Knowledge Sharing Program

2012 Modularization of Korea's Development Experience:

National Standards Infrastructure Underpinning the Economic Growth of Korea

2013

Ministry of Science, ICT and Future Planning

KRISS
Korea Research Institute of Standards and Science

2012 Modularization of Korea's Development Experience:

National Standards Infrastructure Underpinning the Economic Growth of Korea

2012 Modularization of Korea's Development Experience

National Standards Infrastructure Underpinning the Economic Growth of Korea

Title	National Standards Infrastructure Underpinning the Economic Growth of Korea
Supervised by	Ministry of Science, ICT and Future Planning, Republic of Korea
Prepared by	Korea Research Institute of Standards and Science
Author	SEO, Sangwook, Global Metrology Academy, Korea Research Institute of Standards and Science (KRISS), Senior Project Manager BAHNG, Gun-Woong, Division of Industrial Metrology, Korea Research Institute of Standards and Science (KRISS), Principal Research Scientist SO, Hun-Young, Division of Metrology for Quality of Life, Korea Research Institute of Standards and Science (KRISS), Principal Research Scientist
Advisory	JANG, Yongsuk, Science and Technology Policy Institute (STEPI), Research Fellow CHUNG, Nak Sam, Korea Research Institute of Standards and Science (KRISS), Scientist Emeritus
Research Management	KDI School of Public Policy and Management
Supported by	Ministry of Strategy and Finance (MOSF), Republic of Korea

Government Publications Registration Number 11-7003625-000056-01

ISBN 979-11-5545-064-2 94320

ISBN 979-11-5545-032-1 [SET 42]

Knowledge Sharing Program

Government Publications Registration Number
11-7003625-000056-01

Knowledge Sharing Program

2012 Modularization of Korea's Development Experience

National Standards Infrastructure Underpinning the Economic Growth of Korea

Ministry of Science, ICT and Future Planning

KRISS
Korea Research Institute of Standards and Science

Preface

The study of Korea's economic and social transformation offers a unique opportunity to better understand the factors that drive development. Within one generation, Korea has transformed itself from a poor agrarian society to a modern industrial nation, a feat never seen before. What makes Korea's experience so unique is that its rapid economic development was relatively broad-based, meaning that the fruits of Korea's rapid growth were shared by many. The challenge of course is unlocking the secrets behind Korea's rapid and broad-based development, which can offer invaluable insights and lessons and knowledge that can be shared with the rest of the international community.

Recognizing this, the Korean Ministry of Strategy and Finance (MOSF) and the Korea Development Institute (KDI) launched the Knowledge Sharing Program (KSP) in 2004 to share Korea's development experience and to assist its developing country partners. The body of work presented in this volume is part of a greater initiative launched in 2010 to systematically research and document Korea's development experience and to deliver standardized content as case studies. The goal of this undertaking is to offer a deeper and wider understanding of Korea's development experience with the hope that Korea's past can offer lessons for developing countries in search of sustainable and broad-based development. This is a continuation of a multi-year undertaking to study and document Korea's development experience, and it builds on the 40 case studies completed in 2011. Here, we present 41 new studies that explore various development-oriented themes such as industrialization, energy, human resource development, government administration, Information and Communication Technology (ICT), agricultural development, land development, and environment.

In presenting these new studies, I would like to take this opportunity to express my gratitude to all those involved in this great undertaking. It was through their hard work and commitment that made this possible. Foremost, I would like to thank the Ministry of Strategy and Finance for their encouragement and full support of this project. I especially would like to thank the KSP Executive Committee, composed of related ministries/departments, and the various Korean research institutes, for their involvement and the invaluable role they played in bringing this project together. I would also like to thank all the former public officials and senior practitioners for lending their time, keen insights and expertise in preparation of the case studies.

