Steps Towards a Global Metrology System

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Abstract

Metrology is compelled to react to international trends such as the liberalization of trade and the formation of regional markets. The free movement of goods within economic regions calls for the approximation of the national legislations. The system applied in the European Union will briefly described. The functioning of a regional metrology system requires close cooperation with the national metrology institutes of the region and active participation in international activities. The concept of the Metre Convention and the role of regional metrology organizations for ensuring worldwide traceability of measurements to the units of the International System, SI, will be described as well as the requirements for signing mutual recognition arrangements, the prerequisite for mutual acceptance of measurements and calibrations of the signatories.

These measures are designed to create confidence in measurements. As will be shown they are in line with the requirements of the Technical Barriers to Trade Agreement of the World Trade Organization. Since conformity assessments, based on measurements and tests, are of growing importance in international trade, the competence of bodies issuing certificates must be proven and documented for the worldwide acceptance of these certificates to be ensured. One further step towards a global metrology system is the accreditation of calibration and testing laboratories according to internationally harmonized standards and procedures. Finally, PTB´s collaboration with regional organizations and foreign countries with the aim of supporting the development of metrology and accreditation systems as steps towards a global system will be described.

1 Introduction

One of the oldest international organizations is the diplomatic treaty of the Metre Convention with the aim of creating an international system of measurement units. So, why talking about steps towards an international metrology system? Has the organization failed to reach its objective? As will be shown, certainly not, but the world is changing and metrology has to react to new trends and to cope with new challenges. It is informative to recall the reasons for the creation of the Metre Convention.

International trade in manufacture and industrial products in the second half of the 19th century was hampered by the absence of an international metrology system. It was recognized that such a system was an essential requirement for the expansion of international trade. As a result an international convention, the Metre Convention, was worked out and signed in 1875 by representatives of 17 states. The Metre Convention established a permanent organizational structure for governments to act in common accord on all matters relating to units of measurement. This cooperation has been most successful. It ensures the propagation and improvement of the International System of Units, the SI, which is the modern embodiment of the metric system. What are the new challenges and problems with regard to metrology?

As in the past, international trade needs metrological support so as to facilitate trade across frontiers and fulfil the needs of the world trade system. The world trade system is governed by the rules of the World Trade Organization to which more than 140 countries adhere with another 30 negotiating for accession.

Another worldwide trend is the formation of regional markets, free-trade areas and regional unions such as the European Union. Again, metrological support for intra-regional trade is necessary.

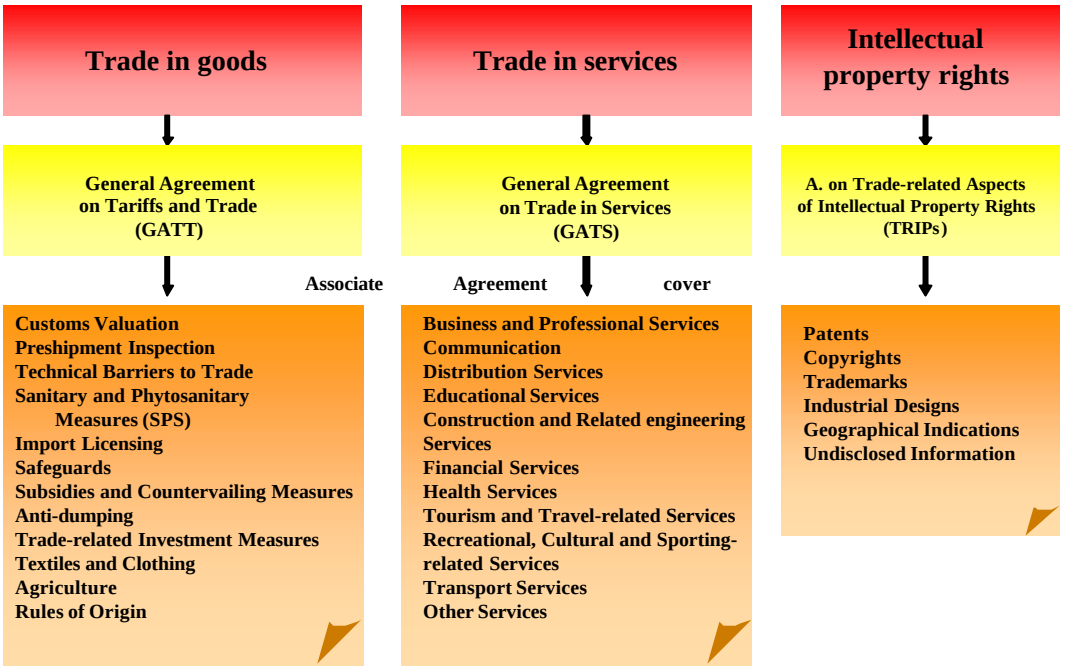
After a short description of the driving forces, globalization and regionalization, I will explain what has already been achieved in the European Union on a regional basis. Then I will describe the ideas underlying the Metre Convention. I will conclude with some information on PTB's activities in assisting other countries in establishing a metrological infrastructure.

