Institutes - Wien)*. TM1 is comprised of several parts that were developed and calculated in various time epochs, from 1872 to 1946. At this moment, with all its shortcomings, this 1st order triangulation represents the foundation of state survey of Serbia.
All the measuring instruments were tested according to the Manual, which comprises detailed propositions and procedures for all types of measurements.

2.2. Metrological Quality Assurance of Geodetic Reference Altitude Networks

The works on the creation of reference altitude network (Precise Levelling and High Accuracy Levelling I) in the territory of the former Yugoslavia started in 1871, when the Commission for European-Grad Measuring entrusted MGI with realisation of Precise Levelling in the territory of Austro-Hungarian Monarchy. In the period 1873 to 1898, a precise levelling traverse network was developed.
The second part of levelling works in Serbia was carried out in the period 1905 to 1911 by Geographic Department of the Serbian Army Headquarters. The Department used two new levels of the Swiss factory Kern and one-piece rods of 3 m (the length of rods were daily controlled with the invar scale).
The new epoch of high accuracy levelling started after the Second World War in the period 1946 to 1963 when a considerable part of the network was reconstructed.

The new network of high accuracy levelling (NVT II) was constructed in 1970, and measuring was carried out from 1971 to 1973 according to then existing modern recommendations of the International Union of Geodesy and Geophysics.

The inclination angle was determined once a month. Invar rods were tested at Federal Institute for Measures and Precious Metals in Belgrade. Also, field testing with the Blay comparator, Geneva scale was performed.

2.3. Metrological Quality Assurance of Astrogeodetic Determinations

Before the First World War, astrogeodetic determinations were described by the operator and observer of these determinations, S. Bošković in the publication "Vertical Deflection in Serbia". Only latitudes and azimuths on 30 points were determined. Astronomical universal theodolites Kern and Ericsson marine chronometers were used for measuring. Astrogeodetic determinations between two wars were carried out by MGI.

Within the grad measuring and according to national reports to the International Association of Geodesy, around 40 points were determined. These reports contain the data on measuring methods, instruments and operators.

In 1954, the MGI astronomy group started astrogeodetic works on **Laplace points**, using the astronomical universal theodolites Askania, as well as passage instruments with contact micrometer Askania.

For astrogeodetic determinations on **geoid points**, astronomical universal theodolites Wild T4 were used, along with the accompanying equipment for time keeping, time registration and reception of time signals.

Aiming at eliminating systematic error detection related to determination of astronomical longitude in the field, as well as at deriving all results into a unique system, the following is of an outmost importance: (1) Analysis of calibration measuring in the Astronomical Observatory Belgrade before and after field determination and in regards to prime meridian, and (2) Incorporating this point into the European Longitude Network.

2.4. Metrological Quality Assurance of Gravimetric Measuring

Calibration gravimetric works represent a set of activities defining an absolute level and scale of gravimetric determinations for a country. Determination of an absolute gravimetric level was related to a concrete pillar at Zemun Airport. The determination comprised of linking it with an absolutely determined point in Paris.

For calibrating gravimeters and ensuring a unique gravimetric scale, a big base Belgrade - Skopje was established (which was later extended), as well as small bases Avala, Sljeme and Krim.Given the great importance of the correct level and scale of national gravimetric determinations, the control was performed twice, by measuring on Italian bases

.
Along with the works on the calibration bases, the works on establishing the 1st order gravimetric network were carried out. Acceleration differences within the network were measured with Worden gravimeter, whose large limb was calibrated on French bases. Systematic errors of the large limb were eliminated in a special way.

Forming and measuring in the main gravimetric network were carried out by FGA in the period 1964 to 1967. Measuring in the network was carried out according to the step method, with the gravimeter North American AGL. Calibration was performed on the base Avala foot - Avala top, in order to ensure a unique scale. The change of scale in time was monitored by periodical constant determination, usually once a month.