Indeed, the successful completion of the case studies was made possible by the dedication of the researchers from the public sector and academia involved in conducting the studies, which I believe will go a long way in advancing knowledge on not only Korea's own development but also development in general. Lastly, I would like to express my gratitude to Professor Joon-Kyung Kim and Professor Dong-Young Kim for his stewardship of this enterprise, and to the Development Research Team for their hard work and dedication in successfully managing and completing this project.

As always, the views and opinions expressed by the authors in the body of work presented here do not necessary represent those of the KDI School of Public Policy and Management.

May 2013

Joohoon Kim

Acting President

KDI School of Public Policy and Management

Contents | LIST OF CHAPTERS

Chapter 3

Contents | LIST OF CHAPTERS

Chapter 4

Chapter 5

Contents | LIST OF TABLES

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Contents | LIST OF FIGURES

Chapter 1

Chapter 2

Chapter 3

Chapter 4

Contents | LIST OF BOXES

Chapter 2

Summary

This study introduces the key role of a national standards system (NSS) with emphasis on national measurement standards (NMS) in Korea, which have provided a scientific and technological (S&T) foundation for industrial development and increased exports to support the nation's economic growth. Advanced industrial countries have been operating national metrology institutes (NMI) whose history is well over a century. The Korea Research Institute of Standards and Science (KRISS) has been serving as the NMI of Korea since 1975 and has seen remarkable growth in its relatively short history of thirty-plus years. The competence in NMS that KRISS has today is recognized as one of the world's leaders in this area. Based upon the experience of Korea' growth as a nation and the KRISS as an NMI as well, this report is designed to share knowledge with developing countries regarding the national standards infrastructure underpinning the economic growth of Korea. It is hoped to provide governmental policy-makers and those organizations assigned to be the NMIs in developing countries with potentially effective strategies.

The three main pillars of the national standards system (NSS) are metrology (measurement standards), standardization (documentary standards), and conformity assessment (accreditation/certification). People solely view documentary standards, which is generally represented as industrial standards, as national standards. In recent years, this understanding has been broadened to include the importance of certification and accreditation to secure the credibility of various industrial products and services. However, it should be noted that 'metrology – measurement standards' plays the key role in properly operating the NSS. Metrology serves as the scientific and technological foundation on which the NSS of a country could be working effectively based on international recognition. Advanced industrial countries such as Germany, USA, UK, France, and Japan have all established and maintained their NMIs from the beginning stage of their industrialization for the purpose

of advancing their capability in national measurement standards. These nations clearly understood that in order to secure international credibility for their industrial activities and achieve consequent sustainable economic growth, their capability in national measurement standards had to be strengthened through the continued investment and support by governments.

National measurement standards, specifically the scientific and technological foundation for the national standards system as discussed above, are the core factors for ensuring the quality of industrial products and the international recognition of these products thereof. Furthermore, NMS is enabling both products and industries to secure their competitiveness in the global marketplaces. The Republic of Korea, due to its lack of capital and natural resources, could not but choose to pursue export-driven economic growth as its key for national strategic development. Alongside this strategy, the Korean government established KRISS in the mid-1970s, during the formative stages of the nation's industrialization, to represent Korea in the national and global metrology community and to perform all related duties. To advance the capability of the NMS to the extent that they could be accepted by all relevant partners of international exchanges and transactions, the Korean government and KRISS continuously invested in the three key areas of 1) securing human resources, 2) securing precision measuring equipment, and 3) establishing an advanced quality management system. The efforts for advancement and development of NMS continue even today and will continue into the future. This is motivated by the strong and direct correlation between the level of a nation's industrial development and its competence in NMS. The continued investments by the Korean government and the outstanding performance of KRISS in R&D activities have together enabled Korea to achieve a world-class capacity for national measurement standards. Compared with advanced countries that have more than one hundred years of history and rich experience in this field, Korea had a relatively late and humble beginning. Today, however, Korea's capability in NMS is on a par with that of advanced countries in terms of both quantity and quality.