2 The World Trade System

Increased dependence on international trade has made governments and businesses aware that an international system is needed for their trade interests to be safeguarded. In 1986, the Uruguay Round of trade negotiations was launched and terminated eight years later. Remarkable results were the reduction of tariffs and quotas for specific products and the

creation of the World Trade Organization, WTO. At present more than 140 countries are members and another 30 are negotiating for accession. Today, the multilateral trading system is a body of international rules member countries are required to follow in their trade relations. The rules facilitate open and liberal trade policies. They cover goods, services and intellectual property rights (figure 1). New subjects are added as they gain in importance and call for regulation.

Fig 1: Agreements of the World Trade Organization, WTO



Each WTO member country must make binding commitments as regards the market access of goods and services. The commitment of developing countries depends on their development, financial and trade needs. Rules for setting disputes and monitoring committees and bodies are available and the WTO oversees the implementation of the multilateral agreements.

The WTO's achievements can be summarized as follows [1]:

- Nearly 90 % of the world trade is regulated under WTO Agreements
- nearly all product and service sectors of the more than 140 member states are covered by one or more of the WTO Agreements
- tariffs dropped significantly over the years, in developed countries from 40 % to less than 4 %.

Estimates show that up to 80 % of trade is subject to standards or technical regulations and that conformity assessment may be required for the product [2].

> ***Conformity Assessment*:** Any activity concerned with determining directly or indirectly that relevant requirements are fulfilled. (ISO/IEC Guide 2, General Vocabulary 1996).

After the reduction of tariffs, standards and technical regulations have increasingly been identified as technical barriers to trade. There are many examples of national standards and regulations for products being used to protect the national markets or to provide advantages for local manufacturers.

To minimize the effect of technical barriers to trade due to standards and technical regulations, the World Trade Organization negotiated the Agreement on Technical Barriers to Trade, TBT. This Agreement provides rules to ensure that technical regulations, standards and procedures for conformity assessment do not form unnecessary obstacles to trade. The WTO TBT Agreement covers all conformity assessment procedures, including accreditation. It requires national technical regulations to be

- transparent
- justified
- non-discriminatory
- based on international standards (if possible).

The Agreement invites the signatory governments to ensure that the standardizing bodies in their countries accept and comply with the "Code of good practice for the preparation, adoption and application of standards" contained in Annex 3 to the Agreement.

The TBT Agreement also encourages

- members to sign mutual recognition agreements on conformity assessment and
- the development of international conformity assessment system.

Why?

Mutual recognition agreements or arrangements (MRA) would avoid repeated tests and assessments which are costly and time consuming but nevertheless common practice today. The reason for this is that there is little confidence in tests and assessments carried out in a foreign country by an unknown organization or institute. Sometimes, the trade policy of countries requires these tests being carried out within their territories.

This is in contradiction to the expectations of manufacturers who want to have certificates of conformity allowing products or services to be put on the market everywhere, following the motto:

one product, one test, accepted everywhere

which is also described as

one-stop testing.

