Bureau International
des Poids et Mesures

Evolving Needs for Metrology in Trade, Industry and Society and the Role of the BIPM

A report prepared by the CIPM
for the governments
of the Member States of
the Metre Convention

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Intergovernmental Organization
of the Metre Convention

Note on the use of the English text

To make its work more widely accessible the International Committee for Weights and Measures publishes an English version of its reports.

Readers should note that the official record is always that of the French text. This must be used when an authoritative reference is required or when there is doubt about the interpretation of the text.

Contents

Foreword

In October 1999 the 21st General Conference on Weights and Measures (CGPM) received the report prepared by the International Committee for Weights and Measures (CIPM) in 1998 on the national and international needs relating to metrology and approved the decisions taken by the CIPM on the basis of this report. The report gave an outline of the long-term national and international needs relating to metrology, the international collaborations and the unique role of the International Bureau of Weights and Measures (BIPM) to meet these needs, as well as the financial and other commitments that will be required from the Member States of the Metre Convention in the coming decades.

Now, only four years later, it is quite clear that the needs for metrology and the technical and organizational developments in the field of metrology have proceeded much faster and in a much wider area of application than was foreseen even in 1999 to the extent that an update of the 1998 report has become necessary.

This new Report on the evolving needs for metrology in trade, industry and society and the role of the BIPM has now been completed and the CIPM is pleased to submit this Report to the Governments of the Member States of the Metre Convention.

During the preparation of the Report, two questionnaires were sent out to the directors of the National Metrology Institutes (NMIs) asking for their views on the most rapidly developing fields in metrology and the most urgent areas in metrology which need to be addressed by the NMIs and the BIPM. This Report is supported by several studies on the economic and social impact of metrology, carried out by economic specialists from some NMIs and government departments, as well as by professional economists from universities and private consultancy companies.

The draft Report has been discussed with the directors of the NMIs during a meeting in April 2002 at the BIPM in Sèvres, while a further consultation of the directors was done by correspondence during the period July-August 2002.

Finally, the Report was approved by the CIPM in its meeting on 10 October 2002.

On behalf of the CIPM we express our gratitude to all who have given their time and expertise to assist in the preparation of this Report.

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President of the CIPM	Secretary of the CIPM

April 2003

Executive summary

Over the last five years the need for accurate and reliable measurements has developed at a great pace, not only in the manufacturing sector and domains of national and international trade, but also in the areas of human health and safety, protection of the environment, communications, and in all fields of science and engineering.

New metrology networks, new partners

- The broad need for internationally recognized, traceable and comparable measurement as well as measurement standards and test in all areas of society has led to new networks of cooperating international and inter-governmental organizations. Over the last two years the CIPM has signed Memoranda of Understanding (MoUs) or Arrangements with the World Health Organization (WHO), World Meteorological Organization (WMO), International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) and the International Laboratory Accreditation Cooperation (ILAC). It is expected that more international cooperation arrangements will be concluded with bodies such as the World Anti-Doping Agency (WADA) and the Codex Alimentarius Commission (created by the WHO and the Food and Agriculture Organization of the UN, FAO).
- In 2002 a new activity related to traceability in laboratory medicine was initiated by the BIPM, IFCC and ILAC, and with representatives also from quality assessment organizations, certified reference materials producers and the in vitro diagnostic industry associations of the European Union, Japan and the United States as well as from the regulatory authorities of these countries. The provisional name of the new activity is the Joint Committee for Traceability in Laboratory Medicine (JCTLM).
- It is of importance that similar cooperations are established at the global as well as at the regional and national levels.

Metrology in developing countries

- An internationally recognized metrology infrastructure in developing countries and countries in transition is now recognized as a high priority. For these countries, the lack of such a structure is hindering development as it raises the vulnerability to non-tariff barriers to trade, that in turn delays market access and further industrial and economic development.

Exchange of information and know-how, awareness stimulation and coordination of assistance to these countries in metrology, accreditation and standardization are now being attempted through a new Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS) comprising the BIPM, the Regional Metrology Organizations (RMOs), ILAC, the International Organization for Legal Metrology (OIML), the International Organization for Standardization (ISO), the International Electrotechnical Commission (IEC), the International Accreditation Forum (IAF), the United Nations Industrial Development Organization (UNIDO), and the International Telecommunications Union (ITU).

Metrology in physics and engineering

- In many domains, particularly in time and frequency, dimensional metrology, as well as other mechanical and electrical applications, the required accuracy is increasing by factors of between three and ten per decade. In several cases, the present accuracy is barely sufficient for trade or safety requirements and limits set by law. Sometimes, traceable references do not even exist. Some NMIs are responding with major research initiatives.
- The general trend towards the miniaturization of products and sub-micron technologies, like the “lab-on-a-chip”, leads to completely new principles of measurement. Nanometrology (including biotechnical applications) is a field at the frontiers of physics in which new measurement techniques are being developed and is a high priority for several NMIs. Much remains to be done in devising suitable primary and secondary standards applicable for very small dimensions or new quantities.

New applications for metrology

- The requirements for metrology in chemistry and biotechnology have become manifest much more rapidly than was foreseen five years ago. International trade in chemicals, certified reference materials, gas and oil products, pharmaceuticals, food and measuring equipment for chemical analysis continues to increase. An increasing range of legal requirements has been approved with respect to safety and environmental protection, all requiring internationally recognized traceable and comparable measurements.
- Traceability of measurements in health care is now high on the agenda. Such traceability will shortly be required by law in the European Union through the In Vitro Diagnostic (IVD) Medical Devices Directive, and similar legal requirements have been or will be introduced elsewhere in the world, for example the United States and Japan. The technical basis for providing such traceability is still rudimentary in some areas.

- Reliable and comparable metrology in food testing is becoming increasingly important not only because of the high volume and the large export value of food products in international trade but also because of the questions raised by society with respect to general matters of food safety including the content of Genetically Modified Organisms (GMOs). In different countries and economic communities legislation which requires comparability of measurement results and related measurement uncertainty is coming into force yet there is no formal system for creating the necessary technical infrastructure.
- Measurements related to the quality of life, biotechnology and the monitoring of our environment with respect to pollution and climate change require reliable, long-term stable and comparable measurements demanding corresponding measurement standards. Also in these matters various countries and economic communities are enacting legislation addressing the quality of measurements.

Metrology, a high return on investment and high value for public money

- Studies of the economic impact of metrology, carried out in the United States, United Kingdom, Canada and the European Union, demonstrate that investments made by governments in establishing an internationally recognized metrological infrastructure rate among the most cost effective of government investments producing a high level of return to society.
- The recent study by outside consultants (KPMG) has indicated the cost-effectiveness of the CIPM MRA and the role of the BIPM as the world's spokesman and coordinator on behalf of the NMIs.
- Member States are urged to maintain and where possible increase investments in national metrology structures that are needed in order to address the increasing demand for traceable and comparable measurements in all fields and to implement at the national level the actions decided at the international level and driven by international trade and other international programmes, e.g. in the food, environmental and health sector.
- Where relevant the designation of other institutes than the main NMI, acting as a NMI for certain defined quantities and measurement ranges, should be considered.

The world's measurement system; cooperation and partnerships

- For all of the above, a reliable, accurate and universally available international measurement system is required. This can only be provided by the ensemble of the world's NMIs working in cooperation with each other and with the CIPM and the BIPM under the Metre Convention.

- Much of this is now taking place through the CIPM Mutual Recognition Arrangement (MRA) of national measurement standards and of calibration and measurement certificates issued by the NMIs. This MRA has now been signed by the directors of the NMIs of all the industrialized States of the world as well as by two international organizations and an increasing number of developing states and economies. The CIPM MRA brings together the NMIs, the RMOs and the BIPM and is seen, among other things, as a key element in removing Technical Barriers to Trade (TBTs) and of direct importance in the implementation of sanitary and phyto-sanitary (SPS, i.e. related to animal and plant quarantines) measures.
- The recent extension of requirements for accurate measurements into new fields and ever more demanding requirements for accuracy in traditional fields are very considerably stretching the capabilities of the NMIs and the BIPM. It is increasingly recognized that no one NMI is capable of providing the whole range of measurement standards and services that are now needed and that networking and close cooperation among the world's NMIs is essential.
- Thus, traceability issues are high on the international agenda and require collaboration between international as well as between national and regional organizations in an increasingly wide range of sectors, bringing together officials from government agencies responsible for trade, regulation and specification standards.

The International Bureau of Weights and Measures, BIPM

- International coordination in the field of metrology is one of the prime tasks of the BIPM under the guidance of the CIPM and in cooperation with the NMIs. The support given by the expert staff of the BIPM is of high value in achieving the aims of an efficient and effective international metrology infrastructure.
- The BIPM, to be effective, must continue to be recognized as a competent and authorized organization in the field of metrology. For this, a competent and knowledgeable staff is needed that can only be recruited and kept if the BIPM is active in metrology in its own laboratories in a selected range of fields covering not only the physical but also the chemical and biotechnology areas. The type of work to be done will be carefully chosen to complement that being carried out in the NMIs.
- The BIPM must continue to be the global organization responsible for keeping up-to-date and disseminating the concept of the International System of Units (SI) and where not currently feasible other suitable and internationally agreed references, to be the custodian of the International Prototype of the kilogram and to establish and disseminate International Atomic Time (TAI) and Coordinated Universal Time (UTC).

- The CIPM, in response to the difficult financial situation now foreseen, has already assessed priorities for work at the BIPM and is terminating some of its existing activities while starting up and strengthening others including metrology in chemistry and fundamental metrological experiments, as well as support for the CIPM MRA and international coordination particularly related to bio- and clinical analysis. All of this is in order to best place the BIPM, together with the NMIs, to address urgent metrological issues in these areas.
- Member states of the Metre Convention are urged to take the necessary steps to ensure that the BIPM be given the financial and other support corresponding to the pace of global developments in metrology.

1 Introduction

1.1 The 1998 CIPM report and the 21st CGPM in 1999

By the end of the 20th century the continually evolving and even accelerating needs for metrology in trade, industry and society, with demands in all fields for reliable and ever more accurate measurements traceable to the SI, led to the decision by the CIPM to produce a report describing these developments and giving guidance to the development of the BIPM at the start of the 21st century.

In 1998, the CIPM published this report entitled *National and international needs relating to metrology* (1). This report gave a broad review of the needs for metrology as identified at that time, describing the national and international structures that provide the technical and legal bases for confidence in measurements. An important part of the report concerned the Metre Convention, the intergovernmental treaty dating from 1875 that continues to provide the basis for international metrology. Under the Metre Convention, the CIPM is given responsibility by the Member States for the BIPM. The report, therefore, also considered the operation and programme of the BIPM and the financial support that Member States would be asked to provide in the coming years.

The 21st General Conference on Weights and Measures (CGPM) in 1999 marked a turning point in the affairs of international metrology. The Conference adopted the main recommendations of the CIPM report. Among these was the extension of the range of activities to be covered by the Metre Convention to include essentially all areas of science and the corresponding extension of the remits of the Consultative Committees. More than a century of slow but continuous broadening of the range of activities carried out under the Convention now arrived in a phase of broad and considerably accelerated developments. In 1875, the Convention covered only length and mass. Despite a number of attempts, starting as early as 1881, to include electrical and other quantities, no extension was made until 1921 when electrical standards were included. Thermometry and photometry were added later in the 1920s and 1930s. In 1960 the decision was taken to include ionizing radiation standards and in 1987 responsibility for time scales was added. In 1993, the first steps in chemistry were taken. In 1999 the Conference endorsed the view that metrology is now a matter that extends to almost all areas of science and that it is the responsibility of the Member States acting through the Metre Convention to provide the necessary infrastructure to support reliable measurements everywhere.

Also in 1999, the directors of the national metrology institutes of the Member States of the Convention signed a Mutual Recognition Arrangement for the recognition of their national measurement standards and calibration and measurement certificates (2). The CIPM MRA, described in some more detail in Appendix 2, is now in the course of implementation and great progress has already been made.

While dealing mainly with the activities carried out under the Convention by Member States, the Conference recognized the need to open up the formal structures for international metrology to developing States and those in transition. A new category of Associate State or Economy of the General Conference was created. This was designed to allow participation in the CIPM MRA at much lower costs than full membership to those States not yet ready to become Member States. There are now ten such Associates and we expect the number to grow rapidly in the coming years.

A full account of the 21st CGPM has been published by the BIPM and is available on the BIPM website (www.bipm.org). Also available on the website are the thirteen Resolutions adopted by the Conference. These concern the need to use SI units in international programmes relating to the environment, human health and medicine as well as a number of technical matters.

The Conference approved the reformulation of the role of the BIPM that was proposed by the CIPM in its Report and adopted a new programme and budget for the BIPM for the years 2001 to 2004. It was understood, however, and noted by the 21st CGPM that the budget approved for the years 2001-2004 would not be sufficient for the continuation of the adopted programme after 2004 (see Appendix 5).

Throughout its existence, the BIPM has demonstrated an ability to accommodate new programmes and terminate old ones that have dropped in priority. Since the early 1960s, however, after the Ionizing Radiation section was established with a doubling of the annual dotation for two years, extensions to BIPM activities have not been specifically funded. Both the incorporation of the Time section in 1988 and the beginning of the Chemistry section in 1999 as well as the three new buildings and the significant updating of the laboratory infrastructure since 1984 have all had to funded by savings made in previous years. For some twenty five years this has been possible because of a long period of falling inflation in which annual increases in dotation voted by a General Conference were, in general, higher than the subsequent rate of price increases. Since the late 1990s this has no longer been the case.

1.2 Content of the new 2003 Report

Since the drafting of the CIPM report in 1997/98 and the 21st CGPM in 1999, there has been a considerable increase in the international profile of metrology. This has arisen for two reasons: the first is due to the CIPM MRA, which is increasingly cited in trade and other agreements; and the second is the rapid rise of the perceived need for metrology in chemistry and the biological sciences. The second of these has resulted from public anxiety as to the effects of such things as genetically modified crops and the consequently increasing regulations that call upon reliable and traceable measurements. A new European Union Directive related to in-vitro diagnostic measurements has stimulated the world’s diagnostics industry to call directly for help from the international metrology community so that the requirements of the Directive can be met by the end of 2003 when it comes into force. Although some of this was foreseen in the 1998 report, the speed at which the need has arisen was not forecast.

In response to these rapid developments, the CIPM decided to draw up this new 2003 Report in which the metrological implications of these new needs are examined and an appropriate response from the BIPM is proposed. It is expected that the reader is familiar with much of the material already covered in the 1998 report whose key points are described only briefly here. In this report only a summary of the background and actions taken are given. Here only a brief outline of the background is given.

In preparation of the new 2003 Report, the CIPM sent out two questionnaires to the directors of the NMIs. The first was sent in May 2001 and asked the directors to give their views on their expectations concerning the development of metrology in their country, on areas of major investments, on new areas of metrology, on the consequences of the application of new technologies, on the development of new networks in metrology, on the general services to be delivered by the BIPM and on priorities to be set. The second questionnaire was sent in December 2001 and asked more specific and detailed questions as to how they value the services at present supplied by the BIPM.

This new Report contains four main sections, covered in Chapters 2 through 5. Following an introductory background chapter, Chapter 2 outlines the current and emerging needs foreseen in metrology, with particular reference to those of developing countries. Included here is a section on the foreseeable effects of new technologies on metrology and the increasing use of the internet for certain metrological operations. The extreme importance of an internationally recognized national metrology system for tackling non-tariff barriers to trade (technical barriers to trade and sanitary and phyto-sanitary measures) is indicated. In Chapter 3 the importance of international cooperation in metrology is discussed, describing the role of global networks and the formation of joint committees. Chapter 4 follows with a discussion on the economic and social impact of metrology. This is something that was not treated specifically in the 1998 report although it was mentioned. A brief analysis is given of a number of recent studies of the economic benefits that accrue from the work of NMIs. In addition, the results are presented of a study commissioned by the BIPM of the economic benefits for the Member States of certain important aspects of the work of the BIPM and the potential economic impact of the CIPM MRA. The last major section, Chapter 5, is devoted to the BIPM, its role, tasks and institutional background and the perspectives for the future, taking account of the needs discussed in Chapter 2. The case is presented for the financial commitment that will be required from Member States. In Chapter 6 the conclusions and subsequent recommendations of the CIPM are presented. The Report ends with some Appendices, including short summaries of the conclusions from the questionnaires (see Appendix 3) and the decisions of the CIPM on the future programme of the BIPM (see Appendix 5).

In the Appendices to the Report the reader will find also supplementary background material concerning the national and international metrology infrastructure. In particular, Appendices 1 and 2 may prove highly useful: the former gives a brief description of the existing national and international structures, including recent and ongoing adaptations, which provide the basic metrological infrastructure; the latter describes the framework of the CIPM MRA and the considerable effect it has on the metrology community.

This Report has deliberately been made shorter and less comprehensive than the one produced by the CIPM in 1998 since no purpose is served by repeating much of the basic background that can be found in the earlier Report. The full text of the 1998 report is on the BIPM website.

2 Evolving needs relating to metrology

Measurements have been carried out for as long as civilization has existed. Reliable measurements, fit for the purpose in hand, have always been a requirement of an organized society. People do not accept false measures in trade and require protection against arbitrariness. Reliable weights and measures have been the responsibility of the State since time immemorial. In all countries of the world today, the responsible authorities see it as their task to define the measurement units and standards and to make proper arrangements for their practical realization and dissemination.