2.5. Local Reference Networks

By the Second World War, the only regulations that existed were those related to surveying details in towns, but main geodetic networks were not separated from the networks outside of towns, nor was higher accuracy of town network points required. Due to short baselines in town networks, certain sources of errors in measuring resulted in the poorer quality and accuracy of these networks in regards to those outside of towns. Therefore, the main town networks were separated as independent entities and in 1956 the Regulation on Geodetic Works in Towns was enacted, defining all the procedures in the realisation of networks.
A big step in positioning was made by introducing satellite observations with the GPS technology. All these technological improvements have resulted in the change of approach to the concept of constructing and realisation of local geodetic position networks with the expert geodetic public.

3 STATE OF METROLOGY IN SERBIA

Rights and obligations of our country in the field of metrology are regulated through the Serbian Accreditation Body (former YUAT) and the Bureau for Measures and Precious Metals - DMDM (former Federal Institute for Measures and Precious Metals).

Serbian Accreditation Body

Establishing the system of accreditation of laboratories for testing measuring instruments started in 1998 and was finally shaped with (Law on Accreditation, 2005), according to which the entire accreditation procedure was entrusted to Serbian Accreditation Body (ATS). This body is the only body authorised for issuing certificates (accreditations) to laboratories that meet the criteria foreseen by regulations and standards harmonised with the European standards. Since 2002, ATS has been the associated member of EA (European Accreditation), completely implementing all the regulations and rules passed by this organisation.

Bureau for Measures and Precious Metals in Belgrade

At the state level, Bureau for Measures and Precious Metals is the first grade laboratory and the most responsible institution for the organisation and coordination of work in the field of legal metrology. It has large human potential, equipment and laboratories in the field of metrology. Laboratories for length, angle, time and frequency are particularly important for quality assurance of geodetic measuring instruments. Within its activities, this institution primarily deals with keeping and maintaining primary measuring standards, as well as control and verification of different secondary and working standards.

Department for Geodesy - Faculty for Civic Engineering in Belgrade

Apart from its educational and scientific activities, Department for Geodesy of the Faculty for Civic Engineering as an accredited metrological laboratory for length and angle, and with the procurement of adequate equipment, the laboratory for frequency could be registered as well. Within its existing activities, it has developed methods of comparing and testing geodetic measuring instruments as well as the overall analysis of the method with accuracy assessment. A team of experts with MA and PhD degrees deal with the issues of metrology of angles, lengths and other dimensions present during geodetic measuring.

4. STATE OF MEASURING STANDARDS IN SERBIA

Uniqueness and accuracy of measuring results (comprised of numeric value, measuring units and error date) are ensured by:

- the system of units,
- measuring standards,
- comparing units from the standards to measuring instruments by comparison,
- methodologically and technically correct measuring procedure in order to realise the planned measuring model that allows error assessment,
-
- error assessment according to the rules of the error theory.

The system of legal units of measurement in our country is the SI system. Serbian primary standards of main and derived units of measurement are realised by the Bureau for Measures and Precious Metals, keeping them and comparing them with international standards (Law on Metrology, 2005). For all the measuring dimensions in geodesy (except acceleration), the national primary standards have been compared with international ones and are kept in BIPM database, and thus it is possible to realise metrological traceability for all geodetic measuring instruments

.

For the reproduction of units, their keeping and comparing to measuring instruments and standards of lower accuracy category, apart from realised standards, measuring equipment and methods, it is necessary to define a hierarchic scheme for the measuring instruments.

4.1. Length Standards

The national length standard is a system of two helium-neon lasers, equipment for maintaining characteristics of the lasers and equipment for comparison length unit to secondary standards. Comparison values of the length unit to other, secondary and working standards and measuring instruments, is carried out by the interferometrical method and the method of frequency ejection. The measuring process is automatised and is conducted by a computer. The laboratory for length is in DMDM.
The following instruments are used as secondary length standards in geodesy:
- *Mekometer ME 5000,* $\sigma_D = \pm(0.2\text{ mm} + 0.2\times\text{D})\ \text{ mm},\ \text{D}[\text{km}]$
- *Wild DI 5,* $\sigma_D = \pm(3\text{ mm} + 2\times\text{D})\ \text{ mm},\ \text{D}[\text{km}]$
- Laser measuring system *HP 5528A*, with the relative measuring frequency uncertainty of approximately is 10^{-11}.