But confidence in the competence of those furnishing test results and making out certificates must be built before the acceptance of certificates may be expected. This requires the harmonization of test and evaluation procedures, the use of traceably calibrated measuring and test equipment, the performance of proficiency testing schemes and the application of quality management systems. Since most test results are based on measurements, it is quite obvious that correct and reliable measurements are crucial for building confidence and for the acceptance of certificates. Before explaining the necessary measures in more detail, another trend, the formation of regional markets, will be described.

3 Regional Markets - Driving Forces for Regional Metrology –

The development of the World Trade System by the WTO has not stopped the trend towards regional co-operations with the aim of creating regional markets or free trade areas. An overview of such regional agreements is given in figure 2. There are many reasons for regional co-operation. Larger markets allow an increase in the production, a reduction of the cost per unit and thereby the competitiveness to be enhanced. The harmonization and reduction of tariffs facilitate trade within the region. But intra-regional trade also needs to be supported by of an effective infrastructure in terms of metrology, standardization and conformity assessment to achieve high efficiency. I will focus on metrological aspects with examples showing the efforts for the realization of the Single Market within the European Union.

The value of products traded by mass, volume or length is enormous. Estimates are of the order of 10 % of the gross domestic product. If the national legislation's for measurements and measuring instruments are not compatible, they will be significant barriers to trade. This was the case in the EU member states. The harmonization of legislation commenced in 1971. Until today a Framework Directive plus 23 specific Directives were elaborated and put into force dealind among other things with weighing instruments, meters for liquids, length measures, utility meters (electricity, water, gas, heat), taximeters and prepacked products.

Fig. 2: Regional Agreements

It must be mentioned that the existing legislation will be replaced to a large extent by the new Measuring Instruments Directive (MID) [3]. The reason for this that the existing directives contain detailed technical specifications which are too restrictive in today's situation of rapidly changing technology. According to the New Approach, the Measuring Instruments Directive intends to remedy the above-mentioned shortcomings by

- establishing essential requirements, performance requirements rather than design specifications (the so-called “New Approach”)
- requiring conformity assessment procedures (according to the so-called “Global Approach”)
  and
- establishing mutual recognition of the results of conformity assessment among the Member States.

After the MID's entry into force no parallel national regimes of legal control of measuring instruments may exist in the Member States. It is an interesting feature of the MID that possible technical solutions satisfying the metrological requirements will be given in international normative documents such as the Recommendations of the International Organization of Legal Metrology, OIML. The application of such documents shall give presumption of conformity with the requirements of the Directive. But the manufacturer may also apply solutions which are not covered by such documents if he can demonstrate that the essential requirements are fulfilled.

Within the EU these directives serve two purposes: They enable free movement of measuring instruments and they ensure correct trading transactions by establishing legal requirements for their accuracies and other performance characteristics. That means the directives are necessary to realize the Single Market and they constitute the legal basis for consumer protection. Taking into account the importance of prepacked products, certain directives on tolerable errors as regards content, on markings, methods of control and nominal quantities have been adopted to eliminate technical barriers to trade.

The enforcement of the directives after translation into national law is the task of the national legal metrology services of the EU Member States. These check the compliance of measuring instruments and prepacked products with the requirements of the directives.

Representatives of the legal metrology services are also involved in the drafting of EU Directives on behalf of the European Commission. To ensure a good co-operation, 18 representative members from national legal metrology authorities in the European Union and EFTA member states signed a Memorandum of Understanding in 1990 to found the European Cooperation in Legal Metrology, WELMEC [4]. At that time Europe was politically divided into East and West, and the acronym WELMEC stood for Western European Legal Metrology Cooperation. Today, however, WELMEC extends beyond Western Europe and includes representatives from Central and Eastern Europe. The acronym WELMEC has been retained. Among the objectives of WELMEC are:

- Development of mutual confidence between legal metrology services
- Achievement of harmonization of legal metrology activities
- Identificaton of specific features of legal metrology which need to be reflected in the European metrology, certification and testing system and
- Promotion of the consistency of interpretation and application of normative documents and propose actions to facilitate implementation.

