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Measurements infrastructure – futurological considerations

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Abstract

Futurology as science for predicting humanity progress is important for planning specific steps to be taken today.

Author made an attempt of scientific prediction concerning development of such important measurement infrastructure components as comparisons of measurement standards, interlaboratory comparisons of measurement results and calibration. Current state of this measurement infrastructure component should be improved to meet the challenges of a complicated and changeable environment. Comparisons of measurement standards are not performed often. Number of participants is limited. CMCs are difficult to obtain. Interlaboratory comparisons and calibrations are separated from comparisons, etc.

Idea of measurement infrastructure future improvement is substantiated. Global informatization provides advantages and opportunities for it.

The answer to modern challenges is seen in the creation of the **Comprehensive Measurement Traceability Network** (hereinafter – the **Network**). The Network is assumed to be the most automated and consequently, the fastest, the most dynamic and comprehensive. Various levels of comparisons for various measurement methods and submethods can be initiated fast, easy and without restrictions. They can be provided continuously, without interruptions. Interlaboratory comparisons and calibrations should be directly linked to comparisons of measurement standards in the Network. Interlaboratory comparisons initiated in the Network differ from comparisons of measurement standards only in the factor that they will be initiated for working measurement standards and instruments. Subjective human factors in initiating, planning, processing and analyzing measurement results will be significantly reduced in the Network.

The purpose, basic (but not all) tasks and principles of such Network future work are formulated. Its advantages are underlined.

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1. Introduction

Future without human-created inventions is impossible. Existing order in comparisons of measurement standards, interlaboratory comparisons of measurement results, and calibrations should not be radically changed in future. Discussion about the possible evolution scenario of this area is the goal for the future.

Comprehensive Measurement Traceability Network creation is one of the possible development ways. Author considers it as the balanced consolidation of measurement standards comparisons, interlaboratory comparisons of measurement results and calibration. Measurements provided by the Metrological Community both national and designated metrological institutes and calibration, measurement and testing laboratories will be consolidated. The name

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Network means that the main purpose of its creation is transparent, fast and reliable provision of measurement traceability. Word «Comprehensive» means that all measurement infrastructure components from separate calibration and testing laboratories to national metrological institutes and possibly metrological systems of industry, agriculture, medicine, etc. can be integrated on a voluntary basis.

Concrete definition of some questions is avoided consciously, for example, participation and role of concerned international organizations, national and designated metrological institutes, accreditation bodies, providers, laboratories of enterprises and calibration laboratories, etc. (hereinafter – Metrological Community) in the Network. Detailed analysis of measurement infrastructure current state and its basic international documents is also avoided. This infrastructure and documents are well known. Fragments of new propositions are compared with the existing infrastructure fragments. Particular important organizational and technical questions connected with national metrological institutes, designated institutes and various laboratories, future Network users (hereinafter – laboratories) overviewed in detail.

Comparisons of measurement standards, interlaboratory comparisons of measurement results and calibration have different procedures, though different measurement methods or submethods are more or less similar. Author is confident that these procedures are organizationally similar. They are often identical in terms of the final result. For example, length of gauge blocks and their uncertainty values are obtained in the process of measurement standards comparisons, interlaboratory comparisons or calibrations. This result does not depend on available measurement standards, measurement methods and their results processing. Taking this into account, the author recommends considering measurement during comparisons of measurement standards, interlaboratory comparisons or calibrations applicable for processing in Comprehensive Measurement Traceability Network in terms of this publication.

In prospect Network consolidates international agreements, rules, procedures, descriptions of mathematical apparatus, software, measurement results and their processing results databases, statistical databases on the measurement standards maintained in the laboratory and travelling measurement standards of institutes and laboratories, administrative, organizational and technical instruments, providing its functioning.

2. Necessity of the new Network

Before publishing the basic principles of the Network, the author repeatedly asked himself particular questions, which can occur to any metrologist, not exactly while reading this article. Argumentation of the Network creation is logical to express as a series of questions and answers.

Will it be the necessity for participants of the proposed Network?

Yes, it will. One of the main reasons for Network creation may be laboratories necessity for comparisons of measurement standards and interlaboratory comparisons of measurement results loops.

Does the period of comparisons comply with necessity?

No, it doesn't. Particular comparisons are provided not frequently and last for years, that doesn't comply with necessity.