Field Calibration Bases:

Paraćin Base
Paraćin base was constructed in 1900, for the purpose of development of the 1st order trigonometric network of Serbia. In the period 1976 to 1980, this base was reconstructed by the Republic Geodetic Administration of Serbia. One of the reasons for its reconstruction was the increased need for testing all kinds of geodetic distance meters that were commonly used.
Paraćin base is in the place of old base which was stabilised in 1904. The length of the base is 5,604 m and is divided into parts. According to the measuring plan, all the points are stabilised in the same way.
Measuring of the Paraćin base aimed at establishing standard values is carried out by: invar wires, EOD Mekometer ME-3000, EOD AGA-8 and DI 20.

Measuring of the base was carried out with elaborated methodology of the measuring procedure. Before and after the measuring, the invar wires and electro optical distance meters (EOD) were compared in European laboratories.
Because of the instability of certain pillars, either vertically or horizontally, as well as the years that have passed since the base was last measured, it was necessary for the base to be measured in several time intervals and for the measuring to be compared with previous standard length values.

Palić test network
Palić geodetic network was primarily created for researching possibilities and powers of various kinds of optoelectronic distance meters. Furthermore, this network may serve for probing both instruments for measuring lengths and instruments for measuring angles. However, this network has not been used for many years.

Kovin Base
Within the programme of development of metrological quality assurance for the needs of Military Geographic Institute for length and angle units, an army primary length standard was

established in 1990. Based on the project of the Department of Geodesy, a base on the Kovin location was constructed, with the total length of 2.2 km. Length standards on the base were obtained by measuring with the precise laser distance meter Mekometer ME 5000.

4.2. Angle Standards

The additional SI unit is the unit of plane angle, radian, which is considered a derived unit without dimensions. The nature and characteristic of angle measurement, variety of implementation, various measuring devices and procedures for solving the problem of measuring the angle between two planes or between two materialised directions, requires the primary angle standard to be realised in two ways. With this realisation, comparing of the unit to secondary and current standards of different purposes and characteristics would be ensured. Primary angle standard in our country is realised with 24 sided optical polygon in the laboratory of the Bureau for Measures and Precious Metals.
Geodetic angle-measuring instruments (astronomical universal theodolites, theodolites, tachymeters) through their limbs contain angle standard of a full circle. Limb index is tested in order to get information on the needed count of limb shifts rather than to perform determination of a scale. Consequently the errors of the limb index will have the estimated influence on measuring. In particular cases (static limb) there is an interest in determination of the limb index errors. However, regardless of the purpose, limb index testing is necessary for both accuracy and cost-effectiveness of measuring.

As secondary angle standards in geodesy, the following instruments are used:

- Theodolite *Wild T3 No. 33420* ($\sigma_u = \pm 0.7''$)
- Level *Zeiss NI 002* ($\sigma_{\Delta h} = \pm 0.2 \ \ \mathrm{mm}/\sqrt{\mathrm{km}}$)

4.3. Time and Frequency Standards

Frequency is a quantity derived from the unit for time. It cannot be materialised but only determined within the accuracy of its reproduction. For primary time and frequency standards, a caesium clock Agilent 5071A is used in our country, connected with the multichannel GPS receiver Motorola VP Oncore. This equipment, together with the accessories such are time interval counter with resolution of 0.2 ns and a computer for processing measuring data, make the TTS-2 device (Time Transfer System) and is used for comparisons with the international UTC scale.