These activities assure a correct and consistent implementation and enforcement of the legislation.

Box 1: Economic importance of correct measurements

Example 1: Gas metering

The national standards for high-pressure gas-flow of the Netherlands and Germany differ systematically. The German cubic meter is slightly smaller than the Dutch one. When it comes to settling bills, this difference grows in importance. Depending on whether you want to buy or to sell gas, either the calibration traceable to the German or the Dutch standard will be advantageous for you. Since trade in gas across European frontiers is of the order of some hundred billion cubic meter per year, the small difference of 0.1 % will result in 5 million US $ per hundred billion cubic meter at an average trading price of 0.05 US $/m^3.

The responsible national metrology institutes, the Physikalisch-Technische Bundesanstalt in Germany and the Netherlands Meetinstitute therefore decided to harmonize the cubic meter. Since the two institutes use different methods for the realization of the standard, the results were used to calculate a weighted mean value, the Euro-cubic meter. This weighted mean value will be checked regularly in accordance with an extensive comparison measurements program. The mean value is the reference for all high-pressure gas measurements in Germany and the Netherlands [7]. This is an important step towards a common European metrological infrastructure.

Example 2: Trade in pre-packed goods

Many goods are sold as pre-packages. The package labels name the commodity, the net content and they may contain further information of interest to the buyer. The labeling is usually prescribed by national regulations which in the European Union have been replaced by EU Directives. One major requirement concerns the average net content which is to be equal to or exceed the declared net content The regulations serve two purposes: consumer protection and fair trade. In Germany the national legal metrology service checks compliance with the regulations since 1972. In the year 2000, 6% of the 32 000 checks revealed non-compliance with the average net content requirement [8]. This means quite a number of producers of pre-packages fill in less than declared and the consumers have to pay more than they get. The under-filling is usually small and will scarcely be perceived by the individual consumer. However, the inadequate filling is unjustified income to the producer, which is detrimental to fair trade and consumer protection. Depending on the commodity and the number of packages produced, the unjustified income can be of the order of some million Euro per year and per producer. The total loss for the consumers in Europe is of the order of hundred of millions of Euros per year and would even be higher without the surveillance by the legal metrology service.

Confidence in competence was further enhanced through the work of the former Western European Calibration Cooperation, WECC, (established in 1974), subsequently by the European co-operation for Accreditation of Laboratories, EAL, (1994) and at present by the European co-operation for Accreditation, EA (since 1997).

> **Accreditation:** *A procedure by which an authoritative body gives formal recognition that a body or person is competent to carry out specific tasks. (ISO/IEC Guide 2, General Vocabulary, 1996).*

The members of EA are the nationally recognized accreditation bodies of the member countries, the candidate countries of the European Union and the European Free Trade Area, EFTA, operating accreditation systems compatible with the European Standard EN 45003 or with ISO/IEC Guide 58. Part of the EA's work is the organization of interlaboratory comparisons [6]. The interlaboratory comparisons in calibration are shown in fig. 3. The continued work of these organizations over the years ensures the necessary confidence in the competence of their members on the basis of documented facts. It was driven by the economic and political development and oriented to the needs of the region. The result is a regional accreditation system providing mutual recognition of certificates issued by its members. Another important fact to be mentioned here is that Memoranda of Understanding (MoUs) have been signed between the European Commission respectively EFTA and the EA. According to this agreement, EA´s important role in the area of conformity assessment, i.e. testing, calibration, certification and inspection to ensure the efficient operation of the Single Market has been officially recognized.

The National Metrology Institutes in Europe also started co-operation in 1973 which led to the creation of EUROMET in 1987. EUROMET is based on a Memorandum of Understanding (MoU) with a clear but legally non-binding objective [5].