Is the comparisons organization burdensome for the pilot laboratory?

Yes, it is. Initiation, providing and finishing comparisons are frequently delayed for this reason.

Do CMCs *publication period comply with necessity?*

No, they also don't. This procedure lasts for years due to particular subjective and objective reasons.

Are too high bureaucratization and lack of automation main reasons for a long period?

Yes, they are.

Is comparison procedures formalization a solution for their further automation?

Yes, it is.

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Do other laboratories have the necessity for comparisons and interlaboratory comparisons not only national and designated institutes?

Yes, they do.

Is the quantity of comparisons provided in particular measurement methods and submethods sufficient for effective measurement units reproduction?

No, it isn't.

Does the comparisons procedure exclude subjective factors?

No, it doesn't.

Is there a need to reduce the subjective factor through further formalization and automation of procedures?

Yes, it does.

Questions list can be continued.

Anyhow answering those questions everybody participated in discussion concerning ways of Network creation.

Report [1] was analyzed for confirming these questions relevance. The same or similar problems are analyzed in the report. The main problem is the long period between comparisons or their absence in case of necessity to confirm measurement capabilities and publish CMCs. Contradictions between «issuing NMIs» [1] having CMCs in the JCRB database and «applicant NMIs» [1] having no such rows still exist. They have necessity for such rows and have no possibility to obtain them. Moreover, key comparisons participants are «issuing NMIs» as a rule. «Applicant NMIs» [1] should participate in supplementary comparisons.

So called hybrid comparisons are proposed as a solution. Detailed scheme of such comparisons is published in [1]. Briefly, their procedure is as follows. Artefact is calibrated by «applicant NMI». Materials are sent to the chairman of the regional metrological organization technical committee according to the measurement method. Artefact is calibrated by «issuing NMI». Materials are transported correspondingly. Technical committee is an independent third party. Committee compares calibration results and publishes report. Third-party experts are involved in the analysis of the report. If calibration results coincide within claimed measurement uncertainty, then CMC should be provided to «applicant NMI». Otherwise «applicant NMI» takes consequences for big discrepancy in the measurement results. In [1] Metrological Community stated particular support to such propositions, but they have obtained no recognition or realization yet. Doubts about the impartiality of the hybrid comparisons process still remain.

Thorough analysis of [1] discovers a rational kernel of hybrid comparisons, regardless of this negative questions and logical answers occurring to them.

Is the subjective human factor excluded in organization, providing, analyzing and publication measurement results of hybrid comparisons?

No, it isn't. It increases to some extent, so the lack of Metrological Community support and trust is observed.

Do propositions [1] include automatization procedure of the organizing, providing, analyzing, processing and using measurement results of hybrid comparisons?

No, they don't. Automatization is absent. This procedure is manual and bureaucratic, includes subjectivity.

Is scientific approach implemented in processing and analyzing final measurement results of hybrid comparisons? Is such an approach possible?

No, it isn't. Such an approach is absent. «Applicant NMI» is responsible for all discrepancies. Accumulation and analysis of statistical data based on the continuous measurements results is not provided.

Can other competent «Applicant» laboratories except NMI participate in hybrid comparisons?

No, they can't. Their participation in comparisons is impossible.

The list of hybrid comparisons disadvantages can be continued.

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3. Measurement subjects and objects

In [2] the author proposed several expanded measurement models for using them in the processing measurement results during measurement standards comparisons, interlaboratory comparisons and calibrations. Models were introduced particularly for use within the Network. As they are assigned for various measurement results processing by various measurement methods and submethods, so they could not be introduced without two new general terms: measurement subjects and measurement objects.

Grounding for these terms introduction is given in [2]. Terms introduction is based on the definition of measurement [3]: «2.1 measurement is the process of experimentally obtaining one or more quantity values that can reasonably be attributed to a quantity».

The following definition of **measurement** as a process of measurement subject and measurement object interaction, which results in quantity value does not contradict it. This definition is given for the introduction of the two new important terms.

Measurement subject is one that realizes or reproduces the quantity value during measurements.

Measurement object is one to which the quantity value is reasonably assigned based on the measurement results.

Measurement subject corresponds to measuring instrument, measuring system, comparator, sensor, meter, etc.