In geodesy, time is required as both interval and epoch (date). Regarding the geodetic tasks where time is used as interval (measuring lengths), time standard in terms of atomic clock is used at the Bureau for Measures and Precious Metals. However, for geodetic tasks (geodetic astronomy, satellite geodesy) where time is used as epoch (date), the UTC (Coordinated Universal Time**)** time system is required, with time intervals corresponding to the definition of unit for time, and time displays differing in integer number of seconds from international atomic time - ATI - and through intermittent seconds approximately corresponding to the Earth rotation.

4.4. Acceleration Standards

Understanding the gravity force acceleration is very important for metrology of a number of physical quantities.
Apart from its importance for determining Earth's shape, gravity force acceleration in geodesy has vital importance for the realisation of the altitude system.
Bureau for Measures does not have a laboratory that would determine the absolute gravity force acceleration.

There is a gravimetric base for calibration of gravimeters in the country - "small" base Avala-foot - Avala-top. It has been established that this base needs new determination.

5. METROLOGICAL LABORATORY ML160

Apart from the existence of primary and secondary standards, networks of laboratories, field calibration bases, test networks and modern equipment define and implement procedures and instructions, elaborated methods and procedures for testing and verification of all types of measuring instruments and all kinds of geodetic equipment.
In the beginning, only testing of geodetic measuring instruments were carried out in ML160, since it had been thus regulated by the Law of 1984, and the Certificates of Conformance were issued by the Federal Institute for Measures and Precious Metals. By the end of 1994, the Laboratory of the Department of Geodesy became an authorised geodetic metrological laboratory which apart from testing of geodetic measuring instruments also issued the Certificates on Conformance.
After the changes in legal regulations that related to the work of metrological laboratories in 2002, the Laboratory of the Department of Geodesy became an accredited metrological laboratory for testing instruments measuring angle and length by the Yugoslav Accreditation Body (YUAT). According to the accreditation rules, relevant documents necessary for the work of the laboratory were passed.

Table 1: Tested instruments

Year	GPS	Total station	Level	Theodo-lite	Distance meter	Levelling rod	Measuring tape	Total
2002	-	31	10	1	2	1	-	45
2003	10	94	31	10	7	7	3	162
2004	10	139	46	19	22	-	3	239
2005	66	88	25	9	3	6	4	202
2006	50	144	46	8	7	29	10	294
2007	58	141	63	7	4	2	3	278

5.1 Activities of the Metrological Laboratory

Accredited laboratories often belong to the highest level of internal measurement hierarchy in a certain field (scientific discipline). Their task is to regularly compare their own working standards with the reference standards maintained by the laboratory with the best measuring ability, which is DMDM in our country.

Within European Cooperation for Accreditation of Laboratories (EAL), the highest measuring ability (related to certain measured quantity) is determined as the least measuring uncertainty that a laboratory can achieve within its competencies, when it carries out measuring of almost ideal measuring standards with the purpose of determining, realising, keeping or renewing the unit of that quantity, or when it carries out regular measuring of almost ideal measuring instruments for measuring that quantity.

Within the existing activities of the Metrological Laboratory of the Department of Geodesy, the methods of comparing and testing geodetic measuring instruments have been developed, as well as an overall analysis of the method with the accuracy assessment. A team of experts with MA and PhD degrees deal with the issues of metrology of angles, lengths and other dimensions present during geodetic measuring.

The laboratory has all available technical conditions that are enables comparing of units (for length, angle and frequency) from secondary standards to current standards and measuring instruments present in the geodetic practice. Secondary standards are regularly tested and compared with primary length, angle, time and frequency standards of DMDM, thus ensuring traceability of calibration and measuring to the International System of Units (SI). Metrological quality assurance of geodetic instruments and tools apart from laboratory testing also encompass field testing on calibration bases and test networks.

The activities of the Metrological Laboratory of the Department of Geodesy are defined with special metrological regulations, instructions for testing measuring instruments in geodesy, comprising of the following activities:

- Ensuring and examining metrological regulations, instructions, procedures and internal documents;
- Ensuring and completing the testing equipment;
- Preparing and testing conformity of the testing equipment;
- Reception and recordkeeping of measuring instruments for testing;
- Testing measuring instruments, establishing their conformity, etc.;
- Testing metrological properties and establishing measuring uncertainty;
- Creation and verification of the protocol on testing measuring instruments, putting seals on approved instruments, and
- Issuing calibration certificates.