The aims of EUROMET are:

- Developing of a closer collaboration between Members in the work of measurement
  standards within the present metrological structure
- Optimizing of the utilization of resources and services of Members and emphasis of the deployment of these towards perceived metrological needs
- Improving of measurement services and making them accessible to all Members
- Ensuring that the national facilities developed in the context of EUROMET collaboration are accessible to all Members.

Since the signing of the EUROMET MoU a significant increase in metrological collaboration has taken place in Europe. More than ever before, contacts and exchange of know-how have emerged among metrology experts of the Member NMIs, the European Commission and NMIs from outside EUROMET. During this time the number of signatories rose from originally 18 to 25 including NMIs from Central and Eastern Europe. Furthermore, EUROMET at present comprises 19 Corresponding Organizations, among them five other Regional Metrology Organizations, five European organizations, three Corresponding NMIs and six Corresponding Applicants for full membership.

EUROMET has classified its collaboration according to four different types:

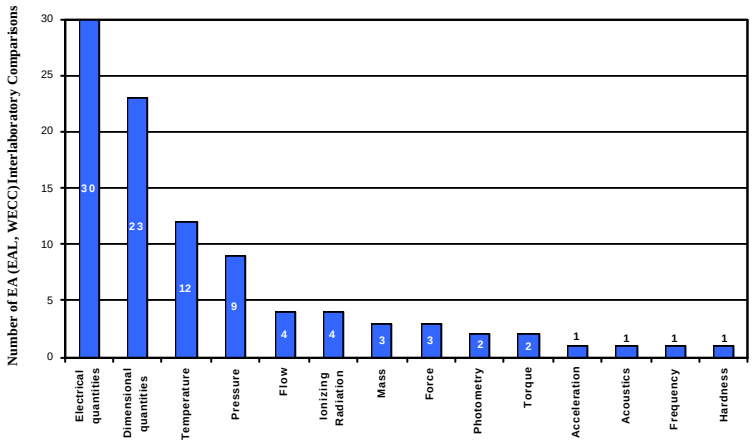
- Cooperation in research
- Comparison of measurement standards
- Traceability
- Consultation on facilities

Although EUROMET has no funds of its own, hundreds of metrology projects have been proposed, launched and completed. A number of projects were supported by various EU programs. The close cooperation over many years has created a high level of confidence in the competence of the member NMIs.

The European example clearly shows the interdependence between realization of the Single Market and development of regional structures in metrology, covering legal metrology, calibration activities and national metrology institutes. Moreover, good working relations have been established between the relevant political bodies and the regional metrology organizations. Two examples of the economic importance of correct measurements are given in box 1.

Fig. 3: EA (EAL, WECC) interlaboratory comparisons in calibration since 1976

(Source: EA-01/12 History of EA Interlaboratory Comparisons (ILC) in Calibration and Testing, Dec. 2001-rev. 3)



Regional metrology organizations have of course been established also in other parts of the world:

APMP	Asia Pacific Metrology Programme
COOMET	EURO-ASIA Cooperation of National Metrological Institutions
SADCMET	Southern Africa Development Cooperation in Measurement Traceability
SIM	Inter-American Metrology System

These regional metrology organization have to play an important role for the functioning of the international metrology system as will be shown in the next chapter.

4 The Global System

Under the umbrella of the Metre Convention, a quite extensive program was set up to build confidence in the competence of National Metrology Institutes (NMIs). To reach this objective, interested NMIs are invited to state their measurement capabilities, to take part in international comparison measurements and to establish and maintain quality systems. Based on these principles a mutual recognition agreement was drawn up by the International Committee of Weights and Measures (CIPM), which was signed by the directors of 38 NMIs and two international organizations in October 1999 [9] as the Mutual Recognition of National Measurement Standards and of Calibration and Measurement Certificates issued by National Metrology Institutes (CIPM-MRA). Subsequently another ten NMIs signed the CIPM-MRA, so that the total number of signatories is 48 + 2 as of January 2002 [10].