This report is composed of five 5 chapters as follows: Chapter 1 describes the basic concepts and functions of the national standards system followed by its economic impact. It also introduces the national standards system in Korea in terms of who is authorized to take over missions for the national standards system. Chapter 2 briefly introduces the standardization and conformity assessment in Korea, putting emphasis on the core tasks of international harmonization. Chapter 3 provides elaboration on Korea's experience regarding what and how it has advanced its capacity in metrology (measurement standards) to the world-leading level. In addition, it analyzes how significant economic benefits KRISS has brought to Korean industries. In Chapter 4, priority issues in metrology are discussed along with how KRISS has addressed those issues so as to yield excellent performance.

Chapter 5 (Lessons Learned and Recommendations) identifies the three key factors of the successful operation of the national metrology institute in Korea; fostering high-quality human resources, securing precision measuring equipment, and establishing advanced quality management systems. "Recommendations" place stresses among anything else on the need to establish strategy on national development plans and to secure continued government support and investment to ensure the advancement of the three aforementioned factors.

More specifically, the study concludes with the following recommendations: 1) to ensure that the establishment of NSS is clearly an integral part of a country's national development plans; 2) to establish all legal groundwork required to set up the NMS; 3) to support the national metrology institute and its research activities by ensuring its operation in autonomy and independence; 4) to ensure the efficient division of roles between the government and private sectors based on expertise; 5) to secure high-quality human resources responsible for advancing R&D in metrology—the scientific and technological foundation of a national standards system - and to secure core measuring equipment; 6) to build effective network of communications with customers; and 7) to encourage the adoption of international standards as national standards in the two pillars of standardization and in conformity assessment.

Chapter 1

Introduction

Introduction

The Korean War had left such deep and painful wounds in the nation that industrialization and modernization were merely a distant dream for Korea. Starting off in the 1960s as one of the poorest nations but possessing an unparalleled zeal for education, diligence, and a strong work ethic, Korea fully utilized available resources of the aids and investments by allies into national policies for economic growth and the advancement of science and technology. These factors along with others have brought upon the phenomenal growth of Korea so that it gained the status of advanced economy upon becoming a member of the OECD Development Assistance Committee (DAC) in 2010 - only sixty years after the end of the Korean War in 1953.

A national standards system and calibration hierarchy of manufacturing tools are essential for industrial development and also form part of the core infrastructure ensuring a nation's sustained economic growth through reliable production of quality goods. In particular, measurement and standards served as the key factors that granted success in its industrialization to Korea that had chosen an export-led growth model for its economic development. To be recognized as quality product in the global market, all testing and analysis data collected during the production process must first be internationally acceptable. In response to such needs, the Korean government established the Korea Research Institute of Standards and Science (KRISS), formerly known as the Korea Standards Research Institute (KSRI), in 1975 when Korea was still in the early stages of industrialization, to serve as the nation's R&D institute for the advancement of metrology.

Throughout history, national standards have played a key role in maintaining social order by establishing confidence in economic activities including commercial transactions in our daily life and taxation. In today's world, economic activities are no longer limited within a geographic boundary, but have expanded to create what is now known as a global economic

environment. It has put much more stress on the importance of national measurement standards than ever before. Especially with regard to the agreements set forth by the World Trade Organization (WTO), the elimination of technical barriers to trade has become a requirement for every nation pursuing economic growth via trade to secure international recognition of its competences in measurement, testing, and analysis which have to be supported by sound national standards. Under the Agreement on TBT,[1] the WTO requires every nation to have international standards adopted and implemented as national standards, as it lays the technological foundation to promote a more transparent and faster flow in trade.

To address such global needs, the CIPM[2] adopted the CIPM-MRA[3] in 1999 to improve worldwide traceability for measurement standards and to establish the degree of equivalence of national measurement standards. To date, the CIPM-MRA has participants from eighty-seven countries and four international organizations. And through activities such as international key comparisons (KC), it is establishing a worldwide system of equivalence of national measurement standards. The national metrology institute (NMI) of Korea, KRISS participates in international key comparisons and has made achievements that demonstrated its world-leading performance in both the quantity and quality of its work. KRISS, with its relatively brief history of just over thirty years, has managed to match the competence of advanced NMIs whose histories span well over a century. The factors which enabled such successful achievements in metrology are attributed especially to securing high-quality human resources, continuous updating of measuring equipment and establishing quality management system based on international standards, among many others.