Measurement object corresponds to the single valued or multivalued measure, material measurement standard, gaseous mixture measurement standard, measurement standard installation, for example, force machine (dead-weight force machine or the lever one), field linear comparator, etc.

Based on the introduced terms and their definitions measurement subjects as well as objects should be both travelling and maintained in the laboratory. Thus, in the process of the comparisons and the interlaboratory comparisons and calibrations measurement subjects as well as objects may circulate between the laboratories. It depends on the particular measurement method and sub-method.

Measurement results and measurement subjects and measurement objects parameters are connected by measurement models. The simplest and common measurement model is direct quantity value measurement model. It is widely used and more or less explained in [4–11].

Extended, multipurpose form of this measurement model is analyzed in [2, 12–14] in terms of measurement results processing for comparisons of measurement standards. Let us put it for example:

$$x_j^i = y^i + d_j + x_j^i \cdot b_j \qquad (1)$$

where

x_j^i is measured by the measurement subject quantity value with number j, reproduced by measurement object with number i;

y^i is quantity value reproduced by the measurement object with the number $i = 1 \ldots i \ldots n$ (**measurement object parameter**);

d_j is **additive measurement subject parameter** with the number $j = 1 \ldots j \ldots k$;

b_j is **multiplicative measurement subject parameter** with the number $j = 1 \ldots j \ldots k$.

In [2], except model (1), five similar models are proposed. For example, in [15] model of direct measurement results comparison of several interferometers is analyzed in detail and in [16] direct measurement of increment quantity value from [2] is analyzed. So, these models are used for estimation of the quantity values reproduced by the measurement objects and the additive and multiplicative parameters of the measurement subjects. Use of several multipurpose measurement models allows to include a wide range of measurement standards and measuring instruments using measurement methods and submethods into the Network.

These measurement models are multipurpose and can be applied for interlaboratory comparisons and calibrations. Measurement object y^i parameter can be either key comparison reference value or reference value for the lower level comparisons. It can be assigned value in the process of the interlaboratory

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comparisons or the result of the measure calibration. Measurement subject d_j and b_j parameters can be additive and multiplicative degrees of equivalence in the measurement comparisons process, the functioning performance of laboratories in the interlaboratory comparisons process according to [17, 18], additive and multiplicative measurement biases (2.18 VIM [3]) in the calibration process according to [19], or the corresponding corrections (2.53 VIM [3]) in the measurement process.

The following use of the measurement term means that it can be used in the measurement standards comparisons, interlaboratory comparisons or calibration processes. Such measurements are considered for separate or combined processing within the Network.

It is necessary to mention that d_j parameter can be interpreted as an estimate of the additive systematic error (bias) of the measured quantity value at the zero point of scale reproduced by the measurement subject. Correspondingly, b_j parameter can be interpreted as an estimate of the multiplicative systematic error (bias) of the measured quantity value, which is realized or reproduced by the measurement subject.

Consequently, the Network can be described using proposed terms as general for various measurement methods and submethods.

4. Futurological considerations concerning the new Network functioning concept

4.1. Goal and tasks of the Network creation

Policy for mutual recognition of measurement standards, calibration and measurement capabilities of National Metrology Institutes (NMIs) is established by [20, 21]. One of the main goals for mutual recognition is the demonstration of measurement results traceability to the SI units. Necessary attributes of traceability demonstration are documented unbroken chain of comparisons-calibrations and measurement uncertainty of each component in this chain.

Author is confident that the order of traceability demonstration is declarative.

In the process of key comparisons organized by International Bureau of Weights and Measures (BIPM), key and supplementary comparisons organized by Regional Metrological Organizations, NMIs declare their measurement results uncertainty. This measurement uncertainty is a priori relative to the following comparisons therefore, as confirmed only by internal research, calculation and statistics of the laboratory. Such uncertainty is nothing but declaration. Comparisons are necessary to confirm it. Omitting details, the same may be said about interlaboratory comparisons as well as accreditation procedure for calibration laboratories at all.

Participation in comparisons is successful when measurements standard [5] by which measurements during comparisons were provided, the degree of equivalence is less than expanded uncertainty declared in a particular measurement point. Moreover, a widespread problem is when declared by NMI a priori measurement uncertainty can be more or less than real one several times.