With the approval of the authorities responsible, the NMI directors

- accept the process specified in the MRA for establishing the database
- recognize the results of key and supplementary comparisons as stated in the database
- recognize the calibration and measurement capabilities of other participating NMIs as stated in the database and
- agree to implement and maintain a quality management system

The BIPM is responsible for the overall coordination, the Consultative Committees of the CIPM, the Regional Metrology Organizations and the BIPM are responsible for carrying out the key and supplementary comparisons and a Joint Committee of the Regional Metrology Organization (RMO) and the BIPM are charged with checking information for entry into the database of the calibration and measurement capabilities declared by the NMIs. The operation of a quality management system can be demonstrated either by accreditation or by self-declaration of the NMI. The NMIs must also state their measurement capabilities for a database to be checked by the

Regional Metrology Organization and verified by the Joint Committee of the RMOs and the BIPM (JC).

The new and important role regional metrology organizations play in the concept of the CIPM-MRA is worth mentioning. It is the task of the RMOs to organize metrology in the region, to ensure traceability and to work closely with the BIPM to ensure linkage to the international level. The RMO will take over tasks which cannot be carried out by the BIPM because it has neither the capacity nor the intention to cooperate with every national metrology institute. It will concentrate on NMIs performing measurements with the lowest uncertainties.

Another new feature of establishing confidence in measurement and calibration activities is the requirement to maintain a quality management system for its measurement and calibration services and to demonstrate its effectiveness. This may be done either by choosing a system in compliance with international guides or standards and assessed by an accreditation body fulfilling the relevant international requirements or by self-declaration and an assessment by the local RMO and a review by the Joint Committee. The demonstration of competence and capability may require visits and examinations by an NMI and/or peers assigned by the local RMO.

Formally, the CIPM-MRA is a technical arrangement among the directors of NMIs having signed it with the approval of the appropriate governmental or other official authorities of their country. It is expected that participation in this arrangement will open the way to, and provide the technical basis for, wider agreements related to trade, commerce and regulatory affairs. It serves already as a technical basis for the accreditation of laboratories according to the relevant international standards developed by the International Organization for Standardization, ISO, and the International Electrotechnical Commission, IEC.

The development of laboratory accreditation practices and procedures, the promotion of laboratory accreditation as a trade facilitation tool and the recognition of competent calibration and test laboratories around the globe is the task of the International Laboratory Accreditation Cooperation, ILAC. ILAC also encourages the development of regional accreditation cooperations and the establishment of multilateral mutual recognition arrangements between ILAC member bodies [11]. The ILAC arrangement is based on regional arrangements. Each recognized Regional Accreditation Body must abide by the procedures defined in ILAC requirements documents. Currently, the European Cooperation for Accreditation, EA, and the Asia Pacific Laboratory Accreditation Cooperation, APLAC, are the only ILAC-recognized regions with acceptable mutual recognition arrangements and evaluation procedures. Such arrangements will further enhance and facilitate the international acceptance of calibration data and contribute to "-one-stop testing-", the wish of manufacturers and traders mentioned above. The pressure on the national level for the realization of this vision and

requirements for the integration of national metrology systems into the global system will be described in the next chapter.

5 The Pressure on National Metrology Systems

Of the 51 member states of the Metre Convention 42 directors of NMIs have until today signed the CIPM-MRA. The additional workload to fulfil the inherent requirements is significant. Estimates for the German national institute, the PTB, show that for the next few years another six staff members are necessary. Of course, the workload for smaller institutes will be less. Nevertheless, there is a common understanding that the overall economic benefits are much higher. This is the reason for non-members to sign the agreement as Associates to the General Conference on Weights and Measures (GCWM). They will pay only a small fee (minimum about 5000 Euro/year) covering the additional costs of operating the agreement but they can participate in the RMO key and supplementary comparisons and have the degrees of equivalence of the national measurement standards and of the calibration and measurement certificates of their NMI recognized by the other signatories and the results included in the BIPM database. This is a way to demonstrate technical competence and to create confidence in measurement and calibration capabilities.

It can be expected that the pressure on other NMIs to follow this trend will increase for several reasons. One will be to facilitate trade with industrialized countries. Since almost all industrialized countries are signatories to the CIPM-MRA they will expect the same efforts in demonstrating competence before accepting calibration certificates.