The Metre Convention had its origin in the period of the nineteenth century that saw the rapid growth in international trade in manufactured products. Some sort of international agreement on units of measurement was seen to be essential. At that time the basis of physical science was being established by such towering figures as Maxwell, Kelvin, Weber and Helmholtz, all of whom were closely involved in defining standards. The science of measurement came to be known as metrology and by the end of the nineteenth century was already highly developed. The major national metrology institutes were established at about the same time. Advances in science and the development of high-technology industry have led to the present advanced state of physical metrology, which is now seen as an essential part of the infrastructure of society.

Today, however, reliable measurements are required over a much wider range of human activities than even in the recent past. For instance, industry undergoes major new developments with the appearance of new materials and techniques, the importance of miniaturized products, and the increasing trend of subcontracting the assembly of subsystems. Clear needs are to be foreseen in areas of metrology that include, among others, laser systems, nanotechnology, electrical measurements, femtosecond optical techniques, time scales, ionizing radiation and material sciences, while more international comparability is needed with respect to many derived quantities, like flow, viscosity, acoustics, etc. In all these cases, accurate measurements referred to traceable standards are an inescapable requirement of success.

One of the effects of globalization of trade has been that traceable, comparable and mutually acceptable measurements across the world are now required not only in the trade of manufactured products and raw materials, but also in almost all aspects of international trade. This now includes trade in foodstuffs, health products and health instrumentation as well as the multitude of measurements that are part of the process of protection of the environment, including the trading of CO_2 shares. Global climate studies bring together an enormous range of sciences and for a sound model to be developed it is necessary that the data from all these areas be comparable. In general, there is now a demand for people to have confidence in the credibility of the results of measurements because in so many ways decisions based on the data that come from measurements are increasingly seen to have a direct influence on the economy, human health and safety, and welfare. The only way for this to be assured is for measurements in all areas of science to be made in terms of a well-defined system of units, namely the International System of units (SI), and that they are seen to be made within the context of the global measurement system whose reliability is assured by the NMIs and the BIPM working together.

2.1 Current and new requirements

Metrology in physics and engineering

Although until recently metrology has dealt almost exclusively with physics and engineering, the rapid development of new techniques and the general need for better, reliable measurements with improved accuracy and control, together with the diversification of materials, have brought additional and new demands on what could be called “classical metrology”. Indeed, in many domains such as dimensional metrology, electrical measurements, time and frequency, optical and pressure measurements, the needs in accuracy during the last fifty years have increased by a factor of ten every ten to twenty years. And this trend has not stopped; on the contrary, it has accelerated. For example, this is the case for time and frequency standards, which are the basis of space navigation and positioning systems. Another example is the very stringent needs in dimensional and mechanical metrology when subsystems designed for assembly are built in different factories, often in different countries, so as to guarantee the interfaces.

In the oil and gas industry trade major benefits would be obtained if, for example, the measurements of flow were significantly more precise. It is a challenge to metrology to improve the reliability and the accuracy of gas and fluid flow measurements, because billions and billions of cubic metres are measured in oil and gas pipelines and then traded to users. Errors of a few parts per thousand represent some hundreds of millions of dollars. Many other examples could be given, perhaps not all with the same economic impact, but still important quantities of goods for trade.

There is now a need to quantify and measure many physical properties for which there were, until recently, no metrologically traceable procedures. One may mention various rheological and thermo-mechanical properties of matter (strength, viscosity, elasticity, heat transfer), the characterization of grains and powders, colors, odours, etc.

Nanometrology

The general trend towards increased miniaturization in manufacturing has led to the evolution of technology from micro- to nanoscales. However, this is not simply a scale problem, but in fact means facing completely new physics. For example, the surface of an object can no longer be considered as smooth, but as a chaotic, rough spread of molecules or atoms and where in mechanical systems account must be taken of the Casimir force. The techniques to deal with such materials are entirely new. As a consequence, the methods of measurement and testing have to change drastically, and this is a major challenge to metrology. But the actual need for metrology at the nano-level is the same as in classical industry: one must demonstrate that any product or manufacturing process meets specified demands. This requires quantitative measurements traceable to common standards.

For example, nanometre accuracy is needed in ultraviolet lithography for which large mechanical and x-ray optical components must be built and measured with tolerances given in nanometres and possibly on a sub-nanometre scale. Among many other applications, one should mention the finish of the edges of optical fibres for telecommunications, improving surface textures, various uses of nanotubes and fullerenes, glass coating with very thin films, etc. Not only must one design new measuring devices for large separations, thereby extending the use of scanning probe microscopes for local analysis of surface properties, but also secondary length standards must be built which are grid-etched at the molecular level.

But nanometrology is not confined to dimensional measurements. In several other domains, very small quantities must be measured. This is the case of electron tunneling, of very faint ionizing radiations, of very faint forces and torques in micromechanics, of small pressures in vacuum techniques, as well as of many applications in biology, trace chemical analysis, pharmacology, etc. An interesting perspective on nanometrology is given in an European Union document referred to under (3).

Metrology in chemistry

Since the 1998 report was drafted, there has been a rapid development in the need for metrology in areas that in the past had only distantly been connected to the world's measurement system. Foremost among these is chemistry in all its aspects. Although the CIPM in the late 1980s began discussing the possibility of taking some action to advance metrology in chemistry, and the Consultative Committee for Amount of Substance (CCQM) was created in 1993, the wider chemical community has only recently begun to take notice of these developments. Even only five years ago, the need to address problems of metrology within the wider chemical community was hardly a subject that was discussed. This is no longer the case.

For example, recently the National Conference of Standards Laboratories (NCSL-I) in the United States created a Chemical Metrology Committee and only in 2002 the annual Conference of the International Association of Official Analytical Chemists (AOAC-I) organized for the first time a symposium on the international and trading aspects of metrology. The ever increasing interest of the chemical and oil industry for internationally recognized traceability and comparability is significant. The chemical community places increasing emphasis on metrology and related activities concerning TBTs. This is clearly seen at the PITTCON conference, one of the largest yearly chemical conferences and exhibitions in the world held in the United States, and at many other chemical conferences in Europe, Japan and several other countries.

Metrology in health care

Important developments have taken place in health care over the past decade. Due to advances in measurement capabilities, the diagnoses of patients have improved considerably, thus contributing to an increased chance of successful treatment.

Unfortunately, there still remain many problems of comparability in hospital measurements not only at the international level but also between and within hospitals. Resolution of these problems would lead to immediate improvements in health care as well as to considerable cost savings. The need to ameliorate the situation was recognized by the European Commission and resulted in the IVD Directive due to come into force at the end of 2003 (4).

The Directive requires traceability to measurement standards of higher order (without being specific as to what standards are required).

Also in other regions in the world, such as the United States, traceability of measurements in laboratory medicine is pursued. The NIST, in close cooperation with the United States medical community, has been and is developing a large number of certified reference materials, providing the tools for more accurate and traceable measurements in laboratory medicine.

The professional organizations in the field, the International Federation of Clinical Chemistry and Laboratory Medicine (IFCC) and the corresponding institutes in the United States and Japan, as well as the IVD industry, together with the regulators, certified reference material (CRM) producers, quality assessment organizations, the accreditors under the International Laboratory Accreditation Cooperation (ILAC), the national metrology institutes and the BIPM have initiated a new activity on traceability in laboratory medicine. The provisional name of the new activity is the JCTLM. The aim is to support the establishment of worldwide comparability, reliability and equivalence of measurement results in laboratory medicine for the purpose of improving health care and to foster, where needed, the establishment of a recognized international network of reference laboratories. This is seen to be essential in order to meet not only the requirements of the IVD Directive but also to meet wider concerns for reliability in laboratory medicine (5).

It should be noted that many of the measurements required in this field are ones that cannot at present be made in units directly traceable to the SI. This is for example the case with fat content and with the biological activity of many pharmaceutical preparations, which are not quantities that can easily be measured in physico-chemical terms. In these cases, standards are based on so-called international units defined in terms of the biological activity of reference samples. It is expected that the BIPM and the WHO will take the lead in the further development of an officially recognized system of traceability.

A database for CRMs in clinical chemistry and laboratory medicine is now being developed. This seems to be a unique example of joint activity between the metrology and medical communities, the regulatory bodies, accreditors and industry.

Metrology in food safety and testing

Food safety and food testing now have a high public profile. Recent examples of disasters in this field (BSE, salmonella, dioxin, etc.) have demonstrated that reliable sampling and measurements are an essential component of proper decision taking. The fact that the existing national systems for such testing within the European Community are not at all optimum has led to the development of a system of European Union and national reference laboratories and accredited official control laboratories, which have to fulfil the criteria of ISO/IEC 17025, including traceability issues, and additional performance criteria of analytical methods (6). In many countries legislation is now addressing the testing of foodstuffs in the whole chain from live animals to final human and animal food products. A large number of working groups under the Codex Alimentarius Commission are developing better and validated measurement procedures. To address all the concerns with respect to genetically modified food (GMOs), better and traceable measurements are being developed. Apart from the fact that food testing is closely associated with public health, it should not be forgotten that food is a major internationally traded product and thus subject to non-tariff barriers to trade. The field of food testing is one in which many reference standards are not, and as yet cannot easily be, linked to SI units.

Metrology on behalf of law enforcement, fraud, forensics, anti-doping, security

There are many more areas where reliable and internationally agreed and recognized comparable measurements are of importance, such as those on behalf of law enforcement (speed, alcohol breath analysers, etc.), customs (e.g. alcohol), fraud, forensics (DNA, etc.), anti-doping, security, etc. Measurements in these areas include physical as well as physico-chemical measurements.

The World Anti-Doping Agency (WADA) in cooperation with the International Olympic Committee is drafting a sector-specific quality conformance standard addressing also issues on traceability and measurement uncertainty.

Metrology related to the quality of life

Many types of measurements are more or less closely related to what the public perceive as “quality of life”. These include measurements of noise (e.g. noise by neighbours, traffic and airport noise), dust (outside and inside), vibration and even measurements of subjective quantities such as taste, smell and appearance (e.g. glossiness of paints is a well-known and critical parameter in paper and car manufacturing). Also in these cases the consumer expects reliable and comparable measurements and specifications.

Metrology related to the monitoring of environmental pollution

The degradation of the environment from the damaging effects of human and industrial activities, be it in the ground, water or in the air, must be measured accurately. This is not only to ensure reliable data for checking conformity to standards and for decision-making related to protective measures but also for new applications; for example, when formal arrangements for emission trading become operative. The costs connected with keeping the environment clean or connected with the cleaning process itself are enormous. Incorrect measurements lead to wrong decisions and may cost the producer or society very large sums of money. National pollution measurement networks have been established in many countries and are still being installed in others. Both national (e.g. in the United States) and regional (European Union) regulations (Directives) (7) with respect to exhaust gases and several other pollutants have been approved. Since environmental problems are not confined within national borders, there are important international implications in any formulation and implementation of regulations.

Metrology monitoring climate change

In order to monitor climate change and provide reliable data for climate modelling, a Global Atmospheric Watch programme has been put in place by the WMO. These are measurement points spread all over the world that monitor the different parameters like wave heights, temperature, greenhouse gases, ozone etc., over very long periods. These measurements are only meaningful if they are anchored well to very long-term, stable, internationally agreed and recognized, global measurement standards, i.e., standards that must themselves be linked to the unchanging fundamental constants of nature. This requires regular calibrations and international comparisons, not only in the field of physical measurements but also in the field of measurements in chemistry and close links to the world's NMIs to provide SI standards.

Metrology in biotechnology and biology

There are new and urgent needs for standardizing measurements of genetically modified food products. Large export markets depend upon public acceptance of the results of measurements of the presence or absence of GM products in food. The current measurement methods lack rigor and are not well characterized or understood. DNA and RNA technology is another area of modern biotechnology where a metrological infrastructure has yet to be developed. In all of these areas it is essential that worldwide comparability and reliability of measurements be quickly achieved to meet the rising expectations of the public.

2.2 New approaches in metrology

The class of quantities for which it is not yet possible to assign SI units, for example quantities like taste, smell, biological activity and quantities in the field of proteomics, in addition to those quantities like hardness, pH, etc., is one that must be taken into account. It is likely that in several other areas, particularly in the food domain, one also has to agree internationally on empirical units. The CIPM, at its meeting of October 2001, accepted the principle that if the needs of trade, industry, regulators and society so require it, such units will be considered by the CIPM and the Consultative Committees despite the fact that they are for the present not linked directly to the SI. As knowledge advances, it is becoming possible to extend objective and SI-related measurements into these fields but in many cases that time is still in the future.

The wide and still increasing applications of information technology (IT) have a large impact on the field of metrology and the way the NMIs and the BIPM will work (8). Developments in IT will certainly influence the relationship between the NMIs and the calibration and measurement laboratories, being the customers of the NMIs. IT applications will make it possible to accelerate the training of new and developing NMIs and will facilitate the transfer of knowledge between the NMIs themselves as well as between the NMIs and their customers.

IT applications will also make it possible to facilitate remote-controlled comparisons and on-site calibrations. Whenever this is feasible, it reduces the costs of travelling, calibration and comparison time, waiting times and the costs involved in double investments and logistics.

In order to test the reliability of software used in metrology, still more efficient and effective verification procedures have to be developed.

New femtosecond lasers reduce considerably the complex measurement chains that relate optical and microwave (length and time) standards, saving laboratory space, investments and duration of measurement, while generating higher accuracies for optical frequency measurements.

New materials and production technologies lead to the miniaturization of measurement devices, so called “lab-on-a-chip” or micro total analysis systems, making it possible to measure very quickly small amounts with lower uncertainties and open the way to the use of innovative types of measurement and the discovery of new phenomena.

Nanotechnology will develop further based on the application of microbiology and bio-technology.

Nowadays, many calibration and measurement laboratories are in the possession of fixed points for the temperature scale or quantum-based primary standards, such as atomic clocks, stabilized lasers, quantum voltage and electrical resistance standards as well as primary measurement technologies for measurements in chemistry. It is essential that these devices and technologies be verified to ensure that the device, technology and method is being correctly applied. For this it is necessary that inter-laboratory comparisons take place, which must be organized by the NMIs.

As some of these developments are rather costly and require state-of-the-art science and technology, it may be wise to arrange for partnerships in development with other planners and users. These partnerships may not only be established between the NMIs, or between the NMIs and the BIPM, but may also include universities and the industry.

2.3 Needs of developing countries for metrology

Recognizing that in some developing countries a legal framework for metrology is completely lacking, one can observe, however, that in a significant number of developing countries a national metrology organization exists, mostly carrying out some legal verification work for the purpose of domestic retail trade. Most of these organizations lack appropriate (national) measurement standards and calibration and verification equipment. They also urgently need metrological education and practical experience.

Appropriately maintained and internationally recognized traceability of the national measurement standards is often lacking as well as regular participation in international comparisons, leading to serious handicaps in trading.

An illustration of the consequences of a poor metrological, testing and quality infrastructure was the fact that in 1999 the Lake Victoria countries Tanzania, Uganda and Kenya faced a ban on fish exports to the European Union because of suspiciously high levels of contamination in the lakes (9, 10). The ban affected the 150 000 workers who lost their jobs, while most of the fish factories were closed or operated far below capacity. The revenues from the export of the Nile perch, which exceeded 200 million US dollars per annum, dropped by 50 %. Due to rapid action in training and establishing credible and traceable testing laboratories, the export ban was lifted and the export of Nile perch was resumed to the European Union by the end of the year 2000, thereafter to other countries outside the European Union, like the United States. Nevertheless, considerable income was lost.

In order to enlarge and strengthen the export possibilities for products from developing countries and to allow them to measure and test products that they import, it is crucial that confidence be established in measurement and test results carried out in these countries. Independently of the accuracy levels realized by the NMIs of the developing countries, it is essential that the existing calibration and measurement capabilities become visible under the CIPM MRA and internationally recognized.

For this we encourage developing countries to become at least Associate States or Economies of the CGPM, perhaps as a preliminary to becoming Member States of the Metre Convention. It is the only way to open the doors to unquestioned measurements and testing of products and services and thus to international trade.

It has to be remarked here that it is not necessary that every country have its own fully equipped NMI; international cooperation with neighbouring countries may well lead to sharing costly measurement standards facilities, thus avoiding unnecessary duplication.

The Regional Metrology Organizations have an important role to play in supporting and coordinating metrological activities in developing states and economies and encouraging them to become Associates of the CGPM. An Associate State or Economy is entitled to join in the RMO key comparisons the results of which are published in Appendix B of the CIPM MRA, while the capabilities of the NMI of the Associate may be published in Appendix C. In this way the reliability and international recognition of the metrology system in the Associate State or Economy becomes globally visible. Moreover, the Associate will have access to all metrological information, know-how, and technology transfer, etc.

Many NMIs of the industrialized countries support developing countries and countries in transition in establishing an internationally recognized national metrology infrastructure.

To assist in the coordination of metrological, accreditation and standardization activities aimed at developing countries, the CIPM is cooperating with the ILAC, OIML, ISO DEVCO (ISO Committee for Developing Countries) and ISO CASCO (ISO Committee on Conformity Assessment standards), IEC, IAF, ITU, and UNIDO. A common approach by the international organizations mentioned above will serve the developing countries and economies by advising on efficient and effective coherent and tailor-made programmes, supporting the establishment of an adequate national infrastructure for metrology, accreditation and standardization. At a first meeting in April 2002, which was also attended by representatives of the RMOs, followed by a meeting in September 2002, the above-mentioned organizations agreed to establish a Joint Committee on coordination of assistance to Developing Countries in Metrology, Accreditation and Standardization (JCDCMAS), aiming to act as a forum in support of the coordination of assistance to developing countries and economies and those in transition with the establishment of their infrastructures.

After ratification of the cooperation and the approval of the terms of reference of the JCDCMAS, it is planned to organize meetings with donor bodies such as the World Bank, Regional Development Banks, Economic Communities and the World Trade Organization (WTO), as a means of assisting these institutions in developing the right projects with the developing countries. The JCDCMAS will not interfere with direct support programmes to developing countries and countries in transition by the governments of the Member States of the Metre Convention.