5.2. Laboratory Equipment and Work Polygons

The main component of the laboratory is adequate measuring equipment tested by DMDM and for which the laboratory has calibration certificates. Measuring equipment encompasses all fields of action and methods of testing geodetic measuring instruments:

a) Laser interferometer system HP 5528A, has a wide range of application for all high precision measuring of length, angle shift, smoothness, keeping of direction, right angularity and parallelism up to 50 m. With adequate positioning of measuring optics, length can be measured in the direction of all three coordinate axes (x, y and z).

Picture 1: Laser interferometer system HP 5528A

Picture 2: Collimator

b) <u>Frequency meter Philips PM6612 of high accuracy</u>, together with the detector of modulated emission of distance meter, is a secondary frequency measuring standard that quickly and efficiently determines a multiplication constant of the distance meter.

c) Distance meter of high accuracy Wild DI5

d) Level Carl Zeiss Ni 002,

e) Theodolite Wild T3,

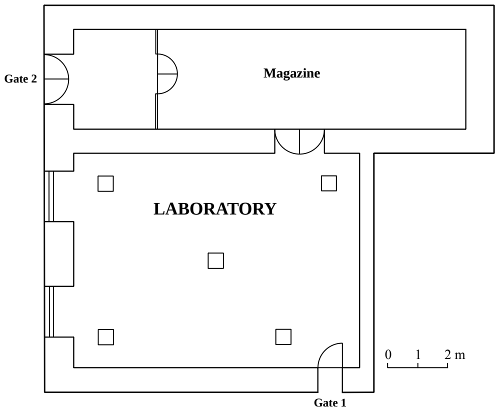
f) Collimator Topcon TC3.

g) bi-frequent GPS system for statics and kinematics, with the possibility of receiving signals from Navstar and Glonass system, Topcon - HiPer GGD and Legacy E.
Work polygon for metrological testing is comprised of:

- polygon of fixed angles
- two polygons of fixed lengths, and
- GPS polygon.
-

The pillars stabilised in the laboratory provide the fixed angles polygon, where testing limbs and other angle indexes is performed. Determination of additional constant of the distance meter is performed with laboratory measuring standards (Picture 3. a), and the measuring accuracy with the adequate field measuring standards (each standard has five pillars). The

GPS polygon encompasses the point of Reference Network of Serbia, located on the roof of the Faculty of Civic Engineering building (Picture 3. b).



Picture 3: a) Metrological laboratory for angle and length b) GPS polygon

One of the laboratory components is a personal computer with a printer with the installed LabView software for controlling and directing the operation of certain instruments and accompanying equipment, ensuring data processing based on the measuring and testing results as well as recording all the data within the geodetic metrological informational system.

5.3. Work Organisation of the Laboratory

Metrological testing of geodetic tools and instruments is carried out by the laboratory members, geodetic experts with the relevant knowledge and experience in metrology in accordance with the requirements of metrological regulations. Head of the metrological laboratory and his deputy are responsible for its work.

In the hierarchy of the work organisation of the laboratory, the head of the second order laboratory is responsible for the work coordination within metrological quality assurance of geodetic measuring instruments and is an initiator of new scientific research. He is an authorised person who signs and issues the calibration certificates for the tested geodetic measuring instruments.

Other members are responsible for length, angle and frequency metrology. They carry out assignments related to testing measuring instruments, developing data processing software and automatisation of testing procedures, as well as to maintaining records and informational system of metrological quality assurance.

5.4. Characteristics of the Measuring Methods

The concept of verification of a measuring instrument is a set of operations that determine whether the measuring instrument fulfils the declared accuracy in a certain moment. A set of operations in the general sense represents a measuring method and it can primarily be the direct measuring method and comparison method.