1. Agreement on TBT: Agreement on Technical Barriers to Trade.
2. CIPM: International Committee of Weights and Measures.
3. CIPM-MRA: Mutual Recognition Arrangement on the Equivalence of National Measurement Standards and of the Calibration and Measurement Certificates Issued by the National Metrology Institutes (14 October 1999).

Figure 1-1 | CIPM-MRA and Signatory of KRISS Joining the MRA (Oct 14, 1999)

Reconnaissance mutuelle
des étalons nationaux de mesure
et des certificats d'étalonnage et de mesurage
émis par les laboratoires nationaux de métrologie
Paris, le 14 octobre 1999
Supplément technique révisé en octobre 2003 (pages 17-20)

Mutual recognition
of national measurement standards
and of calibration and measurement certificates
issued by national metrology institutes
Paris, 14 October 1999
Technical Supplement revised in October 2003 (pages 38-41)

Comité international des poids et mesures

RECONNAISSANCE MUTUELLE
DES ÉTALONS NATIONAUX DE MESURE
ET DES CERTIFICATS D'ÉTALONNAGE ET DE MESURAGE
ÉMIS PAR LES LABORATOIRES NATIONAUX DE MÉTROLOGIE

MUTUAL RECOGNITION
OF NATIONAL MEASUREMENT STANDARDS
AND OF CALIBRATION AND MEASUREMENT CERTIFICATES
ISSUED BY NATIONAL METROLOGY INSTITUTES

Source: www.bipm.org

1. National Standards System: An Overview

1.1. Components and Definitions

As defined in the Framework Act on National Standards, "national standards" refer to the scientific and technological public standards that are uniformly applied across the nation to promote accuracy, rationality and internationality in all spheres of society. National Standards are the key requisites to maintaining social order, and they establish a unified system on a nationwide scale that applies to not only industrial production but also a wide range of areas including education, trade, taxation, and clinical medicine. Therefore, due to their nature as public goods, standards and their relevant activities are overall the responsibility of the government.

A national standards system is known to be composed of three pillars: metrology (measurement standards), standardization (documentary standards), and conformity assessment (accreditation/certification). Metrology consists of the realization of units, measurement methods, reference materials, and measurement systems. They are key

elements needed to guarantee international equivalence and traceability of measurement results obtained in the course of industrial production and scientific research activities. Equivalence and traceability constitute the key values of measurement standards. Standardization or documentary standards refer to documented scientific and technological specifications, guidelines, or regulations. They are either imposed compulsorily by the government or set forth voluntarily by the private sector in order to enhance industrial safety, efficiency, and economic feasibility. Examples include the KS (Korean Industrial Standards), the KICS (Korea Information and Communication Standards) in Korea and the standards of ISO, IEC, ITU, etc. Conformity assessment refers to the systematic checking of whether a product, service, processes, system or personnel meets the national standards or technical requirements by means of certification and accreditation.

Table 1-1 | Definitions of the Components of National Standards System

Metrology (Measurement standards)	Realization of measurement units, measurement methods, reference materials and measurement systems used to guarantee the international equivalence of measurement results obtained in industrial activities and scientific researches (e.g., length standards, time standards)
Standardization (Documentary Standards)	Documented specifications, guidelines or regulations, imposed by the government or set forth voluntarily by the private sector in order to enhance industrial safety, efficiency and economic feasibility (e.g., KS, KICS, ISO)
Conformity Assessment (Accreditation/ Certification)	Systematic demonstration that specified requirements relating to a product, process, system, service, person or body are fulfilled (e.g., certification, accreditation, test, inspection)

Source: KRISS, Overview of KRISS, NMI of Korea (2012)

1.2. Characteristics of National Standards System

Public in nature as implied by the term, national standards are applied across all social areas. Further, they in principle require international collaboration nowadays, as the economic scope is being expanded beyond national borders to the global community. Moreover, a national standards system must be a mission taken over by the government, as it needs long-term investments and its effects are felt in every corner of the nation.