The BIPM, together with the OIML and the IMEKO and financially supported by UNIDO, will organize seminars for developing countries. In addition, the BIPM will initiate summer schools for young metrologists of the NMIs.

Apart from the activities coordinated on the global level, there is a special task for the RMOs to deliver support to developing NMIs in their own region.

2.4 Technical barriers to trade and sanitary and phyto-sanitary measures

Among the aforementioned TBTs is the lack of mutual recognition of measurement and test results. This leads to duplication of measurements and tests in the exporting and importing countries with a corresponding increase in costs and waste as well as delays and the risk of dispute concerning the results.

Regional internal markets like the APEC, European Union, MERCOSUR, NAFTA and the SADC work effectively and efficiently only when TBTs are removed. The mutual recognition of measurement and test results is not, however, something that can be put in place by the stroke of a pen. A reliable infrastructure of mutual confidence in measurements and demonstrable verification must first be there. This takes time. It is for this reason that the European Union is paying a lot of attention and investing a great deal of money in the development of the national metrology infrastructure of new European Union candidate countries.

The implementation of trade agreements under the WTO requires the existence of an internationally recognized system of comparable and traceable measurements (11). As international accreditation agreements are tools for creating confidence in the competence of measurement and testing laboratories, they are based on the understanding that the measurement and test results carried out are reliable, traceable and comparable. This requires the existence of an international network of national metrology laboratories, recognized by regulators and legislators and in which trading partners can have confidence, and to which all the industrial and other measurement, calibration and testing laboratories can refer.

The CIPM MRA was created for this purpose (2). The need to have an internationally accepted and reliable measurement system in place is now understood by governments, trade authorities and regulators. The MRA is now recognized and cited as providing the measurement infrastructure in trade agreements, for example in those signed between the European Union and the United States. This also shows up indirectly via the accreditation agreements referred to in the trade accords signed, for example, between Switzerland, Australia, New Zealand and the European Union. The need for developing countries and economies to be part of this system is obvious.

Also belonging to the non-tariff barriers affecting market access belong the Sanitary and Phyto-Sanitary measures (SPS). These SPS measures address different aspects of quality of life, including plant protection, food (FAO), bio-safety (GMOs) and health aspects (WHO). Proper implementation of the Sanitary and Phyto-sanitary measures require reliable, internationally recognized traceable and comparable measurements.

3 Expanding international cooperation and new networks

3.1 International cooperation on R&D, measurement capabilities and transfer of know-how

It is the task of the NMI to deliver those calibration and comparison services that are needed in that country. Moreover, underpinning these services, the NMI will develop and maintain national measurement standards and measurement devices to the level of accuracy needed for the economy and the society of the country concerned.

For financial reasons, it is almost impossible and certainly unnecessary that every individual country realize and maintain primary measurement standards for every quantity. Certainly for small and developing countries and economies, the need for international cooperation and sharing of capabilities and division of work is a point of serious consideration. International cooperation will reduce costly unnecessary duplication and will make it possible to realize more complementary activities, leading to a broader service to the customers. On the other hand, to avoid false solutions and mistakes it is a principle of good metrological practice and science that the development of new measurement standards and related technical capabilities be realized by at least three or more institutes in the world, preferably applying different principles of measurement.

International cooperation on R&D will lead to more efficient and timely development of improved and new measurement standards and calibration and comparison capabilities. Organized and systematic transfer of know-how has to guarantee that knowledge obtained during development is commonly shared by the participating countries. This requires an open-minded structure in which, in general, a purely commercial approach does not fit.

To guarantee the necessary continuity and real common ownership of the developments and facilities it is mandatory that these common projects be well formulated and based on a contractual relation, including assurances of a level economic playing field, accessibility for customers, delivery times, financing, staff, ownership and patent rights.

Possible problems with respect to language, transportation, customs, VAT and other legal requirements have to be taken into account as well.

The coordination role of the BIPM is increasingly called upon by NMIs.

3.2 International networks, Joint Committees

As metrology is a basic tool in almost every type of trade, industry and society, it is necessary to maintain good cooperation with the active partners having responsibilities in the different fields.

Global networks, in which the BIPM participates, include a large number of international organizations, such as the CIE, IAU, ICRU, IEC, IFCC, IMEKO, ISO, ITU, IUGG, IUPAC, IUPAP and the OIML, while more or less intensive cooperation exists with several other scientific organizations. In most cases the cooperation between these organizations is based on a pragmatic relationship with the CCs of the CIPM and with other bilateral or multilateral working groups, like the Joint Committee for Guides on Metrology (JCGM).

The cooperation of the BIPM with the ISO has recently been broadened to category A liaison with the ISO CASCO committee, while also the links with ISO REMCO have been intensified.

The increased focus on removing non-tariff barriers to trade requires a very transparent international agreement on recognized traceability and comparability, and recognition and acceptance of calibration certificates and measurement reports issued by the NMIs; hence another justification for the CIPM MRA. In this context, the CIPM MRA will be successful if it fulfils the needs of the other parties involved in international trade, such as the traders, the industry, the regulators, the WTO and the accreditation bodies under the ILAC. For this reason the CIPM has requested to be an official observer at meetings of the WTO TBT Committee.

In 2001 the CIPM signed a Memorandum of Understanding (MoU) with the ILAC.

The cooperation with the ILAC includes mutual harmonization of the ILAC Arrangement and the CIPM MRA. These two Arrangements are completely complementary to each other, because the CIPM MRA establishes international comparability and recognition on the level of the national measurement standards of the countries and economies, underpinning all measurements and testing in that country/economy, while the ILAC Arrangement establishes international recognition on the level of the accredited calibration and testing laboratories and inspection bodies. Further, the MoU fosters timely consultation on policies and guidance documents with respect to traceability, certified reference materials and other related measurement issues, exchange of lists of metrology expert/NMI peers involved in the accreditation of NMIs and cooperation in development aid.

The rapid development of metrology in chemistry and the urgent need to realize reliable comparability and traceability in the fields of environmental measurements, clinical measurements and measurements in laboratory medicine in general, in food testing (human as well as animal), forensics and anti-doping, has led to the further development of a series of networks with among others the WMO, the IFCC and the WHO, while contacts are being established with the Codex Alimentarius Commission and the World Anti-

Doping Agency. In this context we mentioned already in Chapter 2.1 the creation of the JCTLM.

A MoU with the WHO has been signed, aiming at cooperation with respect to metrological issues in clinical chemistry and laboratory medicine.

A similar type of formal cooperation is being fostered with respect to the other above-mentioned sectors.

In the meantime also a MoU has been signed between the CIPM and the WMO, addressing the establishment of traceability and comparability underpinning the Global Atmospheric Watch programme.

It is essential that the relationships now being established rather successfully at the global level also be realized by the NMIs at the national level and at the regional level through the respective RMOs.

3.3 Accreditation, the International Laboratory Accreditation Cooperation (ILAC)

Together with the NMIs and other legal metrology institutes, accredited calibration laboratories from industry, universities and other institutes form the national metrology infrastructure that serves the needs in a country for reliable and, in principle, internationally recognized calibrated instruments. The ISO/IEC 17025 standard (12) provides the tool for the creation of confidence in the capabilities and competence of the accredited laboratories.

This technical competence standard requires internationally recognized traceability with respect to measurements and tests as well as statements on measurement uncertainty. Also in sector-specific competence standards, which in most of the cases are derived from the ISO/IEC 17025, traceability and measurement uncertainty statements are now a requirement. An example can be found in the ISO standard 15189 for medical laboratories (5).

In order to demonstrate international recognized traceability, a transparent, internationally recognized metrology system is needed, a requirement fulfilled by the CIPM MRA.

It has to be remarked here that the ISO/IEC 9001:2000 standard (13) also requires, where relevant, traceability of measurement and test results.

As previously mentioned, for several reasons metrology and accreditation are closely related and it is clear that a close cooperation with the ILAC is needed.

In November 2001 the CIPM and the ILAC signed a MoU describing the essential need for cooperation. Based on this MoU a more detailed action plan has been approved, including:

- mutual promotion of the BIPM and ILAC Mutual Recognition Arrangements;
- mutual reference in the respective MRAs of the CIPM and the ILAC;
- timely information and cooperation in the formulation of requirements with respect to internationally recognized traceability, measurement uncertainty, measurement standards and certified reference materials,

method validation, comparisons and accreditation of calibration laboratories;

- joint cooperation in support to developing countries and economies;
- joint educational activities for laboratories and others (e.g. traceability workshops);
- mutual support in assessments of NMIs and agreement on cost-effective techniques for such assessments;
- mutual observer status in relevant consultative committees and working groups;
- mutual attendance in each other's general assemblies.

Consequently there is a clear need on the national level for close cooperation between the national accreditation body (NAB) and the NMI. This can, for example, be realized when representatives of the organizations have seats on each other's governing and/or advisory boards.

Also on the regional level close cooperation between the regional metrology organizations and the regional accreditation bodies has to be fostered.

3.4 The International Organization for Legal Metrology (OIML) and standardization (ISO/IEC)

The OIML and legal metrology

Legal metrology, in the general and wide sense, embraces all legislation regulating the basis of measurements (units and national measurement standards), the formulation of maximum permissible limits of error and other quality requirements for measuring equipment falling within the act regulating legal verification, reverification and surveillance, as well as methods for the testing of such equipment.

The realization and maintenance of the national measurement standards require expert metrologists and specialized laboratories that are more scientifically oriented than the legal metrology verification and surveillance offices. In many countries this is carried out as part of a larger organization, in separate metrology departments for measurement standards, or it is implemented by one or more distinct other institutes, all acting as a NMI. In other countries the NMI is part of a legal metrology organization, also having responsibilities for legal verifications.

In developing countries there is often not yet a clear distinction between the national measurement standards and legal metrology testing. It is essential that the responsibilities and activities of the NMI and the legal metrology organization are well coordinated.

The BIPM and the OIML are coordinating those activities that are of importance to both organizations; these include development of a model metrology law, seminars for developing countries and traceability issues.

Further strengthening of the cooperation between both the organizations will be encouraged where relevant.

Standardization (ISO/IEC)

Since quality is closely related with proper, fit-for-purpose, reliable measurements, a close cooperation between the BIPM and ISO, IEC and ITU is necessary.

As mentioned in 3.2, the BIPM is an A-liaison body in the ISO CASCO. This makes it possible for the BIPM to be directly involved in the writing of ISO conformity assessment standards.

Recently with respect to certified reference materials (CRMs) a closer cooperation has been established with ISO REMCO.

The already existing cooperation with respect to the *International vocabulary of basic and general terms in metrology* (VIM) and the *Guide to the expression of uncertainty in measurement* (GUM) is of course extensive and long-lasting, while the BIPM now also participates in the ISO TAG 4 (technical advisory group on metrology of ISO).

It is fostered and expected that cooperation will increase and will not be limited to the aforementioned fields, but will be extended to cover all written standards in which traceability and measurement standards, including CRMs, are referenced, in particular also embracing measurements in laboratory medicine, food testing and the environment.

It is highly desirable that the type of collaboration between the BIPM and the ISO/IEC, if appropriate, become additionally established at the regional level between the RMOs and the regional standardization bodies and of course, *mutatis mutandis*, also at the national level between the NMIs and the national standardization bodies.

It has to be remarked here that standardization is not limited to the agencies indicated above, but may include such standards writing bodies as the Codex Alimentarius Commission, the WHO and AOAC International, and sometimes in specific cases other national and regional standards writing bodies, for example like those in the health care sector.

4 Economic and social impact

As the definition of the legal units (the worldwide SI) and the definition, realization and dissemination of the national measurement standards are a responsibility of governments, a valid question is raised as to the extent of the economic and social impact of all the activities. Unfortunately, it is not an easy matter to express the economic and social impact of metrology in clear characteristics and numbers that are universally applicable or that can be readily used by authorities to assess the necessary investments in metrology.

The national measurement system is seen as a matter of national infrastructure, serving many crucial aspects of society. Therefore, almost by definition it is very difficult to determine and quantify the economic and social benefits of the metrology programmes. Nevertheless, a number of studies have been made attempting to quantify the economic and social benefits of the metrology programmes.

4.1 Objectives of past studies

As national metrology programmes are generally financed with public funds, it is understandable that one has to demonstrate the added value of these government-financed metrology programmes to the economy and well-being of the country. In addition, feedback to the authorities is needed to allow them to evaluate the effectiveness of the programmes, to justify their continuation or to reassign priorities for new or modified projects. Unfortunately, not many studies have been carried out that provide such quantitative feedback. To our present knowledge the four largest studies known are those commissioned by the NIST (United States), DTI (United Kingdom), NRC (Canada) and the EC (European Union). These studies are based on the application of different economic approaches.

The NIST (United States) has carried out several studies of the economic impact of its work in several specific areas and is continuing to do so. Most of the studies are retrospective and are based on the comparison of the costs of development of a certain measurement standard or certified reference material and the estimated savings to a predefined group of users. On the basis of this model it is, in principle, possible to estimate the cost savings on a national scale, although the NIST has not always done such an extrapolation. However, some benchmark cases have been carried out. The NIST studies also allow case-by-case leverage factors to be calculated.

The DTI (United Kingdom) approach is based on more macroeconomic considerations which yield overall figures. In addition, benchmark studies comparing the United Kingdom NPL calibration and measurement capabilities with the capabilities of other NMIs have been carried out.

The Canadian study carried out on behalf of the NRC is based on a combination of a few case studies, interviews and analysis of statistics. The case studies have been extrapolated to a number giving an indication of the importance on a national scale.

The European Union study is based on the results of six case studies and information gathered from the EC, NMIs and industries in the European Union member states, complemented with econometric estimates.

All four studies aim to provide quantitative arguments for continued government funding and construct simple, clear arguments to convince stakeholders of the value of metrology, including not only the economic worth but also ethical values such as fairness, safeguards, etc. The investigations have been carried out by or with the assistance of economists from universities and from private professional consultancy firms.

4.2 Results of past and recent studies

Measurement and measurement-related operations have been estimated to account for between 3 % and 6 % of the GDP of industrialized countries. Other studies find that in developed countries about 15 % of the GDP is measurement-related. Analyses carried out in the recent past show that investments by governments of developed industrialized countries vary from between 20×10^{-6} to 70×10^{-6} of the GDP of a country (14).

In general it can be observed that countries investing at least 60×10^{-6} of GDP are able to achieve more advanced development than those which have invested only 15×10^{-6} in metrology. In particular, this is demonstrated by the availability and development of reliable and accurate measurements in support of projects in the areas of high-technology manufacturing, food production and safety, pharmaceuticals and clinical measurements. Examples can be found in the United States, Singapore and the Republic of Korea. In some of the rapidly developing countries and economies in the Asia-Pacific region expenditure reached as high as 100×10^{-6} of the GDP. This means that on average there is a leverage factor of about 1000 to 2000 between the government investments and the measurement-related industrial production of a country. Although it is not easily and directly quantifiable, the social impact of metrology in areas like climate change and quality of life should nevertheless not be neglected.

The NIST studies calculate a benefit-cost ratio (bcr) i.e., the ratio of the financial benefit to financial cost, and a rate of return to the nation, called social rate of return (srr) (15, 16, 17, 18, 19, 20). The bcr is an indication of the investment, industry would have had to make, if the NIST did not perform the work. The srr is calculated over a period of time taking into account the investments made by the NIST and the benefits acquired by a selected number of enterprises benefitting from these NIST investments and is expressed as the financial benefit as a percentage of the corresponding NIST financial investment. Industry savings include lower transaction costs, lower regulatory compliance costs, energy conservation, increased research and development efficiency, increased product quality and enabling new markets.

Some typical numbers:

Industry	**Project**	**srr**	**bcr**
Semiconductors	resistivity	181 %	37
	thermal conductivity	63 %	5
Communications	electromagnetic interference	266 %	
Photonics	optical fiber	423 %	
	spectral irradiance	145 %	13
	optical detection calibration	72 %	3
	laser and fiber-optic power calibration	43-136 %	3-11
Energy	electric meter calibration	117 %	12
Electronics	Josephson voltage standard	87 %	5
Materials	thermocouple calibration	32 %	3
Pharmaceuticals	cholesterol	154 %	4.5
Chemicals	sulfur in fossil fuel	1056 %	113

Recent NIST cited studies (21) by the Mayo Clinic in the United States showing the effect of measurement bias on medical decision making. Using results of cholesterol measurements on over 20 000 patients, a statistical model was developed to show that a +3 % measurement error would produce a 5 % rate of false positive cases that would result in needless re-testing or medical intervention. Conversely, a –3 % bias would produce a nearly 5 % rate of false negative results, leading to delayed treatment or no treatment at all. Thus, seemingly small errors produce either needless and wasteful expenses undue suffering and even more tragic results. The costs of diagnostic errors for many patients who need treatment but who, on the basis of wrong test results, go untreated is difficult to quantify, but may even be much higher than the costs incurred for patients who do not need treatment, but receive it anyway as a consequence of errors in measurement. Other studies by the NIST showed that Cardiac Troponin-I is a highly specific diagnostic marker for heart attack. However, owing to a lack of traceability and comparability in the medical clinics still too large a percentage of patients are misdiagnosed.

In a recent testimony before a United States Senate Committee (22) a 1999 study by the National Academy of Sciences Institute of Medicine was cited, stating that while the majority of medical errors are not due to inaccurate measurements, improved measurement accuracy could save lives, a significant amount of time and money, and improve our quality of life.