Based on successful comparisons result, NMIs declare their measurement capabilities by CMCs. CMC declarations are submitted for RMO technical committees. CMCs are reviewed by experts, revised based on their remarks (if available) and approved by voting.

Reference to [5] as a recommendation for measurement results processing is in Guidelines for Planning, Organizing, Conducting and Reporting Key, Supplementary and Pilot Comparisons of Consultative Committee for Electricity and Magnetism (CCEM) [22]. In [5] statistical evaluation of comparisons results is consciously avoided. Confirmation of comparisons participants declarations concerning claimed measurement uncertainty is observed. Confirmation of comparisons participants declarations concerning claimed measurement uncertainty is common for the majority of published reports on comparisons.

Laboratories accreditation by national bodies according to [19] is the bureaucratic procedure with declaration confirmation by accreditation field. Precondition for the declared accreditation field acceptance is measurement results traceability realized through calibration of the laboratories measurement standards by other accredited laboratories or NMIs having CMCs [20].

Interlaboratory comparisons of measurement results according to [17] are local procedure for personnel proficiency confirmation of calibration, testing and measurement laboratories. Laboratory assigns uncertainty to its measurement result claiming its own measuring capabilities. The ratio of measurement result deviation from reference value to the combined uncertainty provides for the analysis of the functioning performance of laboratories. The functioning performance of laboratories is accumulated and analyzed according to [7]. Real measurement uncertainty assessment according to accumulated statistical data is not provided.

Author never considered above-mentioned declaration with further confirmation unnecessary or unreasonable procedure. Nevertheless, taking into account the declarative character of the current order of traceability demonstration, it can't be comprehensive and completely reliable.

The goal of Comprehensive Measurement Traceability Network creation is gradual transition to traceability demonstration order through indicators obtained by measurement statistics.

Measurements are performed by own or sent to them measurement subjects on their own or sent to them measurement objects. Statistical analysis is provided for measurements obtained by laboratories in particular period.

Thus, laboratories continuously perform measurements and publish them in the Network. All measurements are periodically processed by special software with specially developed mathematical apparatus (e. g. Section 3 and [2, 12–16]) in the Network. Hereby, they are combined in the Traceability Network. Hierarchy of the measurement standard traceability will be firstly determined by claimed uncertainty. Further it will be ascertained by statistical data from measurement results from the Network processing.

The more (within reason) measurements are performed in the Network per the unit of time by the larger number of laboratories, the higher accuracy of measurement unit realization is totally. The more links between measurement objects and subjects in the measurement process are obtained the more reliable measurement traceability will be within the Network.

Aims (principles) for the Network creation:

- basing on BIPM and ILAC principles;
- maximum consolidation of Metrological Community members performing measurements by the Network;
- simplicity and clearness of the main principles of the Network functioning and mathematical apparatus to the Metrological Community;
- maximum ease and convenience for the Network users;
- maximum possible exclusion of subjective factors influencing measurements organization, processing and reporting their results based on measurements in the Network;
- including larger number of travelling and maintained in the laboratories measurement subjects and objects for circulation within the Network;
- possible creating of more links between measurement objects and subjects through measurement results put into the Network;
- combined processing of large quantity interconnected measurements by multipurpose mathematical apparatus;
- increasing the certainty of measurement units by processing of measurement results pool by particular measurement method or submethod in the Network;
- increasing efficiency (time reducing) of measurement units distribution from measurement standards with the highest precision to working measuring instruments;
- expediting of measurement results processing;
- fast and effective use of processed measurement results;
- substantial reducing of labour intensity and manual labour amount in the measurement results processing compared to the similar work performed without automation.

Principles and rules of using Network should be developed and adopted by Metrological Community.

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Metrological Community elects qualified Network Administrator. He realizes the Network on its behalf according to the adopted principles and rules.

Main principle of Network realization by Administrator is maximum automation and impartiality of:

- measurements organization;
- measurement results processing;
- measurement results reporting;
- measurement results using.

The Network is the technical realization of adopted by the Metrological Community agreement on organization of obtaining, processing and use measurement results during comparisons of measurement standards, interlaboratory comparisons of measurement results and calibrations.

Network is assigned for automation of measurements organization, automated results obtaining and processing, automated publication of measurement results and their processing, saving the results and providing free access to them and free (intended) use. Administrator organizes software development for this automation on behalf of the Metrological Community.