Table 1-2 | Characteristics of the National Standards System

Infrastructure ensuring reliability	NSS is an infrastructure for providing reliability in measurements over a wide range of areas such as trade, manufacturing, education, science and technology, safety, energy, and the environment.
International collaboration required	NSS cannot work properly until it is comparable and equivalent to those of other countries. Therefore, international collaboration is essential for NSS by nature. For example in national measurement standards, international comparisons are carried out among NMIs, based on the resolutions of the CGPM operated under the Meter Convention (1875, Paris).
Mission of Government	NSS requires strategy and investment with long-term plans. In addition, though it is not a profit-making business, its benefit spreads to every corner of society. Therefore, it is the government that should be responsible for and invest in the NSS.

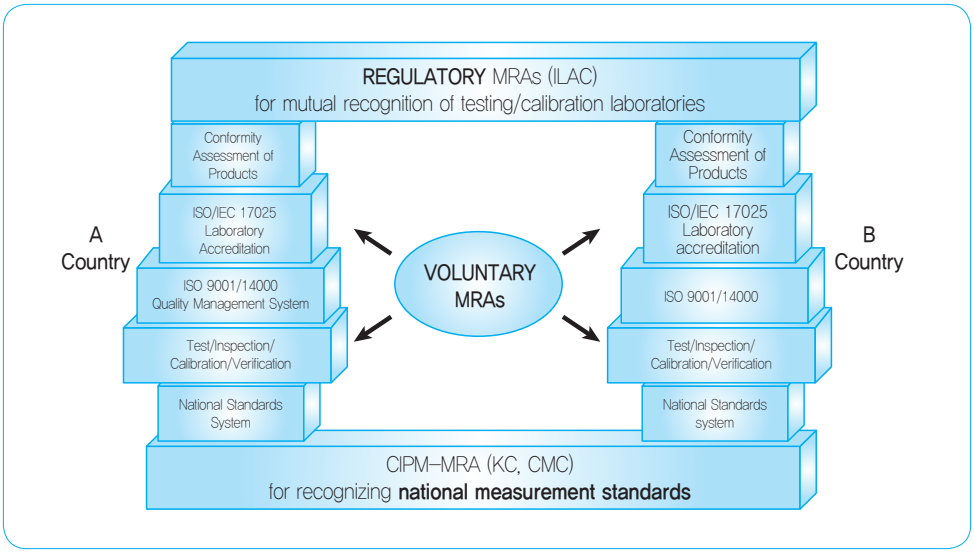
Source: KRISS, Overview of KRISS, NMI of Korea (2012)

1.3. Functions of Metrology, National Measurement Standards

Closely linked to one another, the three aforementioned elements of NSS are distinct but not separable, as are the hardware and software of a computer. Among them, metrology supports the scientific and technological aspects of the activities relating to standardization (documentary standards) and conformity assessment. Once measurement standards are proved not to be accurate and stable, the subsequent results of measurements and tests throughout a nation will be surely losing reliability, which will eventually weaken the competitiveness of the nation.

In history, when a new dynasty came to power, the kingdom first took up measures to unify all existing standards, along with military forces and currencies. The historic pattern attests to the importance of metrology. For example, in the late 19th century, the Korean Empire set up a royal agency committed to the unification of metrology standards. In 1966 during his visit to the Republic of Korea, U.S. President Lyndon B. Johnson presented a set of measurement standards for length and mass as a symbol of scientific and technological cooperation between the two countries. [Figure 1-2] illustrates how closely the three elements are interrelated and how the NMS takes the key role.