In 2001 health care costs in the United States are estimated to exceed 1300 billion US dollars per annum, which is about 14 % of United States GDP. It is estimated that typically 10 % to 15 % of these costs are measurement related. The Washington Post and Medical Laboratory Observer have reported that 25 % to 30 % of health-related measurements are performed for non-diagnostic reasons (re-test, error prevention and detection). This means that potentially some 10 to 30 billion US dollars per annum could be saved.

The Committee on Quality of Health Care in America stated in a 1999 report that “Dollars spent on having to repeat diagnostic tests… are dollars not available for other purposes”.

The U.K. studies (23, 24) have made use of direct measurements based on a pre-existing Mapping Measurement Impact economic model. Further case studies have been carried out and use has been made of economic analysis, including econometric input/output analysis, trade flow and Total Factor Productivity (TFP).

The investigation shows that measurement in the United Kingdom as a whole delivers a significant impact on the economy of 0.8 % of GDP, which equates to 5×10^9 GBP per annum in terms of TFP. It is believed that this leverage of economic impact by an annual government budget to the NPL of 38 million GBP is exceptionally large (leverage factor of 130). The United Kingdom government considers the investments in the national metrology infrastructure as one of the best examples of government investments with a large return.

The Canadian economic impact study (25) carried out on behalf of the NRC INMS (Institute for National Measurement Standards) has considered a few of the core functions of the INMS including the maintenance of primary standards, research and development and calibration and metrology services.

Furthermore, a study has been made of the potential economic impact associated with the four strategic areas of nanotechnology, biotechnology, nutraceuticals and functional foods, and energy.

In addition, desk studies have been carried out making use of certification and accreditation data. Overall, the study conservatively estimates that the current INMS annual government investment of about 12 million Canadian dollars provides a benefit-cost ratio of about 13:1.

The European Commission, Directorate General Research, has commissioned an "assessment of the economic role of measurements and testing in modern society" (26). Apart from giving some overall conclusions, the report discusses six case studies in the following sectors: nanotechnology, the automobile industry, the pharmaceuticals industry, the European natural gas sector, the in-vitro diagnosis industry, and the control of emissions and pollution of the environment. The studies are based on economic data and interviews with the industries concerned.

The study shows among others:

- The European Union spends 83 billion euros per year, or nearly 1 % of European Union GDP, on measurement activity (NMI turnover, accredited calibration laboratories turnover, certification costs to industry, instrument costs, and industrial spending on measurements). Adding social spending on health, environmental regulation, safety testing, anti-fraud projects and normal day-to-day measurement activities raises this figure considerably.
- For example, 13 billion euros per year are spent on measurements and testing across European health services and 5 billion euros per year are spent on safety and emissions inspections of automobiles in the European Union.

- Econometric estimates of the economic impact of measurement activity show that this spending generates almost 230 billion euros of directly estimable benefits through application and from the impact measurement knowledge has on technology-driven growth. This is equivalent to 2.7 % of European Union GDP. In other words, for every euro devoted to measurement activity nearly three euros are generated; thus a benefit-to-cost ratio of 3:1 (and this is already realized without taking into account the very large benefits to society in terms of health, safety and the environment, which would raise the benefit-to-cost ratio even further).
- Measurement has many of the characteristics of a public good, which in the absence of public funding would be underprovided by the market.
- Building a Europe-wide measurement infrastructure is essential for the further development of the single market and for its continuing efforts in health, safety, the protection of the environment and the fight against fraud.
- Measurement reasearch and development programmes show a bcr between 5 and 111 with an average of 16, which is comparable to equivalent projects in the United States.
- Nano-engineering is viewed as a strategic trade sector by several countries. In the wafer-stepper production industry about 35 % of the costs are directly attributable to measurement, meaning 1.5 billion euros per year for the total industry of wafer steppers. Improvement in metrology is clearly needed, leading to more powerful wafer steppers having huge influence on innovation and improvement in the semi-conductor industry and thus on the economy and trade. Intense cooperation between the NMIs, research and university communities and the industry is highly desirable. Public investments are needed.
- Metrology plays an essential and integrated role in the automobile industry. The turnover of the European automobile industry is 321 billion euros. Accurate, comparable and traceable measurements of almost all physical quantities and several chemical quantities (e.g. exhaust emissions) is required for constructing innovative, safe, energy-economic, low-cost maintenance and environmentally friendly cars, also leading to improved position of manufacturers in an extremely globalized and internationally competitive market.
- Pharmaceuticals represent about 12 % of health care expenditure in developed countries. Health care expenditure in Europe being on average 8 % of European Union GDP and in the United States 14 % of US GDP. World pharmaceutical sales were about 270 billion US $ in 1997, being about 70 % of total medical product sales. The sector is strongly regulated with measurements and testing based on Good Manufacturing Practices. The industry favours a different system for release of pharmaceuticals. Parametric release forms an integral part of the manufacturing process at critical points in this process. The industry is interested in investigating the benefits of closer cooperation with the NMIs in improving

spectroscopic analysis, chemometrics, sensors, and commutable certified reference materials, etc.

- Western European gas consumption in 2000 reached just under 390 billion cubic metre, being about one-fifth of total energy demand. It is easy to see that a metering error of 1 % equals about 4 billion cubic metres having a commercial value of 800 million euros per year at a consumer price of 0.20 euro per cubic metre. Errors due to metering, as well as those arising in temperature and pressure measurements, can easily be of the order of 4 % to 6 %. International comparability of high-pressure meter calibration facilities, based on traceability realized in the different countries concerned, demonstrate that differences can easily be larger than the reproducibility of the meters in use. Fundamental research by the NMIs to improve measurement techniques and methods is highly needed, including also parameters such as caloric value and energy content.
- In 1998 the World market for IVD products was about 20 billion euros. The European Union IVD Directive (4) requires traceability to standards of higher order. The economic impact of traceability has different aspects depending on the viewpoint of economic impact on the levels of industry, trade or society. Although the costs of establishing traceability may be considerable it is expected that the IVD Directive will lead to more reliable devices delivering much improved comparable measurement results and thus for the industry concerned a much larger market. The economic impact at the society level is considerable. Traceable and comparable measurement results serve directly the primary goal of laboratory medicine, in generating useful and reliable information for medical decision-making. Reliable measurements will reduce the need for repeated measurements. In Germany alone the costs of repeated measurements amount to 1.5 billion euros per year.
- In Europe a coherent policy for pollution control of industrial processes has led to the introduction of the Integrated Prevention of Pollution Control Directive (IPPC) and the European Pollutant Emission Register (EPER) and related Directives. There is a clear need for improving comparability and accuracy of measurements. Improved techniques and methods are also needed for measuring low levels of pollution.

Although the studies referred to are quite different, there seems to be considerable consensus on the final quantitative and qualitative conclusions.

Major conclusions are:

- there is a clear economic rationale for public funding of the national measurement systems maintained and realized by the NMIs of the countries/economies;
- the NMIs deliver considerable spillover benefits in international competitiveness and commercial innovation processes, as well as providing support for the measurement industry sector and for small and medium-sized enterprises;

- the NMIs generate significant non-economic benefits in the form of improvements to many aspects of quality of life, such as in health and safety, environment and consumer protection;
- the NMIs impact on the economy by maintaining the national measurement infrastructure, supporting innovation, enabling fair and safe competition and representation of the country;
- extra attention and consequent financing should be given to emerging technologies, including metrology in the areas of nanotechnology, quantum-based measurements, software, chemistry and biotechnology; additional funding should be supplied for internet calibrations and comparisons.

It has to be noted that the results of all the studies are of course country-specific and are not directly transferable or necessarily applicable to other economies and countries. The general approach and conclusions are valid, however, taking into account the level of development and the broadness of the metrological activities in each country.

It is clear that not all economies and countries are in a position to develop and maintain primary measurement standards, nor may this be needed. This means that countries not having their own primary standards need to have their national reference standards calibrated by a NMI which has primary standards and is internationally recognized by its participation in key comparisons and the CIPM MRA. It is observed that whenever possible these countries like to make use of the facilities of the BIPM, which are independent from possible national interests and priority settings and are free of charge.

Considering the general desire of these, mostly smaller, economies and countries to have guarantees for independent and impartial development and maintenance of (inter)national measurement standards and unlimited access for their NMIs to these standards, it may be desirable and quite economical to have some of the primary/reference and traveling standards with the connected calibration facilities developed or at least maintained by the BIPM. This includes such devices as travelling Josephson and quantum-Hall standards, a calculable capacitor and a watt balance. It has to be remarked here that at the international level the principal cost of maintaining the measurement system is that of supporting the BIPM, which in 2002 is about 9×10^6 euros. The contribution of each individual Member State is thus a very small fraction (usually less than 1 %) of what they spend on their own NMI.

Apart from the ongoing investments in the continuous development and improvement of “classical” measurement standards, it is clear that in the very near future major investments are needed in the relatively new fields of metrology in chemistry, biotechnology and microbiology.

Taking into account the results of the above-mentioned studies it can be concluded that these governmental investments show significant returns and are therefore well justified.

4.3 The KPMG study for the BIPM

KPMG Consulting was commissioned by the BIPM to conduct a study of the potential economic impact of the CIPM MRA (27). The study focuses on two specific impacts: economic consequences that might affect individual NMIs as a result of being a signatory to the centrally coordinated multilateral CIPM MRA, and effects that might result from the MRA's role in the reduction of TBTs.

The potential economic impact of the CIPM MRA is considered in both theoretical and empirical terms. In this study the tenets of economic theory are used to discuss the pertinent aspects of the MRA, including its role in conferring benefits through the creation of mutual recognition, establishing advantages of cooperative programmes between NMIs, and stimulating second-order effects by creating welfare gains through the reduction of TBTs. In addition, a review is presented of standard approaches to measuring empirically the benefits of reduced TBTs. A survey was designed and implemented to measure the effect of the MRA on its signatories (i.e. NMIs) and on associated public and private sector activities including trade and regulatory affairs. The goal of the empirical study is to measure – or to establish a reasonable estimate of – the impact that the MRA has on economic activity currently and its expected impact in the future.

By extension, a measure of the MRA's impact also offers an opportunity to interpret the economic role that the BIPM plays in the international metrology community. As such, the empirical methods used in the study (i.e. NMI survey and interviews with leading organizations) are designed to help identify specifically the benefits associated with the BIPM's unique role in international metrology. This interpretation supports insight and arguments about the implications of the MRA for the BIPM.

The key findings of the study are as follows:

- Based on information gathered in the NMI survey, it is reasonable to suggest that the CIPM MRA results in a notional saving of approximately 75 000 euros for each NMI in the cost of establishing and maintaining mutual recognition with one other NMI compared with the cost of the same activity prior to the MRA. Or in other words, to obtain the same broad international recognition by bilateral arrangements would have been hopelessly expensive.
- The results also indicate that the total notional saving to the community of NMIs is of the order of 8.5×10^7 euros per annum, at present levels of costs and comparison activity. A corollary is that the cost of establishing mutual recognition on the scale currently achieved would have been prohibitively expensive in the absence of the centrally coordinated MRA.
- A conservative, order of magnitude, estimate of the MRA's potential role in reducing TBTs internationally is presented, implying that the MRA might confer significant benefits to signatory nations. It is suggested

further that strategies for realizing this potential be pursued by the BIPM at the international level and by NMIs domestically.

- The long-term realization of the potential benefits of the MRA is likely to require a proactive role for the BIPM and the NMIs in promoting the MRA, specifically as this relates to organizations charged with the responsibility for governing international trade (i.e. international trade bodies and domestic trade representatives). It is argued that this proactive role is necessary to promote a positive balance between the costs and benefits of MRA membership over time.
- Quoting directly from the KPMG Report: "There is a widely held view that BIPM's "promotional" role, internationally and in support of domestic NMIs, can only be based on its credible, neutral, international voice. It is also well accepted that BIPM's credibility is a function of its ability to speak from a position of scientific expertise and that BIPM must maintain its scientific credibility over time in order for it to establish and promote the CIPM MRA specifically and metrological issues more generally worldwide."
- Export trade data, derived from OECD's International Trade by Commodities Statistics, for a set of twenty-eight CIPM MRA/OECD signatory nations, including all major trading and industrialized nations in the world, indicate that from a total of about 4.7×10^{12} euros in exports for the year 2000 around 4.2×10^{12} euros is traded among these twenty-eight countries. It is considered likely that a reduction of non-tariff barriers to trade may result in a net benefit of 10 % of this export trade amount. Even when only 0.1 % net benefit is generated by the effects of the CIPM MRA, this means a benefit of 4.2×10^{9} euros per year!

5 The BIPM

5.1 The role of the BIPM

The goal of the BIPM is worldwide uniformity of measurement.

The BIPM will achieve this goal by providing the necessary scientific and technical basis for such uniformity and by collaborating with other institutions and organizations that have related missions. Therefore, its principal tasks are:

The International System of Units (SI)

- to keep up-to-date and disseminate the text of the International System of Units known as the SI Brochure.

Basic scientific and technical tasks

- to conserve and disseminate the primary standard of mass, the International Prototype of the kilogram;
- to establish and disseminate International Atomic Time (TAI) and, in collaboration with the International Earth Rotation Service, Coordinated Universal Time (UTC);
- to make its own realizations of other base and derived units of the SI and , if necessary, other units that are not yet possible to link to the SI;
- to participate in the development of primary methods of measurement and procedures in chemical analysis and bioanalysis and where necessary to maintain its own standards in these fields;
- to undertake research focused on the development of present and future measurement units and standards, including appropriate fundamental research, studies of the conceptual basis of primary standards and units and determination of physical constants, and to publish the results of this research.

Specific technical services in support of NMIs

- to carry out certain international comparisons of practical realizations of certain base and derived units of the SI, as may be necessary to meet the needs of the ensemble of the national metrology institutes (NMIs);
- to provide a specialized calibration service for NMIs for selected national measurement standards whenever this is desirable and feasible;
- to provide opportunities for technology transfer during calibrations and comparisons organized by the BIPM;
- to provide facilities for the exchange of scientific staff between the BIPM and NMIs;
- to provide certain consultancy services to NMIs related to peer review of their activities.

Global coordination of metrology

- to provide support as necessary in the operation of the CIPM Mutual Recognition Arrangement (MRA) of national measurement standards and of calibration and measurement certificates issued by national metrology institutes through the operation of the BIPM key comparison database, the management of the Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB) and through participation in meetings of Consultative Committees and appropriate meetings of the Regional Metrology Organizations (RMOs) and through the publication of the results of key and supplementary comparisons;

- to provide the scientific and administrative Secretariat for the General Conference on Weights and Measures, the CIPM and its Consultative Committees as well as the secretariat for meetings of directors of NMIs and the various Joint Committees and to publish reports of their deliberations.

Relations with other organizations

- to enter into agreements with intergovernmental and international organizations where such agreements would help in the coordination of the work of these organizations with that of the BIPM or the CIPM and where it may stimulate corresponding coordination at the national or regional level;
- to collaborate, and where appropriate enter into agreements to establish Joint Committees with intergovernmental and international bodies having related missions;
- to act on behalf of the NMIs of Member States of the Metre Convention in representing their common interest as the occasion arises.

Information and publicity

To promote as widely as possible using all appropriate methods, the activities carried out under the Metre Convention, in particular:

- to provide through the BIPM website, a centre for information on matters related to the Metre Convention, the CIPM, its Consultative Committees, Joint Committees, the CIPM MRA, including the key comparison database, and matters related to international metrology;
- to edit and arrange for the publication of *Metrologia*, the international scientific journal of metrology;
- to ensure, with other appropriate organizations, that basic documents needed for uniformity of measurements, such as those on the vocabulary in metrology (VIM) and on the expression of uncertainty in measurement (GUM), are kept up-to-date and widely disseminated;
- to organize workshops and summer schools for the benefit of staff from the NMIs.

Cost effectiveness and evolving role of the BIPM

The BIPM will carry out these tasks in the most cost-effective and efficient way possible designed to achieve its goal and will continue to be ready to adapt and change its tasks as the need arises and as decided by the CIPM acting under the authority of the Member States of the Metre Convention.

5.2 The BIPM as an institution

The BIPM is a very small institution but its influence and the help it gives to NMIs is nevertheless quite considerable. The high value placed by directors of NMIs on the BIPM services is shown in the responses to the questionnaire sent to directors in December 2001 (see Appendix 3). The reputation of the BIPM in organizations outside the circle of NMIs is also high as has been shown in the KPMG study of the economic benefits of the CIPM MRA and is quoted in chapter 4.3 in this Report.

The BIPM needs its own highly qualified scientific staff in order to be able to provide the services used by NMIs, namely, comparisons, calibrations, technology transfer, support to Consultative Committees, the BIPM website, the BIPM key comparison database (KCDB), hosting guest workers, etc., and to be seen and able to act as the global intergovernmental organization in the field of metrology. It can do this, because, and only because, it carries out a programme of scientific work in its own laboratories, which is the essential prerequisite to having highly expert scientific staff. It is also necessary to have such a programme in order to attract and keep high-quality scientific staff and be an institute that attracts short-stay visitors from NMIs. The choice of programme is important because it must provide the essential core competences of a metrology laboratory as well as stimulating the equally essential synergies that must operate within the institute.

In each area of work at the BIPM there are rarely more than three scientific staff, but this is just sufficient provided that (a) they are of high calibre and (b) they maintain close contacts with colleagues in NMIs. As these staff members are able to maintain a sufficient scientific credibility to be treated as peers by their colleagues in NMIs and in other organizations, they are thus competent to provide all the services mentioned above.

When viewed from the standpoint of its contribution to world science, the scientific work of the BIPM can occasionally make a significant impact. However, this is not its primary purpose. Its principal aim is to maintain the scientific competence of its staff through their work on improving measurement standards (particularly travelling and transfer standards) and this it does to a high degree.