In general, omitting for some time questions on economic feasibility of the Network creation author is confident that Administrator's work should be commercialized. Laboratories expenses for Network use will be compensated, as a result of subjects and/or objects exchange among the laboratories and measurement results processing in the Network:

- measurement subjects and objects parameters should be considered **estimated**;
- uncertainty of the measurement subjects and objects parameters should be considered **estimated** according to statistical data from combined measurements processing throughout the Traceability Network;
- measurement subjects and objects of the laboratories which are/were circulating within the Network should be considered **calibrated**;
- calibration results should be considered **traceable**;
- calibration methods should be considered **validated**;
- laboratories measurement capabilities and personnel proficiency should be considered **confirmed**;
- time and costs of laboratories for their measurement standards calibration, accreditation and preparation for it, interlaboratory comparisons loops should be **reduced**.

As a result, the infrastructure of separate measurement traceability chains should be integrated into the comprehensive infrastructure of the Traceability Network.

4.2. Main principles of the Network functioning

Work within the Network should be based on particular principles regardless of measurement standards comparisons, interlaboratory comparisons or calibrations provided. Taking into account that measurements are performed due to these procedures, the main principles of their organization are as follows.

1. **Free initiation of the measurements**

Measurements are initiated by any laboratory complying with the particular criteria. The Metrological Community establishes the criteria and the Administrator monitors following them. Initiating laboratory, fills in the questionnaire in the Network before start of measurements. Administrator checks compliance with the criteria and approves. Measurements are initiated.

2. **Free access to measurements**

Any laboratory intending to participate in measurements fills in the questionnaire in the Network. It is approved by the Administrator for participating in measurements if it complies with the criteria established by the Metrological Community. The new participant is involved in particular measurements.

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The Network's logistics part automatically includes the involved laboratory in the measurement schedule.

3. **Measurements continuity**

Particular quantity of measurement subjects and objects belonging to various laboratories were involved in the measurements and were circulating among them. Circulation is provided according to the schedules compiled in an automated mode taking into account logistics optimization. Optimization criteria are established by the Metrological Community.

4. **Measurement units traceability**

During the measurement process the Network should stimulate and provide technical links among measurement standards groups, which differ by measurement uncertainty. Traceability chains should be integrated into the Network. Such integration is provided by increasing the number of links between measurement subjects and objects circulating among the laboratories.

5. **Mathematical unambiguity of processing**

Measurement subjects and objects parameters and their uncertainties should be calculated by the least square method, e.g. [2, 12–14]. Mathematical apparatus and corresponding specialized software update is provided by the Administrator.

6. **Confidentiality**

Metrological Community establishes levels of available information confidentiality in the Network. Administrator controls confidentiality adherence. Laboratories should have the opportunity of changing confidentiality levels for particular information, which they enter into the Network.

7. **Separation by the measurement uncertainty**

Software controlling logistical optimization plans measurements performance for subjects with similar claimed uncertainty. Further uncertainty obtained by statistical data from measurements processing is calculated automatically.

8. **Security**

The Network should be secured from unauthorized interference and data manipulation. Administrator ensures secure mode of the Network operation.

9. **Reliability**

Quantity of measurements and their uncertainty should comply with requirements for parameters of measurement objects and subjects with acceptable uncertainty estimated by the statistical processing results.

10. **Voluntariness**

Nobody can oblige the laboratory to use the Network for organization, processing, reporting and using materials of measurement standards comparisons, interlaboratory comparisons and calibrations. Laboratory can act in other way. Laboratory can partly organize its own work in the Network and partly otherwise.

4.3. Comments on the «Free initiation of the measurements» principle

Initiating laboratory should comply with simple, understandable and clear criteria, for example:

- initiator should propose the travelling measurement subject or object complying with the Metrological Community criteria for circulation in the Network;
- measurement subject or object is preferable to be kept from participating in comparisons or external calibration before starting circulating in the Network;
- initiator should have measurement subject or object maintained in the laboratory complying with the Metrological Community criteria for calibration of the measurement subject or object maintained in the laboratory;
- proposed travelling measurement subject or object should be subjected to internal calibration by the initiator before starting circulating in the Network;
- measurement results and their uncertainties should be obligatory entered to the Network by the initiator.