Apart from the existence of secondary standards, test networks and modern equipment, the organisation of the Geodetic Metrological Laboratory also implies the existence of relevant regulations, defined procedures and instructions, elaborated methods and procedures for testing and verification of all types of measuring instruments and all kinds of geodetic equipment.

In order for the measuring method to provide a relevant optimal result, it is necessary to conduct analysis of the method and previous accuracy assessment, detailed elaboration of the method, result processing and accuracy assessment from the measuring data.

The method analysis includes determination of working method, calibration of measuring instruments, determination of all sources of errors, as well as their character, derivation of formulas for accuracy assessment. The previous accuracy assessment is carried out on basis of derived formulas in the method analysis and by examining obtained measurements for certain sources of errors.

The main characteristics of a measuring method in terms of metrology are the realisation of repeatability and reproducibility of measuring.

EAL recommendations to accredited metrological laboratories are related to **increased measuring uncertainty,** which is obtained by multiplying standard uncertainty of an output value estimation by the covering factor $k = 2$. It is particularly important to accept the recommendations since we are in the process of harmonisation with the European metrological infrastructure.
Testing and verification encompass a number of phases that finally have to provide an answer as to whether metrological characteristics of measuring instruments are as those defined in the manufacturer declaration or possible changes have occurred.

6. IMPACTS ON GEODETIC COMMUNITY

Due to intensive use of geodetic instruments, the noncompliance of instrument conditions can occur, especially vertical index and collimation with total stations, as well as, inclination angle with levels. By calibrating their instruments, the owners obtain information on reasons of instrument conditions from the laboratory staff. After first calibration, the owners ask for calibration of the equipment more frequently, realizing their responsibility of measuring data forwarded to investors. Also, by that means, they contribute to quality assurance system in the national level.
The calibration methods differ from country to country. By comparing methods between laboratories, laboratory specific methods are verified within the international level.

7 CONCLUSION

According to all the above mentioned, it can be concluded that the state of geodetic metrology in Serbia is the following:

- Hierarchy of measuring standards and methods of units comparison has been established.
- The realization of primary length, angle, frequency, and time standards has been performed at the national level. The national primary standards have been compared with the international standards and are kept in the BIPM database, and thus it is possible to realise metrological traceability for all geodetic measuring instruments.
- There are instruments of high class accuracy that can be used as secondary length and angle standards.
- The trend in the contemporary geodetic metrology is that the entire procedure of testing and verification of measuring instruments is carried out in a well-equipped laboratory, with fewer activities in the field.

The realisation of metrological quality assurance of geodetic measuring instruments can be also performed on the field on calibration bases and test networks within which the length and angle measuring standards have been formed. Their regular maintenance could provide conditions for their incorporation in the system of metrological quality assurance.

- Forming information system of geodetic metrology should be initiated.
- It is necessary to form a common service for testing and standardisation of geodetic measuring instruments at the national level.

The goals of further activities of the Metrological Laboratory are as follows:

- Implementation of the quality policy,
- Improvement of the geodetic metrological information system,
- Membership in national and international metrological institutions, as well as
- Extending the scope of activities by introducing new working methods and procuring adequate equipment for secondary standards.

REFERENCES:

[1] Delčev S.: Existing State Trigonometric Network of FRY in the Light of Contemporary Requirements, doctoral thesis, Faculty of Civil Engineering, Belgrade, 2001.

[2] Dragićević S.: Model of Metrological Quality Assurance of Geodetic Measuring Instruments, master thesis, Faculty of Civil Engineering, Belgrade, 1992.

[3] Milovanović V.: Metrological Basics of Geodesy in SFRY, Counselling - basic geodetic works and equipment for their realisation, Struga, 1987.

[4] Mrkić R.: Addendum to the Programme of Development of Geodetic Activities in Serbia - Geodetic metrology, Geodetic Service 59, Belgrade, 1991.

[5] Mrkić R.: Geodetic Metrology, Naučna knjiga, Belgrade, 1991.