In the past, most of the scientific staff of the BIPM were permanent employees who spent a large part or all of their career at the BIPM. This was the case in most national laboratories as well. With the creation of the Research Fellow positions in the 1980s, however, the BIPM has been able to attract high-calibre staff for short periods of from two to three years. The six Research Fellows at present at the BIPM represent about 20 % of the total professional scientific staff.

For the future, we can foresee an increasing number of such short-term appointments largely supported by NMIs, in which case the work carried out would be designed to fit in with corresponding national programmes. Indeed, for the new programmes in chemistry and bioanalysis proposed here, a possible option is to initiate them with Research Fellow positions supported by some NMIs. A similar arrangement could be made for initiating work on a watt balance and the calculable capacitor.

Provided that there is a sufficient core of permanent staff, the initiation of new programmes or extension of existing ones by means of short-term appointments has some advantages in that no long-term commitments are made at the beginning and that high-level experts can be obtained for short periods whereas such people may not wish to come permanently to the BIPM.

5.3 Programme of work and dotation of the BIPM

As was foreseen both in the 1998 report of the CIPM on national and international needs relating to metrology and at the time of the 21st CGPM in 1999, the workload of the BIPM has increased considerably since 1999. Many new activities have been started in response to the implementation of the MRA; new laboratory work in chemistry has begun and the visibility of the BIPM in world metrology has significantly increased, notably through agreements and new contacts with other international organizations.

It was also foreseen at the time of the 21st CGPM that maintaining the funds at the level voted for the period 2001 to 2004, being the same in real terms as for the period 1997 to 2000, would not be sufficient to sustain all these activities beyond 2004. It was stated at the time that the 22nd CGPM in 2003 would be faced with the decision either to increase the dotation of the BIPM by a significant amount or accept a significant reduction in the activities of the BIPM.

In preparing the proposals for the programme and budget for the 22nd CGPM, the CIPM has taken note of the following:

- the programme of laboratory work adopted by the 21st CGPM;
- the many services provided by the BIPM by virtue of its scientific expertise;
- the additional work stemming from the CIPM MRA, namely, the KCDB, the JCRB, information technology, and the BIPM quality system;
- new activities related to other international organizations, the WMO, the WHO, the JCTLM and the coordination of assistance to developing countries;
- the continuing extension of the need for international action in metrology, into new fields, notably in chemistry, in bioanalysis and in medicine;
- the increasingly important role of the BIPM in representing and promoting world metrology;
- the responses of directors of NMIs to the two questionnaires relating to the services supplied by the BIPM and the discussion at the April 2002 meeting of directors;
- the conclusions of the Report on the potential economic impact of the CIPM MRA drawn up by KPMG;

- the great efforts already made by the BIPM to manage its affairs in as economic a way as possible and using the dotation in the most cost-effective way possible;
- the impossibility of maintaining all these activities beyond 2004 with the present dotation.

Based on the considerations in this report on the evolving needs for metrology in trade, industry and society and the role of the BIPM, the CIPM has recommended a programme and budget for the BIPM for the years 2005 to 2008. This is presented to the Governments of the Member States of the Metre Convention in two documents: first in the Convocation of the 22nd General Conference on Weights and Measures (Paris,13-17 October 2003 (27)) sent to member governments in December 2002 and second, in the document entitled "Programme of work and budget of the BIPM for the four years 2005 to 2008" sent to member governments in April 2003.

The major elements of the proposed programme of work are:

- Mass: the conservation and dissemination of the unit of mass, including balance development, weighing in air and vacuum, air density, properties of mass standards and participation in the Avogadro constant international project and a watt-balance project at the BIPM,.
- Time: calculation, dissemination and development of the time scales TAI and UTC, including studies of time-transfer techniques, and space/time reference systems and calibration of time-transfer receivers.
- Length: measurement of frequency of laser standards in the visible using femtosecond combs relative to the BIPM atomic microwave frequency standards; studies of performance of femtosecond combs (up to 2006), line scales and optical interferometers for nanometrology and other purposes (watt balance and calculable capacitor).
- Electricity: maintenance and development of primary electrical standards for the volt, the ohm and the farad based on BIPM Josephson, quantum-Hall references with construction of a calculable capacitor reference; international comparisons and calibrations, participation in the watt-balance project.
- Ionizing radiation: maintenance of standards as international reference standards for most national comparisons in dosimetry and in particular for the Secondary Standards Dosimetry Laboratories (SSDL) run by the International Atomic Energy Agency (IAEA); maintenance and development of the International Reference system for radionuclides, calibrations in dosimetry.
- Chemistry: development of a gas-standards programme with the maintenance and development of ozone standards as international references for most national ozone standards underpinning national, regional and global ground-ozone monitoring networks; small programme in organic analysis, in particular an international programme on organic pure substance reference materials with application at the BIPM of direct assay methodologies.

- Gravimetry: periodic comparisons of absolute gravimeters and maintenance of BIPM gravity network in cooperation with the International Union of Geophysics and Geodesy (IUGG).

This programme of work will allow the BIPM to meet its responsibilities as laid out in the role described above. It allows for the necessary synergies between the different activities to provide a solid scientific base upon which the services to NMIs can be provided efficiently. More details of this programme are given in the document "Programme and budget of the BIPM for the years 2005 to 2008" distributed to Member Governments in April 2003. This programme differs from that currently being carried out following certain changes made by the CIPM in 2002. These are given in Appendix 5.

6 Conclusions and Recommendations of the CIPM

Based on the information reflected in the Chapters 2 through 5, as well as on the information obtained from the questionnaires and the discussions with the directors of the NMIs of the Member States, the CIPM in its meeting in October 2002 agreed the following conclusions and recommendations:

General conclusions and recommendations

- The removal of non-tariff barriers to trade is high on the political agenda of countries and requires internationally recognized traceability and comparability of calibration, measurement and test results.
- High-tech industry needs highly accurate measurements sometimes requiring completely new concepts of measurement standards and calibration facilities such as nanometrology, femtosecond and quantum-based standards together with a wide application of information technology.
- Internationally recognized traceability and comparability is urgently needed in all areas of trade, industry and society, including new areas such as measurements in sectors relating to the environment, food, health care, anti-doping measures and forensics.
- To address all the needs of trade, industry and society, to set the right priorities and to bring in all the available expertise; new networks and joint committees have to be and are already established with relevant organizations like the WTO, WMO, WHO, Codex Alimentarius Commission, IFCC, ILAC, WADA and others, while the present long-lasting cooperation with ISO/IEC, OIML and others should be intensified.
- For a timely and coordinated implementation of reliable and internationally accepted measurements in the different sectors of trade,

industry and society, much closer cooperation is needed between bodies globally, regionally and nationally.

- In cases where the NMI is not able to cover all fields of measurements needed in a country, serious consideration should be given to the designation, under the overall coordination of the NMI, of other institutes in the country which can take responsibility for one or more specified quantities and measurement ranges.
- Where possible coordinated support is needed for the proper and timely development of the metrological infrastructures of developing countries and those in transition. A Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization (the JCDCMAS), bringing together the BIPM, IAF, IEC, ILAC, ISO, ITU, OIML and UNIDO, has been created and should assist in the process of development and tuning of the different support programmes for the countries mentioned.
- Studies on the economic and social impact of having “fit-for-need and purpose” national measurement standards and primary certified reference materials, carried out in a number of countries, demonstrate that government investments in this sector are among the best investments with a high rate of economic and social return.
- The CIPM Mutual Recognition Arrangement, aiming to the international recognition of national measurement standards and of calibration and measurement certificates issued by the national metrology institutes of the Member States of the Metre Convention and of the affiliated countries and economies, is a key factor in the process of reducing non-tariff barriers to trade and operates in a very cost-efficient and effective way.
- International and global coordination under the the Metre Convention is indispensable for achieving an efficient and effective long-term stable global measurement system that can address all needs of trade, industry and society with respect to traceable and comparable measurements and tests.

The BIPM

- The BIPM as the executive body of the Metre Convention has to have the status and means to accomplish its tasks as the focus for scientific and industrial metrology in the world.
- The BIPM must continue to be responsible for keeping up-to-date and disseminating the International System of Units and, where this is not yet feasible, provide other suitable and internationally agreed references; it must remain the custodian of the International Prototype of the kilogram and establish and disseminate International Atomic Time and Coordinated Universal Time. Further, the BIPM will maintain a number of relevant laboratories that deliver added value to the NMIs thereby necessitating a basis for the maintenance of sufficient expertise of its staff

in order to be able to speak, act and coordinate metrology on behalf of the global community.

- The BIPM will continue to organize comparisons and to deliver appropriate services and know-how transfer free of charge to the NMIs of the Member States in those fields where it has laboratory activities.
- Having concluded that future financial resources will not be sufficient to carry out all current activities and develop the essential new ones, the CIPM has made some changes in the scope of BIPM activities on the basis of a re-evaluation of priorities. These include the termination of activities in photometry-radiometry and, in due course, in laser measurements and the commencement of a few urgent new activities, including further global coordination projects, additional support for the BIPM key comparison database and laboratory work in the field of organic chemistry and some fundamental metrology experiments (see Appendix 5).

Recommendations to Member States

- The CIPM recommends the governments of the Member States to give and maintain sufficient financial support to their national metrology infrastructures, including the important area of metrology in chemistry with applications in many sectors of trade, industry and society, and to make available the necessary financial resources to the BIPM as requested in Draft Resolution J presented to the 22nd CGPM in order to create and maintain a firm global basis for immediate and long-term effective internationally recognized traceability and comparability.
- The CIPM recommends the governments of the Member States to approve the tasks and the corresponding budget for the BIPM as presented to the 22nd General Conference of Weights and Measures in October 2003.

Appendix 1.
National and international metrology infrastructure

Note: this is an updated version of the corresponding text that originally appeared in the 1998 CIPM Report on national and international needs for metrology, including recent and desirable adaptations.

1.1 The National Metrology Institutes (NMIs) and the Regional Metrology Organizations (RMOs)

The NMI

In practically every country a law exists that requires the Government to provide for the establishment of appropriate measurement standards through some sort of NMI.

The NMI is in charge of realizing, maintaining and disseminating the national measurement standards of that country. Depending on the level of industrial development, the needs of its society, the economic situation and the size of the country, these national measurement standards are primary or secondary. The major aim of the NMI is to deliver internationally recognized traceability and comparability to its customers who may, for example, be calibration and measurement laboratories from industry, institutes, or government. The NMI can achieve these goals either by calibrating the customers' measurement standards and measuring devices or by organizing inter-laboratory comparisons in cases where the clients have intrinsic primary standards. More and more the services of the NMIs include the delivery of primary certified reference materials, which are characterized and assigned values by the NMI.

Taking into account recent developments in metrology, which nowadays also covers the fields of chemistry and biotechnology, including their applications in environmental measurements, health care, food testing, forensics, drugs and anti-doping, and considering the consequent necessity to liaise with those organizations having responsibilities in these fields, it is important that the NMIs establish networks with all parties involved.

In many cases the NMI is not able to establish for itself metrological activities in all of these new fields of metrology. In that case it is strongly recommended that the NMI or its government designate other institutes to maintain national measurement standards and related calibration facilities for one or more quantities and measurement ranges. These "designated" institutes will then have to join in the relevant activities of the international organizations concerned, whether they are RMOs, the BIPM or the related Consultative Committee. Of course, these designated institutes have to fulfil also all the requirements expected of the NMI itself, including the installation of a quality system based on ISO/IEC 17025, being accredited or having peer-review visits and full participation in international studies and key and supplementary comparisons.

There are advantages in having one central NMI from several points of view: these include maximum synergy and efficiency, transparency, as well as international visibility and recognition. In many countries, however, this is not the case for historical reasons. In particular, in several small countries a decentralized NMI exists, consisting of a cooperation between the NMI and one or more calibration laboratories from universities, other national institutes or governmental organizations, or sometimes even private companies.

While such a decentralized system can be effective; it has to be ensured that continuity is sufficiently guaranteed and that a fair economic playing field is maintained in the case of commercial companies playing the role of the NMI in a defined field of metrology.

Conformity of the quality system is favoured with the ISO/IEC 17025 standard (12), eventually completed with requirements formulated in the ISO Guides 34 (29) and 35 (30) in the case of delivering CRMs, while in most cases accreditation of the designated institutes will be required from an appropriate body that is a signatory to the ILAC MRA.

A considerable number of NMIs themselves (some 50 %) have been or are planning to become accredited. In many countries/economies the NMIs are required also by their governments to demonstrate their competence by having their own laboratories accredited.

Over the past few decades the NMIs have worked closely together with their national accreditation bodies in accrediting calibration laboratories from industry, institutes and government. The NMI, together with the accredited calibration laboratories, constitutes the national metrological infrastructure, which is a major leverage in disseminating traceability. To fulfil the needs of its national society, the NMI may also consider more international cooperation with other neighbouring NMIs, sharing facilities and division of work.

With respect to the support to developing NMIs it is expected that the NMIs of more developed economies will work together with the BIPM under the Metre Convention and with financing institutes and development organizations, such as UNIDO.

For the full international recognition of the competence and reliability of the designated institutes and the traceability and comparability of the national measurement standards maintained by them, it is essential that these institutes are seen and internationally recognized by entering into the CIPM MRA through the signatory NMI. It is thus essential that the country to which the NMI belongs is a signatory to the Metre Convention or, if this is not yet possible, at least an Associate of the CGPM.

Overall, it has to be remarked that worldwide over the last five years governments have invested and are still investing heavily in the improvement of their national metrology infrastructures; in particular it has to be noted that over the last ten years globally about 10^9 euros has been invested in new and advanced metrology buildings.

The Regional Metrology Organization, RMO

The role and tasks of the modern RMO have expanded considerably in recent years. Apart from regional coordination, transfer of know-how, common R&D, sharing capabilities, delivering traceability on behalf of NMIs not having primary standards or methods, etc., the realization and implementation of the CIPM MRA has added a considerable amount of work. An enormous burden has been created by the task of reviewing the calibration and measurement capability claims and the quality systems of all the NMIs in the region and those from other regions and by the requirement to organize regional key, supplementary and bilateral comparisons. To facilitate these activities, representatives of the RMOs come together in the JCRB to discuss the CMC claims and the operation of the CIPM MRA. The RMOs are also the liaison to NMIs having national measurement standards of lower accuracy by delivering traceability and organizing comparisons on that level. Moreover, they coordinate and deliver support, such as the transfer of know-how and training, to NMIs of developing countries and economies and those in transition. In January 2003 the following RMOs are operational: APMP, COOMET, EUROMET, SADCMET and SIM with its sub-regions ANDIMET, CAMET, CARIMET, NORAMET and SURAMET.

1.2 The Metre Convention

The Metre Convention is the intergovernmental treaty under which formal agreements are made on units of measurement and most matters related to the world's measurement system. The Convention was signed in 1875 and laid down the formal structure within which governments now cooperate on these matters. Under the Convention, the SI was established and is maintained and kept up-to-date to meet the newest scientific developments and the needs of trade, industry and society. France is the depository State of this intergovernmental treaty. So far the Metre Convention has been signed by fifty-one States. Included are all the industrialized and major States of the world, accounting for some 90 % of world GDP. It is expected that the number of Associates, particularly the smaller and developing countries, will increase considerably in the near future.

Once every four years, Member States send delegates to the General Conference. A governing board, the CIPM, acts under the authority of the Member States and has full responsibility for overseeing and guiding the activities of the BIPM.

The CIPM is assisted by ten Consultative Committees, addressing scientific issues in all fields of measurement.

The aim of the Metre Convention is to define and supervise the world's measurement system, the SI units and the realizations and dissemination of these units to meet the needs of today and tomorrow. The requirement for reliable, traceable and comparable measurements in the modern world is increasingly demanding and may require the definition of new measurement quantities, units and related measurements standards, even going beyond the existing SI.

During its meeting in October 2001 the CIPM decided to look into this problem and seek useful solutions in close cooperation with the organizations involved in the measurement areas concerned, such as laboratory medicine and food testing.

The organization under the Metre Convention (see Fig. 1, page 139)

The CGPM

The Member States of the Metre Convention meet every four years at the CGPM. The CGPM decides on the major issues and on the tasks and budget of the BIPM. At its meeting in October 1999, the CGPM decided to create the new category of Associate State or Economy of the CGPM for those countries and economies that are not yet able to sign the Metre Convention. In particular, this possibility is of importance to developing countries for which the financial fees of the Metre Convention are still somewhat of a burden. Associates of the CGPM may attend the meeting of the CGPM, but have no voting rights. They are, however, in a position to sign the CIPM Mutual Recognition Arrangement of national measurement standards and of calibration and measurement certificates issued by national metrology institutes, the CIPM MRA.

So far, there are ten Associates of the CGPM. It is expected that the number of Associates will increase considerably in the near future.

The CIPM

Under the Metre Convention, the CIPM is the Governing Board over the BIPM, acting on behalf of the Member States of the Metre Convention. It prepares the meetings of the CGPM, which are held at least once every six years. Over the past few decades the CGPM has met every four years. The CIPM secures the decisions made by the CGPM and takes all the measures to ensure the aims of the Metre Convention by coordinating the metrological activities in the world and by establishing cooperation between parties and stakeholders involved in metrology. The CIPM is made up of eighteen members each of a different nationality. The Director of the BIPM is *ex officio* a member of the CIPM.

In its recent meetings the CIPM has, among others, decided on the following topics:

- to initiate a study, including questionnaires to the directors of the NMIs, leading to this Report to the 22nd CGPM;
- to study the position of the BIPM as the global nucleus and spokesman in the field of metrology and prepare the organization for the needs of society in the rapidly developing world of today and tomorrow;
- to broaden the scope of the BIPM by starting a Chemistry section which is now establishing with the help and close cooperation of the NIST primary ozone standards which will form the basis for ozone measurements by the WMO Global Atmospheric Watch programme (GAW);
- to sign a MoU with the WMO;
- to sign a MoU with the ILAC;
- to sign a MoU with the WHO;
- to establish a new activity related to traceability in laboratory medicine, provisionally known as the JCTLM;
- to cooperate with relevant other international organizations in establishing the JCDCMAS.