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Those measurement results are not public. Though, after subject or object starts circulating, the initiator loses the opportunity to correct the measurement results.

If nobody joined to the initiated measurements for a particular period, then they are removed from comparison and archived. That is, measurements are stopped automatically when all objects or subjects by the particular submethod have passed all the laboratories in the Network according to the schedule and nobody joins the measurements. Comparisons can be initiated repeatedly. Measurement subjects and objects parameters obtained in the previous loop can be used as the reference for repeated comparisons.

Laboratory can use the Network for measurement results processing during any measurement subject or object calibration if it considers used in the Network mathematical apparatus applicable for it. Calibration results can be published in the Network in agreement with the customer. Calibration results of own measurement standards and instruments can be also published.

Creation of «horizontal» measurement links combined with «vertical» measurement links is extremely necessary. Combined adjustment of all measurement results by LSM for a particular period forms the Network.

Measurement results from own measurement standards calibration in two or more laboratories including the own one are encouraged for publishing in the Network. Exchange of similar travelling measurement subjects or objects between the laboratories for cross-calibration with simultaneous «blind» entering of the measurement results into the Network is also encouraged.

Considering that measurement uncertainty of such calibration results will be estimated statistically during comparisons in the Network according to [24] and [25], then such publicity should be positively perceived and encouraged by the Metrological Community and accreditation bodies.

Parallel measurements of similar measurement objects and subjects can be initiated. The Network will propose to combine them by measurement objects and subjects exchange after some time. After this, measurement objects and subjects parameters will be the result of combined measurement results processing.

Measurements based on two or more measurement models with corresponding methods can be initiated. For example, direct method for measurements of gauge blocks length and their comparisons method can be combined.

Additional costs for measurements and their entering to the Network should be balanced by shortening bureaucratic procedures of the laboratory quality management system maintenance [19].

4.4. Comments on the «Free access to measurements» principle

Any laboratory complying with the particular criteria from 4.3 section can join measurements. Laboratory can join the measurements according to a simplified procedure without providing a travelling measurement subject or object for circulating in the Network. Still the laboratory should demonstrate availability of the measurement subject or object complying with the Metrological Community criteria. Laboratory will perform measurements on it during travelling measurement subject or object calibration.

Additional conditions:

- laboratory can join to the claimed quantity measurement process in the part of measurement range or even in particular measurement point;
- measurement range can be expanded if new participant proposed own measurement subject or object with larger range for circulation in the Network.

4.5. Comments on the «Measurement units traceability» principle

The optimum decision is performing measurement process in the Network providing opportunity to join for all concerned National Metrological Institutes. Comparison organization according

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to the Network principles will provide opportunity for 100-150 NMIs and designated institutes to perform comparisons in a relatively short term. Modelling such comparisons of 120 measurement subjects and 192 measurement objects published in [14] undoubtedly proves it. Additive and multiplicative degrees of equivalence (biases) for measurement subjects will be estimated during such comparisons. They will be used as the reference values for the further comparisons and calibrations. This is the highest rank of the Network.

Comparisons of measurement standards will gradually develop into interlaboratory comparisons after joining of designated institutes and competent active laboratories to the Network. Measurement subjects and objects exchange among them will start the Network incrementing from below. Middle rank will gradually develop in the Network.

Small calibrating, testing and measuring laboratories can solve their various problems at the lower rank. For example, they can perform hybrid comparisons procedure as in [1] omitting long-term bureaucratic procedures. For this purpose, laboratories should calibrate their own object or subject and publish results in the Network and send it for further calibration to middle or high rank laboratories with the suggestion of publishing calibration results in the Network.

Relevant measurement subjects and objects parameters and their uncertainties should be automatically used for the further comparisons and calibrations. So, mistakes, which can occur in the process of entering corrections can be avoided and measurement uncertainty can be objectively evaluated through the Network (instead of the single traceability chain).

4.6. Comments on the «Confidentiality» principle

Laboratory may participate in measurements incognito, i.e. laboratory provides its name during involvement to the measurements in the Network with corresponding non-publication mark.

Measurement reports are available for measurement laboratory only before their processing by Network software. Such measurement results are automatically included in the processing. After processing the measurements by the Network, laboratories lose the ability to change them.