The pressure may also come from domestic sources: industry, accreditation bodies, trade organizations, governments, professional associations, regional organizations or laboratories may request calibration certificates according to internationally accepted standards. The formation of regional markets will also require metrological support as described in chapter 3. This will become obvious as soon as these regional markets have been created and are fully operational. It can be expected that the development of metrology according to the needs of the region and intra-regional trade will appear on the political agenda of the governments concerned. Taking into account the role assigned to regional metrology organizations in the design of a global metrology system, the implementation and application of internationally recognized procedures should be envisaged. This will facilitate not only bilateral but also multilateral and even the international recognition of certificates.

While there are not too many possibilities of demonstrating competence it is possible to decide for what physical quantities and to what degree such competence should be demonstrated. It is to be noted that the national measurement standards and the calibration capabilities need not be of the highest accuracy but must be adequate to met the national needs. And if

there is no need for a particular quantity there will be no need for a national standard for this quantity. The important points are the correct declaration of the measurement capabilities in terms of measuring range and uncertainty, the traceability to international standards, the results of regional or international comparison measurements and the operation of a quality management system.

A national metrology institute is not a profit-making undertaking, to the contrary, the realization and maintenance of measurement standards require adequate laboratories and qualified personnel. The budget for such institutes is usually provided by the government because tasks of public interest are performed. The importance of a functioning metrology system in today's world to support the national economy and to contribute to the social development is not known and appreciated by government officials to the necessary extent. It is therefore the task of specialists to act as advocates of metrology and raise this awareness. Governmental support is necessary not only for financial reasons. The national metrology system needs a legal basis, it needs a national body for the organization and operation of the system, and it needs a national representative to communicate with the outside world.

The world is changing, and the requirements for metrology change as well. New developments which must be reacted to are, for example, the growing importance of electromagnetic radiation and potential interferences, the analysis of foodstuffs with regard to hazardous substances or the application of nanotechnology in production. For the timely and adequate reaction to these developments, close cooperation among all parties concerned is necessary. The beneficiaries or customers should specify their needs as regards measurements and calibrations and the specialists should design and adapt the national system accordingly. There is no reason to believe that the development of a national metrology system can be regarded as finalized. It is a continuous process.

6 Concluding Remarks

It has been shown that the development of metrology and metrology systems is strongly interlinked with the development of global and regional trade. The relevant specialist organizations have established systems for metrology and accreditation with the aim of creating confidence in their competence and thus facilitating the international acceptance of certificates. In some regions of the world, especially in Europe, North America, Australia and East Asia, the organizational and technical prerequisites have already been provided and national metrology institutes and regional metrology organizations follow the procedures of the CIPM-MRA. Although these countries are not the majority, their trade volume accounts for more than 80 % of world trade.

For the realization of a real global metrology system, the other regions and countries which do not belong to the above-mentioned group must establish or upgrade their systems to join the club. This is not an easy task. But it is in the interest et all those concerned that as many countries as possible follow the international trends. The European Union for instance has special programs to support other countries in their efforts to fulfil the requirements with regard to the TBT- Agreement and conformity assessment procedures. The World Bank and the regional development banks provide funds for the same purpose. The German Ministry for Economic Cooperation and Development has entrusted the PTB with the implementation of projects in the field of metrology, standardization, testing, quality, accreditation and certification. We have been active in this area for more than 30 years and many national metrology institutes in South America and Asia have been assisted in setting up their laboratories and in training their staff members. Projects under implementation can be found on our website [12]. The accreditation of quite a number of laboratories of our partners according to the rules of the European cooperation for Accreditation and the signing of the CIPM-MRA by directors of our partner institutes document their competence and their integration into the global metrology system. PTB, the oldest metrology institute in the world, is prepared to share its experience with others. It is our goal to help reduce the gap between more than 140 WTO members and the 48 signatories to the CIPM-MRA and thereby work for a really global metrology system.

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