The BIPM

The BIPM is the centre for world metrology and is the executive arm of the Metre Convention. It has laboratories and offices at Sèvres. Its programme and financing are discussed in Chapter 5 of this Report and in the Convocation of the 22nd CGPM to be held in October 2003.

Meetings of directors of NMIs

As a means of improving the communication between the BIPM/CIPM and the directors of the NMIs, annual meetings have been introduced to which the directors and the members of the CIPM and senior staff of the BIPM are invited. Scientific and technological developments, globalization of trade and industry as well as the increased and broadened importance of reliable and comparable measurements in all sectors of society require quick, intense and careful policy and decision-making processes. Intensive cooperation between the NMIs themselves and between the NMIs and many other organizations involved in measurements require regular consultations. Moreover, frequent contacts between the directors of the NMIs and the BIPM will facilitate the harmonization of services delivered by the BIPM based on the needs of the NMIs. These contacts will also lead to better and regular transfer of expertise, improved quality of the services involved and the rapid solution of problems when they arise.

The Consultative Committees (CCs)

Beginning in 1927, the CIPM created a number of Consultative Committees bringing together the world's experts in specified fields as advisers on scientific and technical matters. Among the tasks of the CCs are the detailed consideration of advances in science that influence metrology, the preparation of Recommendations for discussion at the CIPM, the instigation of international comparisons of measurement standards and the provision of advice to the CIPM on the scientific work in the laboratories of the BIPM. The number of CCs as well as their scope has constantly been adapted in order to fulfil the needs of the NMIs and society.

There are at present ten CCs addressing the fields of:

- Electricity and Magnetism (CCEM)
- Photometry and Radiometry (CCPR)
- Thermometry (CCT)
- Length (CCL)
- Time and Frequency (CCTF)
- Ionizing Radiation (CCRI), consisting of three Sections
- Units (CCU)
- Mass and Related Quantities (CCM)
- Amount of Substance, Metrology in Chemistry (CCQM)
- Acoustics, Ultrasound and Vibration (CCAUV).

Included in the CCM, in addition to those on mass, are activities related to force, pressure, density, hardness, fluid flow and gravitational acceleration. Furthermore, an Ad Hoc Working Group on Viscosity has recently been established.

Most of the CCs have one or more working groups addressing specific specialist fields. For example, the CCQM has created seven working groups on organic analysis, inorganic analysis, gas analysis, electrochemical analysis, bioanalysis, surface analysis and key comparisons.

As a result of the implementation of the CIPM MRA, the role and tasks of the Consultative Committees have increased considerably. International comparisons, so-called key comparisons, are now regularly organized for almost all measurement quantities. It is the task of the CCs to organize these key comparisons, validate methods, evaluate the results and agree on the final results and conclusions. In addition, the CCs have the responsibility for reviewing the results of regional key comparisons as well as other relevant bilateral comparisons. In many cases the experts of the CCs are also involved in the harmonization of the categories of CMCs realized and offered by the NMIs. Moreover, they may have to review the CMC claims of the NMIs to be published in Appendix C of the CIPM MRA.

Compared with the level of activity five years ago, the workload of the CCs has been multiplied significantly. These new expanded tasks require close cooperation with the RMOs.

In order to ensure good cooperation with all the NMIs and RMOs, the composition of the CCs has been reviewed. In particular, by admitting more observers to the CCs it is possible to involve all RMOs. A flexible admission policy for the working groups of the CCs makes it possible for the NMIs of developing countries and economies, as associates of the General Conference, to participate in the CC activities and at least be able to learn what is happening.

Owing to the increased activities of the CCs (more key comparisons and studies, more CC working groups and thus more meetings) the BIPM and in particular its Heads of section, who act as the Executive Secretaries of the CCs, together with the support staff are much more burdened than before. Compared with the situation ten years ago the average number of meetings of Consultative Committees and their working groups has at least doubled if not tripled.

Joint Committees

Joint Committees with other organizations complete the organizational structure under the Metre Convention. We mention here the JCGM with its two working groups, one on the VIM and the other on the GUM. In the JCGM the BIPM cooperates with the OIML, IUPAP, IUPAC, IFCC, ISO and the IEC.

Recently a new activity related to traceability in laboratory medicine has been initiated in cooperation with the IFCC, the ILAC and other stakeholders, provisionally known as the JCTLM.

A new JCDCMAS has also been established.

In CODATA the BIPM joins other scientific organizations in defining and assigning values of the fundamental constants.

The BIPM cooperates with the International Astronomical Union (IAU) in its Working Group on Relativity for Celestial Mechanics, Astrometry and Metrology (RCMAM).

It is expected that more joint committees will be established in the future.

Appendix 2.
The CIPM Mutual Recognition Arrangement (CIPM MRA)

As a consequence of laboratory accreditation and international trade agreements established in the mid-1990s, it was felt urgent that a transparent and reliable system be put in place with respect to the reliability and comparability of the national measurements standards of the countries, which are the sources of traceability for all calibrations and measurements. If no confidence can be established in the basic standards of measurement and testing in countries it is very unlikely that one can have international confidence in the results of measurements and tests carried out by industry, traders, regulators and other institutes.

These considerations have led to the creation of an international agreement addressing the issues at stake under the umbrella of the Metre Convention.

During the meeting of the CGPM in October 1999, the directors of the NMIs of thirty-eight Member States of the Metre Convention together with two other international organizations (the IAEA and the IRMM of the European Union) signed the CIPM MRA.

By the end of the year 2002 the CIPM MRA has been signed by the NMIs of fifty-two Member States and Associate States and economies and two international organizations bringing the total number of signatories to fifty-four.

Behind the signatory of a NMI a list of several designated institutes, having responsibility for certain defined national standards and measurement ranges and related calibration and measurement facilities, may be mentioned.

The objectives of the CIPM MRA are:

- to establish the degree of equivalence of national measurement standards maintained by NMIs;
- to provide for the mutual recognition of calibration and measurement certificates issued by NMIs;
- thereby to provide governments and other parties with a secure technical foundation for wider agreements related to international trade, commerce and regulatory affairs.

These objectives are achieved by a process of:

- international comparisons of measurements, to be known as key comparisons;
- supplementary international comparisons of measurements;
- quality systems and demonstrations of competence by NMIs.

The outcome of the CIPM MRA is published in the form of statements of the calibration and measurement capabilities of each NMI and designated institute in a database maintained by the BIPM and publicly available on the Web (31).

The major parts of the database are: Appendix B stating all the results of the key and supplementary comparisons; and Appendix C where the CMCs of the NMIs participating in the CIPM MRA are listed.

The organizational structure responsible for establishing and maintaining the CIPM MRA is based on:

- the overall coordination by the BIPM under the authority of the CIPM, which itself is under the authority of the Member States of the Metre Convention;
- the CCs of the CIPM, the RMOs and the BIPM being responsible for carrying out the key and supplementary comparisons;
- the JCRB, being responsible for analyzing and transmitting entries into the database for the calibration and measurement capabilities declared by the NMIs (Appendix C).

The database, which is still growing, now already contains a few ten thousands of individual CMC entries, covering almost all fields of measurement.

The Joint Committee of the Regional Metrology Organizations and the BIPM (JCRB)

The JCRB is charged with:

- coordinating the activities among the RMOs in establishing confidence for the recognition of calibration and measurement certificates, according to the terms of the MRA;
- making policy suggestions to the RMOs and to the CIPM on the operation of the MRA;
- analysing the application by each RMO on the basis of the criteria of the MRA;
- analysing and entering into Appendix C the proposals of each RMO in respect of the calibration and measurement capabilities of their member NMIs and reporting to the CIPM;
- facilitating appropriate inter-regional supplementary comparisons;
- writing an annual report on the activities of the Joint Committee to the CIPM and to the signatories of the MRA.

At present, the JCRB meets twice a year and has demonstrated that it is able to make good progress and to establish confidence between all the participating RMOs and the NMIs.

Major points on the agenda of the JCRB concern the proper and efficient organization of the activities under the MRA, the planning and fine-tuning of the related activities of the RMOs, the consideration and harmonization of the way in which the quality systems of the NMIs are judged by the respective RMOs, and the building of mutual confidence.

With respect to the criteria on quality systems the ISO/IEC 17025 standard is favoured. In the case where a NMI is not accredited, an international team of peers may visit the NMI in order to obtain the necessary insight into the way quality and competence is realized and maintained.

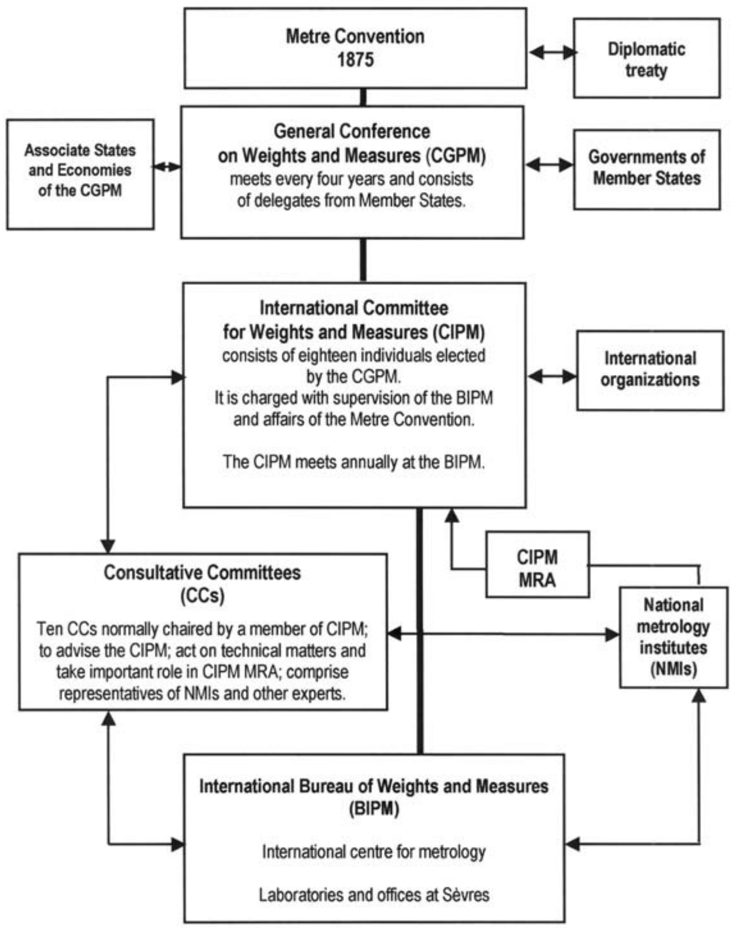


Fig. 1.- The organization of the Metre Convention

Appendix 3.
Results and conclusions of the questionnaires to directors

Introduction

The replies to the two questionnaires give a good view on the future expectations of the NMIs concerning developments in metrology and provide a valuable input to the discussion of the role of the BIPM and the future programme and budget in preparation for the 22nd CGPM. The replies have been discussed at the meeting of directors of NMIs on 22 and 23 April 2002. This document gives a summary of the responses.

1 The first questionnaire

The first questionnaire was sent to directors in May 2001. Its aim was to obtain the advice of directors before beginning the update of the 1998 Report on "*National and international needs related to metrology*". A total of twenty-one responses were received from NMI directors plus one from an RMO. Robert Kaarls, Secretary of the CIPM, summarized the responses in a note to the CIPM in October 2001 as follows:

Twenty-one responses were received from nineteen Member States and one RMO.

Answers to the questions:

1. Chapter 4 of the 1998 report of the CIPM on *National and international needs relating to metrology* was seen as the most important one.
2. In the new Report separate chapters should be dedicated to the economic impact, the CIPM MRA, the RMO and new applications/areas of metrology
3. It is generally foreseen that the importance of the RMO will grow with more tasks. There are mixed visions with respect to more tasks for the JCRB; this group is not seen to represent all views of the NMIs; the directors' meeting should play a broader role. The JCRB should stick to its role in the scope of the CIPM MRA.
4. It is expected that there will be significant impact of technological and scientific developments; mentioned are quantum-based phenomena, time/frequency/length standards, micro- and opto-electronics, biomolecular chemistry, intrinsic standards and applications of all modern possibilities of information technology (IT).
5. Advanced IT will change considerably the way of operations of the NMIs, including aspects as remote controlled on-site calibrations and

comparisons, training and know-how transfer, automation, imaging, form analysis, etc.

6. Important changes and developments are expected in areas like chemistry, biotechnology, health care, environment, fraud, molecular electronics, HF and communication measurements, software testing/metrology, and dynamic measurements.
7. Major investments are expected on behalf of chemistry, biotechnology, certified reference materials and nanometrology. In smaller and developing countries one expects also to put a lot of money in completing the own national measurement standards, in calibration facilities and in training.
8. Most NMIs have not been able to give answers to the questions on economic and social impact. One NMI indicated that public investments as an average return 14 % per year.
9. The priorities to be set are already clear from the answers to the questions 6 and 7.
10. Reports on economic and social impact have only been made available by the NIST (United States) and NPL/DTI (United Kingdom) while a Canadian report is expected soon. Denmark has some reports (case studies) available in the Danish language.
11. About the role of the BIPM many opinions have been expressed with sometimes contradictory views. Some answers seem to indicate that the BIPM should restrict itself to organizing, coordinating and promoting metrology, without its own scientific/technological capabilities in the form of laboratories. In general, however, it is understood that the BIPM should have and maintain excellent scientific/technological expertise in order to have the undisputed, global authority in the field of metrology. Scientific sections and laboratories should be maintained. A number of calibration services should be delivered to NMIs of small or developing Member States. However, there should be no duplication of work which is also normally done by the larger NMIs. Thus, the BIPM should focus only on more or less unique world measurement standards, unique transfer standards and primary reference materials, time scales, ionizing radiation, key comparisons, and BIPM databases. Much more international coordination and promotion by the BIPM is expected, while also the topics of training and know-how transfer are frequently mentioned.
12. Most answers indicate at least a continuation of services delivered so far until now by the BIPM; no preference of services was detected. Some NMIs believe that calibration for small and developing NMIs may be delivered by the bigger NMIs in the region concerned. But many more activities are expected as indicated under point 10, eventually requiring necessary changes in order to achieve the new aims.
13. All NMIs indicated that the BIPM should increase considerably the efforts in coordinating the metrological activities of international organizations.
14. This question on any other new topic or issue to be considered did not generate more innovative thoughts.

Note: It has not been possible to include in the above summary all suggestions and comments presented in the answers of the NMIs. However, it is believed that the summary includes the major common remarks. Most of the suggestions, however, have been addressed in this Report.

2 The second questionnaire

It was clear from the replies to the first questionnaire that its questions concerning the services provided by the BIPM were not sufficiently detailed to obtain the sort of information that was needed to guide decisions on its future programme. The CIPM therefore decided at its meeting in October 2001 that a second, more detailed, questionnaire should be prepared. This second questionnaire was sent out in December 2001. A total of thirty-three replies were received and a comprehensive view of the directors' opinions was obtained.

The second questionnaire asked for the evaluation of directors of the services provided by the BIPM under the following headings:

A the two specific services related to mass and time;

B calibrations for other quantities;

C comparisons, ongoing key and other, using the BIPM standards as reference;

D transfer of technology and experience;

E research and development aimed at unique reference standards or materials and transfer standards:

F support to Consultative Committees and working groups;

G the BIPM website;

H the BIPM key comparison database;

I publications;

J representation on behalf of NMIs to other international organizations;

K rstablishment of formal links with other organizations;

L other services and activities.

Directors were asked to indicate according to the following scale how they rate each of them:

1 = no need/no value;

2 = limited need/limited value;

3 = desirable/needed/good value;

4 = highly needed/high value;

5 = has to be done/extremely valuable/unique.

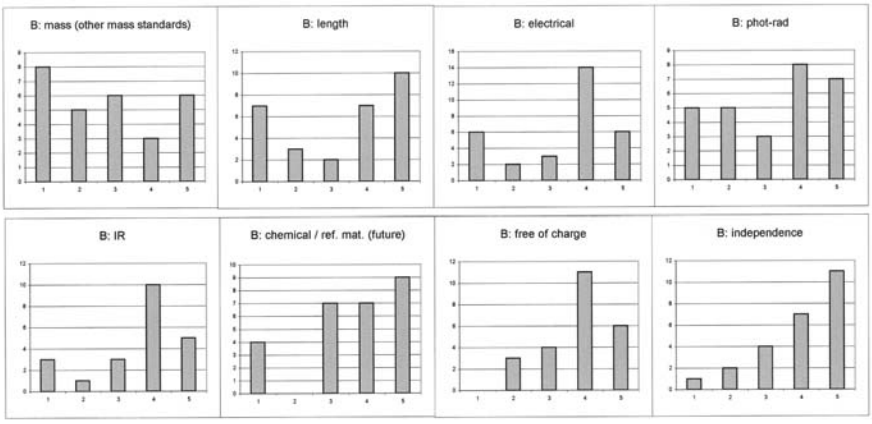
The detailed results of the second questionnaire are presented in:

(a) a set of histograms showing the individual replies to each of the questions; these show replies to all the B questions (on calibrations), all the C questions (on comparisons), all the D questions (on technology transfer), all the E questions (on R&D) and so on.