List of the adjusted measurement objects and subjects parameters and their technical reports, measurement capabilities of the laboratories, etc. should be public for accreditation bodies. Measurement results are available to the relevant national accreditation bodies or other organizations or laboratories only after the publication of the results and the actual name of the laboratory.

4.7. Comments on the «Separation by the measurement uncertainty» principle

Measurements can be initiated for measurement subjects or objects with any measurement uncertainty rank. That is, measurement standards with the highest precision are not necessary for it. Further, the Network separates measurement standards in groups by estimated uncertainty and the logistics program organizes measurements in groups and links among groups, after measurement standards of different ranks have joined the measurements.

For example, the first group of laboratories having the smallest uncertainty are compared with each other and laboratories of the second group (partly) having slightly larger uncertainty. The second group of laboratories is compared with each other and laboratories of the first and the third group (partly) having slightly larger uncertainty, etc. Comparison of the measurement standards having uncertainty, which differs several tens of times makes no sense. Difficulties in the system of equations solving are the result of it. If measurement uncertainties are very different, then the system of equations may be poorly conditioned. Its solution will degenerate.

Separation may be provided based on measurement uncertainty estimated on previous loops of measurements by LSM, after pooling statistical data. That means that Network can transfer the laboratory to a higher or lower group for further measurements.

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4.8. Comments on the «Safety» principle

Laboratories accused of manipulating measurement results and other data are not allowed to work in the Network. Administrator traces manipulation and blocks access to the Network. Appeals are processed in the order approved by the Metrological Community.

5. General description of measurements organization example in the proposed Network

Author describes a separate measurement method or submethod for which such procedure will be appropriate in general. Example is described based on existing procedures as if the Network already functions. Having imagined that consensus among BIPM, NMIs and laboratories concerning entering data of measurements by particular method or submethod to the Network according to the above tasks and principles exists.

Thus, key comparisons by BIPM measurement results may be processed in the Network for example. Their results may be used as the reference for processing measurement results during key comparisons of regional metrological institutes. Their results may be used as the reference for additional comparisons. All concerned NMIs and laboratories having high-precision instruments, but lacking particular experience or appropriate status can be involved in comparisons. Interlaboratory comparisons based on those NMIs and laboratories can be organized for all concerned laboratories. Comparisons and further interlaboratory comparisons can be organized in the short term. Technical realization of the Network basic principles will contribute to this. At the same time, larger quantity of travelling measurement subjects and objects can be included in circulation among the laboratories. Each laboratory provides measurements on several travelling measurement subjects and objects. The highest demand for measurement performance will be for leading NMIs, no pilot laboratories will be involved. The Network will perform the pilot laboratory actions.

Own measurement uncertainty calculations by laboratories will be still considered a priori and used for calculation of measurements weights in the process of comparisons adjusted by the Network. Degrees of equivalence and measurement standards reference values (i.e. measurement subjects and objects parameters) uncertainty will be calculated by Traceability Network according to combined statistical processing considering a priori weights. Further measurement weights will be evaluated according to the real estimates of measurement uncertainty obtained from statistical processing.

Measurement standards reference values and degrees of equivalence will be automatically used as the reference values for calibrations processed by the Network. They will obtain estimates of their biases based on them. Measurement uncertainty will be calculated strictly by LSM [12–14] within the Traceability Network.

In total, initiation of such procedures in any field will have a positive effect on measurement results traceability improvement.

6. Conclusions

1. Goal, tasks and main principles of **Comprehensive Measurement Traceability Network (Network)** creation are developed. The Network will allow improving measurement traceability demonstration, making it faster, dynamic, comprehensive and more effective due to maximum automation.

2. Network creation allows passing from declarative order of traceability demonstration with its further approval to traceability demonstration through continuous accumulation and processing of statistical data.

3. Permanent (continuous) Network operation allows any laboratory joining measurement process in any moment based on its necessity and capabilities. Laboratory can initiate necessary measurements in case of their absence. The Network will inform the Metrological Community about initiation of the new measurements. One should not wait for new comparisons or interlaboratory comparisons of measurement results initiation for several years.

4. The Network will perform some functions of quality management system for the laboratory. Burdensome bureaucracy level necessary for accreditation and audit preparation will be decreased by this. Statistical data from measurements processing will provide accreditation bodies an incontestable database on appropriate competency level of the laboratories.

5. The Network creation will improve measurements infrastructure.

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