[6] Geodetic Reference Networks of FRY, Study, Faculty of Civil Engineering, Department of Geodesy, Belgrade, 1995.

[7] Project of Yugoslav Reference GPS Network, Faculty of Civil Engineering, Department for Geodesy, Belgrade, 1998.
[8] Dictionary of Legal Metrology, DMDM, Belgrade, 1998.
[9] Law on Measuring Units and Measuring Instruments, Official Gazette of FRY, No. 12/98, Belgrade, 2000.
[10] Law on Accreditation, Official Gazette of Serbia And Montenegro, No. 44/05, Belgrade, 2005.
[11] Law on Metrology, Official Gazette of Serbia And Montenegro, No. 44/05, Belgrade, 2005.
[12] Milovanović V. and others: Using distomat DI 20 for Determining Field Length Standards, JUKEM 86, Collection of Papers, Belgrade, 1986.
[13] Rules on the Quality of the Metrological Laboratory for Angle and Length Testing, Faculty of Civil Engineering, Belgrade, 2002.
[14] Marendić-Miljković J. and others: Serbian Time and Frequency Standard, Congress of Metrologists 2007, Zlatibor, 2007.
[15] http://www.bipm.fr/
[16] http://www.iso.org/
[17] http://www.juat.gov.yu/

BIOGRAPHICAL NOTES

Prof. Dr. Siniša Delčev, born in 1959. Graduated in 1982 as Dipl.-Ing. in Geodesy and obtaining doctorate degree in 2001, both from Belgrade University, until 1983. teaching assistant at Belgrade University. Since 2002. Assistant Professor of Geodetic Metrology and Higher Geodesy

Violeta Vasilić, born in 1968. Graduated in 1994 as Dipl.-Ing. in Geodesy from Belgrade University, until 1995. teaching assistant at Belgrade University. Since 2006. Secretary of the Chair of Geodesy and Geoinformatics, Faculty of Civil Engineering, Belgrade University.

Prof. Dr. Vukan Ogrizović, born in 1970. Graduated in 1996 as Dipl.-Ing. in Geodesy and obtaining doctorate degree in 2007, both from Belgrade University, until 1997. teaching assistant at Belgrade University. Since 2008. Assistant Professor of Geodetic Astronomy.

Prof. Dr. Jelena Gučević, born in 1970. Graduated in 1994 as Dipl.-Ing. in Geodesy and obtaining doctorate degree in 2005, both from Belgrade University, until 1995. teaching assistant at Belgrade University. Since 2002. Assistant Professor of Surveying.

CONTACTS

Assistant Professor Siniša Delčev, Ph.D.
Faculty of Civil Engineering
Department of Geodesy and Geoinformatics
Bulevar kralja Aleksandra 73
Belgrade
SERBIA
Tel. + 381 11 3370293
Fax + 381 11 3370293
Email: delcev@grf.bg.ac.yu
Web site: www.grf.bg.ac.yu

Teaching Assistant Violeta Vasilić
Faculty of Civil Engineering
Department of Geodesy and Geoinformatics
Bulevar kralja Aleksandra 73
Belgrade
SERBIA
Tel. + 381 11 3370293
Fax + 381 11 3370293
Email: tatic@grf.bg.ac.yu
Web site: www.grf.bg.ac.yu

Assistant Professor Vukan Ogrizović, Ph.D.
Faculty of Civil Engineering
Department of Geodesy and Geoinformatics
Bulevar kralja Aleksandra 73
Belgrade
SERBIA
Tel. + 381 11 3370293
Fax + 381 11 3370293
Email: vukan@grf.bg.ac.yu
Web site: www.grf.bg.ac.yu

Assistant Professor Jelena Gučević, Ph.D.
Faculty of Civil Engineering
Department of Geodesy and Geoinformatics
Bulevar kralja Aleksandra 73
Belgrade
SERBIA
Tel. + 381 11 3370293
Fax + 381 11 3370293
Email: vasovic@grf.bg.ac.yu
Web site: www.grf.bg.ac.yu