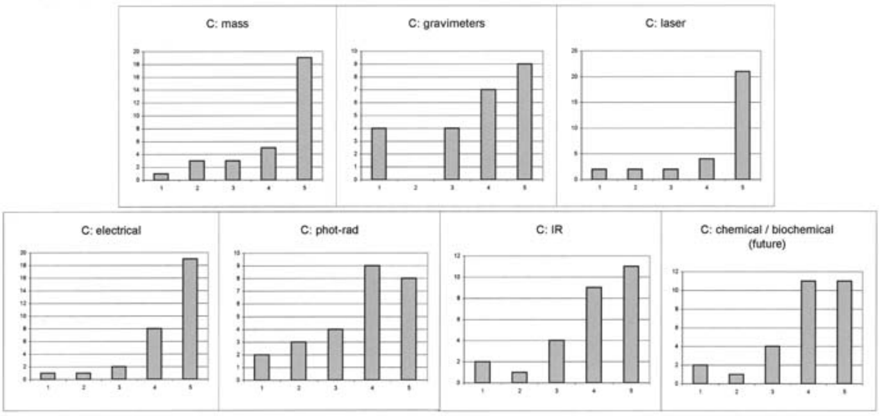
(b) a single Figure, that shows the average mark given by each lab for the ensemble of questions B, C, D and E.

In the histograms, the ordinate represents the number of responses for each level of evaluation from 1 to 5 given as the abscissa.

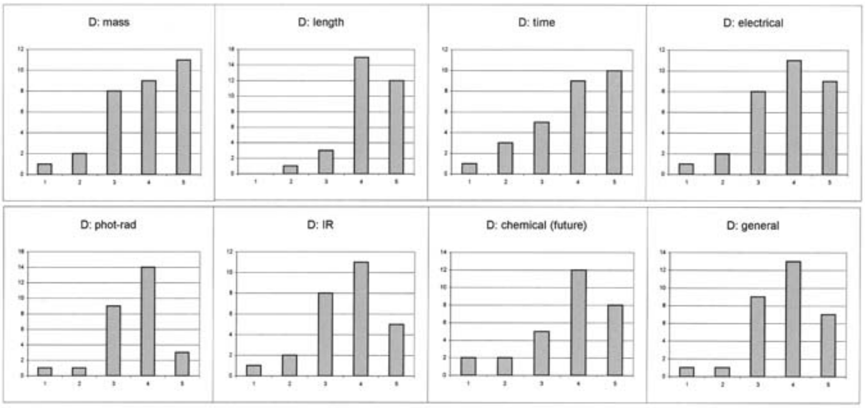
No questions were asked concerning services A and as regards services under L, only general impressions were requested.



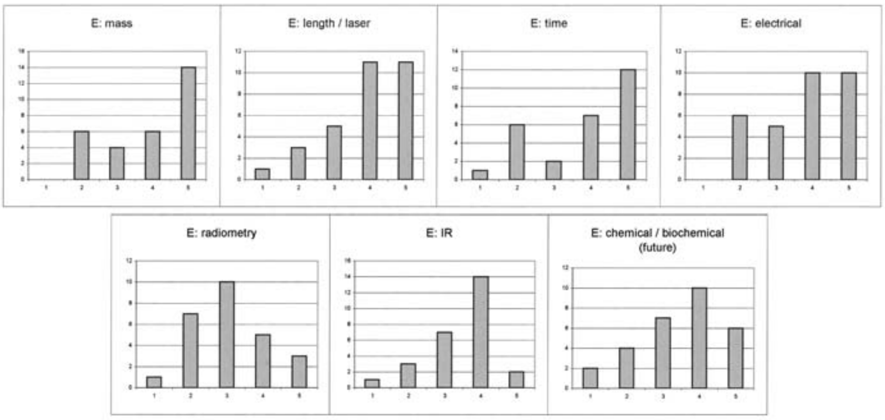
B: Calibrations and reasons for choosing the BIPM



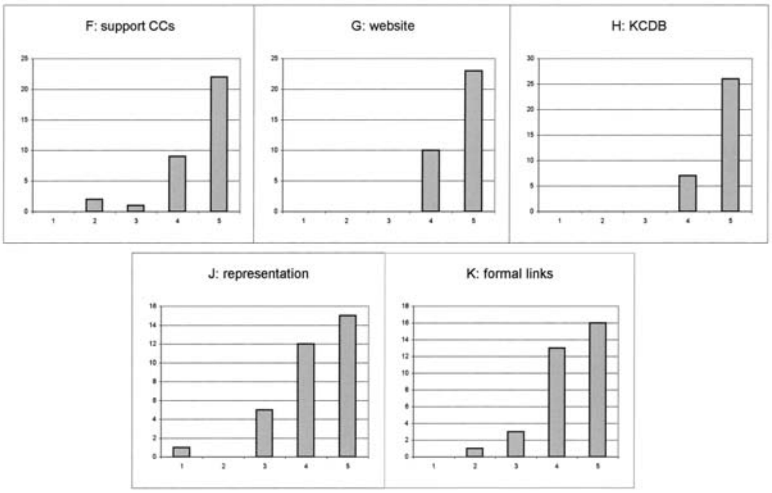
C: Comparisons



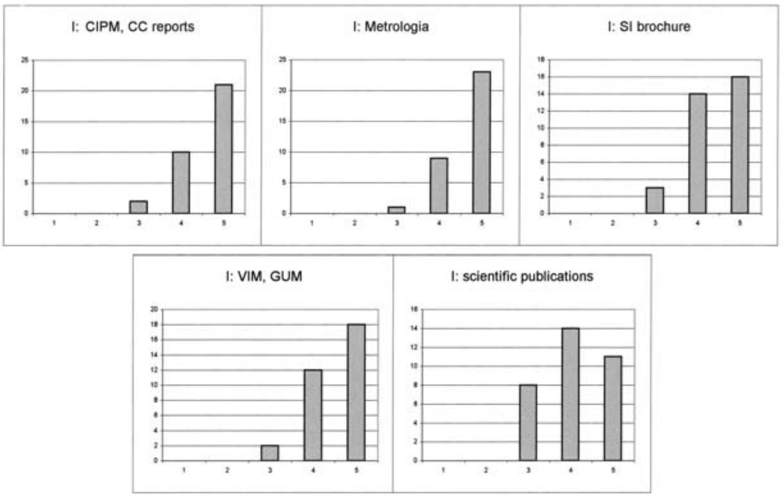
D: Technology transfer



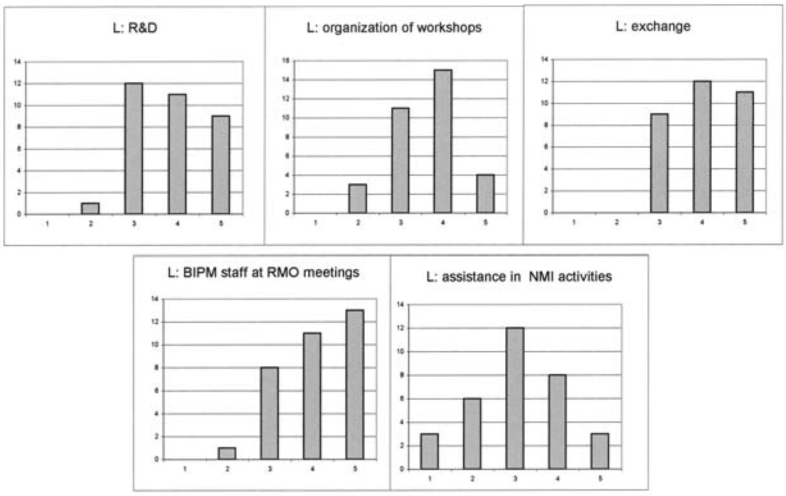
E: Research and development



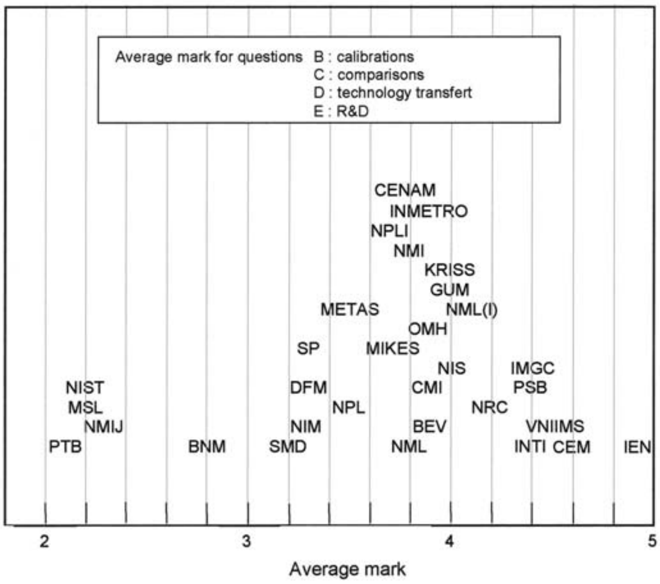
F: Support to Consultative Committees;
G: Website; H: KCDB; J: Representation; K: Formal links



I: Publications, CIPM and CC reports, *Metrologia*,
SI brochure, VIM and GUM, scientific papers



L: Research and development, organization of workshops,
exchange of staff, BIPM staff at RMO meetings



Average marks to questions B, C, D and E

Appendix 4.
Resolution 1 of the 21st CGPM

Long-term needs relating to metrology

The 21st Conférence Générale des Poids et Mesures,

considering

- Resolution 11 of the 20th General Conference, which requested the International Committee to study and report on the long-term needs relating to metrology,
- the study which was completed in 1997 after extensive international consultations,
- the resultant report, entitled *National and international needs relating to metrology: International collaborations and the role of the BIPM,* which was sent by the International Committee in 1998 to the governments of the Member States,

welcomes the many decisions made by the International Committee as a consequence of the study and, in particular

- the progressive broadening of the terms of reference of the Consultative Committees to cover the principal fields of metrology where collaboration between the national metrology institutes is important, not only in physics and engineering but also in other disciplines such as chemistry and biotechnology,
- the strengthening of the role of the Consultative Committees and the admission of observers to their meetings to enable more Member States to participate,
- the emphasis on evaluating and publishing the degree of equivalence of national measurement standards of the Member states and on the establishment of an associated mutual recognition arrangement of national measurement standards and of calibration and measurement certificates issued by national metrology institutes,
- the introduction of periodic meetings with the directors of the national metrology institutes of the Member States,
- the statement by the International Committee of the role of the Bureau International des Poids et Mesures (BIPM) in the early decades of the 21st century,

- the increased collaboration of the BIPM with related international organizations, especially the regional metrology organizations, the International Laboratory Accreditation Cooperation and the Organisation Internationale de Métrologie Légale,
- the considerable progress already made by the International Committee in implementing its decisions,

notes the discussion in the report of the International Committee of the long-term financial commitments required from the Member States,

thanks the many organizations and individuals who have contributed to the study and the report of the International Committee.

Appendix 5.
Decisions by the CIPM on the future programme of the BIPM made at its meeting in October 2002

(This Appendix is extract from the Report of the CIPM 2002 meeting).

An extensive discussion took place on the programme and budget of the BIPM for the years 2005 to 2008. The CIPM considered the results of the consultations with directors of NMIs (the questionnaires, the meeting in April and the responses to a document sent to directors in July 2002) on the future programme and budget of the BIPM. The outcome was that the CIPM decided to make some changes to the programme of the work of the BIPM so as to face up to an expected shortfall of income and at the same time to respond to changing needs in metrology. The following is a summary of the discussion and the conclusions.

According to the rules of the CGPM, the official Convocation containing the elements of the agenda, including particularly the CIPM proposals for the dotation for the next four-year period, must be sent to member governments at least nine months before the opening of the Conference. For the 22nd CGPM that opens on 11 October 2003, the last day for receipt of this document is thus early January 2003. In fact, the Convocation is always sent out by the end of December.

Introduction

Members of the CIPM and directors of national metrology institutes had been informed that an increase in 2005 of 1.1 million euros (some 12 % of the 2004 dotation) would be needed to maintain all of the BIPM current activities and that an increase of 1.9 million euros (some 20 % of dotation) would be needed to maintain the current programme and embark upon extensions into organic chemistry, bioanalysis and medicine.

The first reactions from some Member States to these proposals indicated it was extremely unlikely that the 22nd CGPM would agree to vote a step increase in budget for the year 2005 of more than about half of even the 1.1 million euros needed to maintain the current activities, plus a small amount for inflation for that and the succeeding years. We were informed that if, at the time of the Conference, a proposal is made for an increase much greater than this, it is likely to be vetoed.*

The difference between these indications and what was requested was sufficiently large that the bureau recommended to the CIPM that it take strategic decisions at its meeting in October 2002 on how to deal with this and that these not be left until after the CGPM in 2003.

For the purposes of making concrete proposals for the programme of work and budget, the following starting hypothesis was taken: that there will be a 5 % (0.45 million euros) step increase in dotation on 1 January 2005 plus an increase for inflation of 1.5 % in this and the subsequent three years of the quadrennium 2004 to 2008.

Broad strategic options

Since the 21st CGPM in 1999 the BIPM has been pressed to undertake, and has undertaken, considerably more activities than were envisaged at the time. The role of the BIPM in coordination of international activities in metrology, relations with other organizations as well as the work stemming from the implementation of the MRA have all been much greater than foreseen. The response of the BIPM has been widely welcomed by NMIs and it is clear that all of this must continue.

On the basis of the hypothesis stated above, significant reductions in the current BIPM programme will, however, have to be made.

In deciding how to proceed, the CIPM took a number of considerations into account:

1. The needs of NMIs in respect of the services supplied by the BIPM as set out in the responses to the second questionnaire to directors; these include all the coordination and international relations activities as well as KCDB, JCRB and the scientific and technical work in the laboratories that provide calibration and other services to NMIs and the scientific base of the BIPM.
2. There are no across-the-board economies that would have a significant effect.
3. The magnitude of the savings that needs to be made is such that one of the large scientific sections will have to be closed.
4. In deciding which of the large sections must be closed, there are strategic decisions that must be taken regarding what should remain as the base for the future core programme of work.

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* The formal procedure for adopting the dotation at a General Conference requires it to be adopted with no votes against. Abstentions are allowed but if there is a single vote against it fails. The consequence of a failed dotation Resolution is that the dotation voted by the preceding General Conference remains unchanged. This is because the successive Resolutions on the dotation simply modify the previous one. Thus, if the proposed modification fails the dotation for the last year of the previous quadrennium continues until such time as agreement to change it is reached.

5. The consequences of the changes with respect to the staff of the BIPM.

Much of the thrust of the report on evolving needs for metrology in trade, industry and society and the role of the BIPM*,* adopted by the CIPM in 2002, relates to the emerging needs for international metrological activity in chemistry, biotechnology and medicine. Contacts we have had with NMIs all over the world confirm this view. It was the opinion of the Committee that while it is clear that a large activity at the BIPM in these fields is for the present not possible, it is essential to have a minimum of two high-level specialists in these fields. If we do not do this, we shall not be present in any of the international forums and we shall not even know how to respond to requests for information to meet the most urgent needs. Even if, as has been suggested by some directors, BIPM activities in these areas can be mainly supported by staff seconded from some NMIs, it will still be necessary to have a minimum of in-house expertise to provide continuity, without which such a programme could not work.

While it is not yet clear how the BIPM will in due course become involved, at the first meeting of a working group of the JCTLM on traceability in laboratory medicine there was already a call for setting up an infrastructure to supply reliable data for an eventual database to hold lists of reference materials and reference methods that will be drawn up by this group. So far, the BIPM provides the secretariat for this new group.

It is widely recognized that the success the BIPM has had up to now in its international work of coordination rests on its scientific credentials. This was also a clear outcome of the outside consultations made by KPMG. Without a scientific base, it would not be possible to attract high-level specialists, in any field, to come to the BIPM. If it were simply an office it is unlikely that any of the present senior scientific staff would be here. The short experience we have in chemistry indicates that having a specialist on the staff has been an essential support to our coordination work.

If the BIPM does not, therefore, enter in some way into the fields of organic chemistry, bioanalysis and medicine, it is difficult to see how it can play the pivotal role in these new fields of metrology that the recent KPMG study indicated it has enjoyed in physical metrology. This role is highly valued not only by directors of NMIs but by an increasing number of organizations outside the direct field of metrology but with interests closely related to metrology.

The first important decision made by the CIPM was that it is essential to embark on a minimum laboratory programme in the new areas in order to secure the future of the BIPM and to meet the clearly stated requirements of NMIs.

In order to take the decisions necessary to reorientate the BIPM so that it enters at least to a minimum extent into these new fields, it was necessary to have a clear view of the short and medium term priorities in respect of each of the current programmes of the BIPM. This was because the new work must be at the expense of some of the existing programme. A high priority in making these decisions was also the importance of making the best use of the highly qualified and motivated staff of the BIPM.

Priorities in the present programme

It is clear that the BIPM is an essential component of the international metrological infrastructure. Its presence in international activities representing the interests of NMIs, its role in coordinating international metrology, its contacts with other international organizations directly and through Joint Committees, its support to Consultative Committees and RMOs as well as its key role in the implementation of the CIPM MRA through the KCDB and JCRB, are all activities having the highest priority. There is little or no argument that all these activities have to be maintained and developed and that to do this there must be a sound scientific base.

Within the scientific and technical programme there are, however, various levels of priority, these are:

Top priority:The mass and time-scale programmes

These are the central core of the BIPM's scientific activities: for the mass work we have a specific mandate in the Metre Convention and for time scales we have a specific mandate through successive CGPM Resolutions. The content of the mass and time programmes are continually under review, but while small economies can be foreseen in the time work resulting from increasing use of automation, it is the view of the CIPM that the mass programme should expand to include a watt-balance project. This is because a requirement for any future definition of the unit of mass based on atomic or fundamental constants is a long-term commitment to monitoring the mass of the present artefact, the International Prototype. The BIPM is uniquely positioned and capable of making such a commitment.

Second priority: Ionizing radiation and chemistry

The ionizing radiation programme at the BIPM provides the principal reference for most national dosimetry and radioactivity comparisons and provides the link to the SI for the extensive network of Secondary Standards Dosimetry Laboratories run by the International Atomic Energy Agency. No economies can be foreseen as the present activities are at the lower limit of viability.

The present small chemistry programme is the first step into the new fields discussed above and must have a high priority.

Third priority: The electricity, the laser and gravimetry programmes

The electricity and laser programmes each have particular significance:

In the case of the electricity programme, it would be an essential contributor to any watt-balance project at the BIPM. It also holds the only high-accuracy travelling standards of the Josephson volt and the quantum-Hall resistance.

Both of these are unique and currently provide the only means to check the consistency of NMI standards at the highest level of accuracy. Such a capability is essential (either at the BIPM or elsewhere) for the foreseeable future. It is also planned, in collaboration with the NML CSIRO (Australia) to build a new calculable capacitor to be installed at the BIPM to provide one of the few long-term world references in this field. Several NMIs have expressed interest in participating in this project. Note also that half of all the calibration certificates issued by the BIPM are for electrical standards serving nearly half of all the Member states of the Metre Convention. Some capability in electrical measurements is part of the essential core competence of the BIPM.

In the case of the laser programme, the new programme is centred on femtosecond-comb technology. With the development of this new technology, the thirty-year programme of laser comparisons of 633 nm He-Ne lasers using the BIPM lasers as reference has come to an end. This also provides a natural break point for other visible and infrared laser comparisons. The femtosecond-comb work is at the frontiers of science and is in preparation for a possible future BIPM role in comparing optical frequency standards at a level of accuracy beyond that feasible by satellite techniques. The short and medium-term aim of the new BIPM programme in this field is thus to prepare for optical frequency comparisons, to validate the performance of frequency combs and meanwhile to provide a service of frequency measurement for the 633 nm standards of the smaller NMIs.

The gravimetry programme is very small but it is highly valued and increasingly seen as essential by the geophysics community at whose request we recently established a formal working group. A new request has arrived asking for further support from the metrology community to help improve links between all aspects of geophysics and the SI. The long-standing series of comparisons of absolute gravimeters at the BIPM is strongly supported by the International Union of Geophysics and Geodesy. The gravimetry work at the BIPM will contribute to a watt-balance project.

Fourth priority:

In the fourth priority we place the photometry and radiometry programme and the small activity in nanometrology. In the case of the photometry and radiometry programme the arguments for work at the BIPM are less compelling than for the other programmes mentioned above. The rationale for this view relates to the fact that with the almost universal adoption by NMIs of the cryogenic radiometer as the reference for radiometric and photometric standards, the former role of the BIPM in maintaining the mean world lumen and candela on a set of incandescent lamps has disappeared. Furthermore, there are no BIPM travelling standards that are essential for the comparison of cryogenic radiometers. It is admitted, however, that the lumen and the candela as maintained by the BIPM would enable the BIPM to continue its long-standing calibration service that is highly appreciated by many smaller NMIs. However, it should also be noted that the present complement of three professionals but no technical staff is not sufficient for the current programme.

The nanometrology programme provides a small but useful support to the work in this field of the CCL but cannot be considered to have high priority at the BIPM as CCL work in this area is still relatively limited.

Core competences

Underpinning all of the above, there are a certain number of core competences that should be preserved at the BIPM. These include a basic knowledge of electrical measurements, optics and interferometry, pressure and temperature measurement as well as electronics, mechanical design and a mechanical workshop to build experimental apparatus.

Programme decisions

The CIPM considered these priorities and made the following decisions:

1. A maximum of two new staff will be recruited for organic chemistry and a small laboratory programme started during the period 2004 to 2006.
2. A watt-balance project will be started and a calculable capacitor project will be pursued in collaboration with the NML CSIRO.
3. The staff of the KCDB will be re-enforced and provision made for a permanent Secretariat for the JCRB.
4. The photometry and radiometry programme will be terminated in 2004. The three professional staff will be transferred to the Electricity section and when the present three professional staff of the Electricity section retire within the next few years, will become the core of the Electricity section. The calibration service of incandescent lamps will, therefore, cease but attempts will be made to arrange calibrations for the BIPM's former clients with some NMIs in their local RMOs. (Note: On average a total of about twenty-five lamps are calibrated each year).
5. The work in the laser section will be concentrated solely on the femtosecond laser project and it will continue only until 2006 when it will be closed. The longer-term continuation of the present programme would continue to require heavy investment in both equipment and high-level scientific staff and under the present circumstances this is beyond our resources. The existing four permanent staff of the section will progressively be re-deployed to other areas of the BIPM.

Staff

The Committee expects the changes outlined above to be achieved without any forced staff redundancies by taking advantage of retirements, internal transfers from areas being reduced or closed and the completion of all the short-term Research Fellow appointments.

The present staff (October 2002) comprises 71 permanent employees plus six Research Fellows. It is planned to reduce this by 2008 to 67 permanent staff and no Research Fellows. Note that year on year, staff numbers fluctuate as a result of retirements and overlapping recruitments and in 2003 there will be up to 75 permanent staff but only five Research Fellows.

However, visiting scientists are essential for the scientific programme of the BIPM. They also are needed to provide some additional scientific support so that heads of sections can be more visible in RMO technical meetings, an activity we recognize as of high priority and one that should be increased. The CIPM asks the NMIs to be ready to send suitable people on secondment, at their expense, to the BIPM for periods of one or two years so as to maintain a constant presence of four or five Research Fellows. This is specifically mentioned in the draft Resolution on the dotation given below.

Additional funding

The absence of any additional capital funding for new equipment or updating facilities or basic infrastructure distinguishes the BIPM from many NMIs. Since there is now, and in the future unlikely to be any margin between current income and expenditure, the CIPM considered asking Member States to make a single lump-sum contribution for restructuring during the next four-year period. This would have been a sum of about 1 million euros, sufficient to cover the updating of laboratory air conditioning, refurbishment of laboratories, and major renovation of the roofs of the two seventeenth century buildings of the site, the Pavillon de Breteuil and Petit Pavillon In the end, however, no such request for a single lump sum is being made because it was thought that the chances of success were too remote. These additional costs are therefore absorbed into the CIPM's proposed increase in the dotation given below. The possibility of an additional contribution to the BIPM pension fund was also discussed but not proceeded with.

While considering the consequences of a shortfall in income from existing Member States and Associates, we must not forget the possibility of an increase in income from growth in the membership of the Metre Convention or from other sources and this must be explored.

The Draft Resolution on the dotation to be submitted to the 22nd CGPM

The starting point for the calculation of the dotation for the new quadrennium is the dotation voted by the previous General Conference for the last year of the current quadrennium. In the present case, this is the dotation for 2004 voted by the 21st CGPM, namely, 9 094 000 euros. To this should be added the contributions from the three States, Greece, Malaysia and Yugoslavia, that have joined (or reintegrated) the Convention since the 21st CGPM. Their contributions together amount to 1.76 % of the total. Thus, the new starting point for the calculation of the 2005 dotation is 9 254 000 euros.

The CIPM proposes that this be increased by 8.5 % (which includes a real increase of 6.7 % plus 1.8 % to cover price increases in France) on 1 January 2005 to 10 041 000 euros and that on 1 January of each of the three succeeding years of the quadrennium it be increased by a further 1.8 % to cover price increases in France.

The dotations thus requested for each of the years 2005 to 2008, given below in Draft Resolution J, will allow the programme of work to be carried out that will meet the minimum requirements of Member States while allowing a balanced budget to be maintained for the years 2005 to 2008.

Details of the programme and individual budgets for the four years of the quadrennium are sent to member Governments about six months before the Conference. For the 22nd General Conference these will be in a document entitled "Programme of work and budget of the BIPM for the years 2005 to 2008" that will be sent out in April 2003.

Dotation of the BIPM for the years 2005 to 2008

Draft Resolution J

The 22nd General Conference,

considering

- the increasing importance of metrology for trade, industry, the environment and human health and safety in all Member States of the Metre Convention,
- the corresponding need for an efficient, highly expert, international coordination of metrological activities,
- the central role played by the International Bureau of Weights and Measures (BIPM) in such coordination and the services it renders to Member States of the Metre Convention,
- the broadened responsibilities given to the BIPM at the 21st General Conference in 1999 but without any corresponding increase in dotation,
- the additional increase in workload, unforeseen at the time of the 21st General Conference, that has also been absorbed by the BIPM since the last General Conference,
- the extension of the range of work under the Metre Convention now carried out in Member States, notably in areas of chemistry, biotechnology and medicine,
- the need to extend the range of expertize among the scientific staff of the BIPM to meet demands for work in these new areas,
- the considerable efforts that continue to be made by the BIPM to enhance the efficiency of its operation, and its commitment to continue these efforts,

invites national metrology institutes

- to arrange, at their expense, a continuing series of short-term placements or secondments of their staff to the BIPM to work on projects of mutual interest integrated into the BIPM programme,
- to accept staff of the BIPM to work in their institutes on programmes of mutual interest,
- to sponsor a permanent programme of Fellowships at the BIPM for suitable staff with a view to establishing four such Fellowships at the BIPM by the end of 2004, and

decides that the fixed part of the annual dotation of the BIPM will be increased in such a way that the fixed part and the complementary part (defined by Article 6, 1921) of the Rules annexed to the Metre Convention (1875) shall, for those States that are members of the Metre Convention at the time of 22nd General Conference, be

10 041 000 euros in 2005

10 222 000 euros in 2006

10 406 000 euros in 2007

10 593 000 euros in 2008.

Final remarks on BIPM services that will cease

These were hard decisions and the Committee was well aware that they will have an impact on those NMIs that use the services in the fields that are to be reduced. Insofar as it is possible the BIPM will try to make arrangements with NMIs in the same region to supply, at least for a limited time, some of these services that will no longer be provided by the BIPM. In the new areas, the Committee expect that in due course the BIPM will be able to supply services to NMIs, services that directors in their responses to the questionnaire marked of high potential value.

List of acronyms used in the present volume

1 Acronyms for laboratories, committees and conferences

ANDIMET	Northern South American Metrology Cooperation (Bolivia, Colombia, Ecuador, Peru and Venezuela)
AOAC	International Association of Official Analytical Chemists
APEC	Asia Pacific Economic Cooperation
APMP	Asia/Pacific Metrology Programme
BIPM	International Bureau of Weights and Measures/Bureau International des Poids et Mesures
CAMET	Central American Metrology Cooperation (Belize, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua and Panama)
CARIMET	Caribbean Islands Metrology Cooperation (Antigua and Barbuda, Barbados, Dominica, Dominican Republic, Grenada, Guyana, Haiti, Jamaica, St Kitts and Nevis, St Lucia, St Vincent and the Grenadines, Suriname, The Bahamas, Trinidad and Tobago)
CC	Consultative Committee of the CIPM
CCAUV	Consultative Committee for Acoustics, Ultrasound and Vibration/Comité Consultatif de l'Acoustique, des Ultrasons et des Vibrations
CCDM*	Consultative Committee for the Definition of the Metre/ Comité Consultatif pour la Définition du Mètre, see CCL
CCDS*	Consultative Committee for the Definition of the Second/ Comité Consultatif pour la Définition de la Seconde, see CCTF
CCE*	Consultative Committee for Electricity/Comité Consultatif d'Électricité, see CCEM
CCEM	(formerly the CCE) Consultative Committee for Electricity and Magnetism/Comité Consultatif d'Électricité et Magnétisme
CCEMRI*	Consultative Committee for Standards of Ionizing Radiation/Comité Consultatif pour les Étalons de Mesure des Rayonnements Ionisants, see CCRI
CCL	(formerly the CCDM) Consultative Committee for Length/ Comité Consultatif des Longueurs
CCM	Consultative Committee for Mass and Related Quantities/ Comité Consultatif pour la Masse et les Grandeurs Apparentées
CCPR	Consultative Committee for Photometry and Radiometry/ Comité Consultatif de Photométrie et Radiométrie

* Organizations marked with an asterisk either no longer exist or operate under a different acronym.

CCQM	Consultative Committee for Amount of Substance: metrology in chemistry/Comité Consultatif pour la Quantité de Matière: métrologie en chimie
CCRI	(formerly the CCEMRI) Consultative Committee for Ionizing Radiation/Comité Consultatif des Rayonnements Ionisants
CCT	Consultative Committee for Thermometry/Comité Consultatif de Thermométrie
CCTF	(formerly the CCDS) Consultative Committee for Time and Frequency/Comité Consultatif du Temps et des Fréquences
CCU	Consultative Committee for Units/Comité Consultatif des Unités
CGPM	General Conference on Weights and Measures/Conférence Générale des Poids et Mesures
CIPM	International Committee for Weights and Measures/Comité International des Poids et Mesures
CIE	International Commission on Illumination
CODATA	Committee on Data for Science and Technology
Codex Alimentarius Commission	Commission created by the by the FAO and the WHO to develop food standards, guidelines and codes of practice
COOMET	Cooperation in Metrology among Central and Eastern European Countries and European/West Asian Countries
CSIRO	see NML CSIRO
DTI	Department of Trade and Industry of the United Kingdom, see NPL DTI
EUROMET	European Collaboration in Measurement Standards
FAO	Food and Agricultural Organization of the United Nations
GAW	Global Atmospheric Watch programme of the WMO, see WMO
IAEA	International Atomic Energy Agency
IAF	International Accreditation Forum
IAU	International Astronomical Union
ICRU	International Commission on Radiation Units and Measurements
IEC	International Electrotechnical Commission
IFCC	International Federation of Clinical Chemistry and Laboratory Medicine
ILAC	International Laboratory Accreditation Cooperation
IMEKO	International Measurement Confederation
INMS	Institute for National Measurement Standards (Canada), see NRC INMS
IRMM	Institute for Reference Materials and Measurements, European Commission
ISO	International Organization for Standardization
ISO CASCO	ISO Committee on Conformity Assessment
ISO DEVCO	ISO Committee for Developing Countries
ISO REMCO	ISO Reference Materials Committee
ISO TAG 4	ISO Technical Advisory Group 4 (metrology)
ITU	International Telecommunication Union

IUGG	International Union of Geodesy and Geophysics
IUPAC	International Union of Pure and Applied Chemistry
IUPAP	International Union of Pure and Applied Physics
JCDCMAS	Joint Committee on Coordination of Assistance to Developing Countries in Metrology, Accreditation and Standardization
JCGM	Joint Committee for Guides in Metrology
JCRB	Joint Committee of the Regional Metrology Organizations and the BIPM
JCTLM	Joint Committee on Traceability in Laboratory Medicine
KPMG	KPMG Consulting, Ottawa (Canada)
MERCOSUR	Southern South American Trade Cooperation
MoU	Memorandum of Understanding
MRA	Mutual Recognition Arrangement
NAB	National Accreditation Body
NAFTA	North American Free Trade Agreement
NCSL-I	International Conference of Standards Laboratories
NIST	National Institute of Standards and Technology, Gaithersburg MD (United States)
NMI	National Metrology Institute
NML CSIRO	National Measurement Laboratory, CSIRO, Pretoria (Australie)
NORAMET	North American Metrology Cooperation (Canada, Mexico and the United States of America)
NPL	National Physical Laboratory, Teddington (United Kingdom)
NPL-DTI	National Physical Laboratory, Department of Trade and Industry,Teddington (United Kingdom)
NRC	National Research Council of Canada, Ottawa (Canada)
NRC INMS	NRC Institute for National Measurements Standards
OECD	Organization for Economic Cooperation and Development
OIML	Organisation Internationale de Métrologie Légale
PITTCON	Pittsburgh Conference (yearly conference and exhibition on chemistry)
RCMAM	IAU Working Group on Relativity for Celestial Mechanics, Astrometry and for Metrology
RMO	Regional Metrology Organization
SADC	Southern African Development Cooperation
SADCMET	Southern African Development Community Cooperation in Measurement Traceability
SIM	Sistema Interamericano de Metrología
SSDL	Secondary Standards Dosimetry Laboratories under the IAEA
SURAMET	South American Metrology Cooperation (Argentina, Brazil, Chile, Paraguay and Uruguay)
TBT	Technical Barriers to Trade Committee of the WTO, see WTO
UN	United Nations
UNIDO	United Nations Industrial Development Organization
WADA	World Anti-Doping Agency
WHO	World Health Organization

WMO	World Meteorological Organization
WMO GAW	WMO Global Atmospheric Watch programme
WTO	World Trade Organization
WTO TBT	World Trade Organization, Committee on Technical Barriers to Trade

2 Acronyms for scientific terms and others

bcr	Benefit-cost-ratio
BSE	Bovine Spongiform Encephalopathy (live stock disease)
CMC	Calibration and Measurement Capabilities
CRM	Certified Reference Material
DNA	Deoxyribonucleic Acid
EPER	European Pollutant Emission Register
GDP	Gross Domestic Product
GLONASS	Global Navigation Satellite System
GMO	Genetically Modified Organism
GUM	Guide to the Expression of Uncertainty in Measurement
IPPC	Integrated Prevention of Pollution Control
IT	Information Technology
IVD	In Vitro Diagnostic
KCDB	BIPM Key Comparison Database
R&D	Research and Development
RNA	Ribonucleic Acid
SI	International System of Units
srr	Social rate of return
SPS	Sanitary and Phyto-Sanitary
TAI	International Atomic Time
TFP	Total Factor Productivity
UTC	Coordinated Universal Time
VAT	Value Added Tax
VIM	International Vocabulary of Basic and General Terms in Metrology

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