Figure 1-2 | Essential Role of Measurement Standards in National Standards System



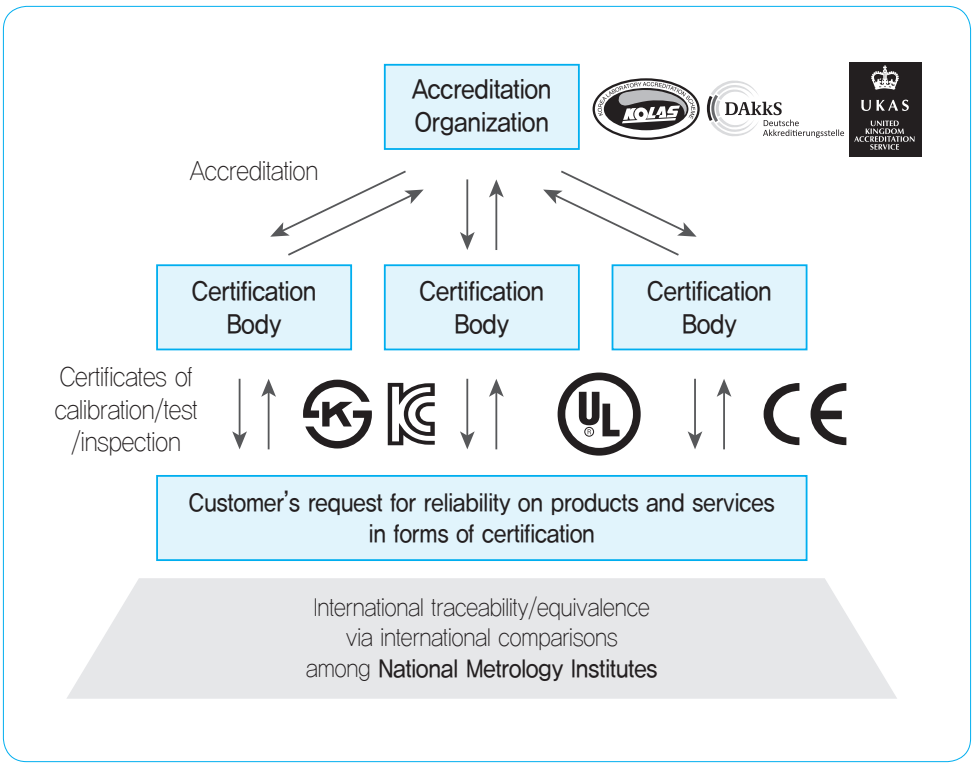
Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

Accreditation organizations and certification bodies assess and verify whether or not an organization certifying products and services is fairly and appropriately operated in conformity with the relevant international standards. Further, they control and supervise those accredited certification bodies by means of follow-up management activities to maintain and guarantee the reliability of certification systems.

The core of the certification process is to check whether the data in the reports released by national certification agencies are traceable to the national measurement standards and whether the system is operated in conformity with international standards. To comply with international standards requires measuring instruments to be calibrated by means of comparison with national measurement standards that are traceable to international standards. By comparing the national measurement standards of the country with those of other countries, the national metrology institute thus ensures that the reported data (i.e. measurement results) issued by national certification bodies secure global recognition. Commercial transactions always require product test reports that can be internationally accepted. In this sense, the reports directly affect the global competitiveness of the products.

Therefore, the competence of the national measurement standards maintained by the national metrology institute directly affects the nation's global competitive edge. [Figure 1-3] depicts how accreditation and certification bodies are related where traceability and equivalency secured by national metrology institutes play an essential role.

Figure 1-3 | Relations among Accreditation Organizations, Certification Bodies and National Metrology Institutes



National metrology institute (NMI): securing equivalence via international comparisons of national measurement standards

Certification bodies: obtaining international accreditation by securing traceability to the national metrology institute (NMI) responsible for measurement standards

Source: Gun-Woong Bahng, NSS in Korea (2012)

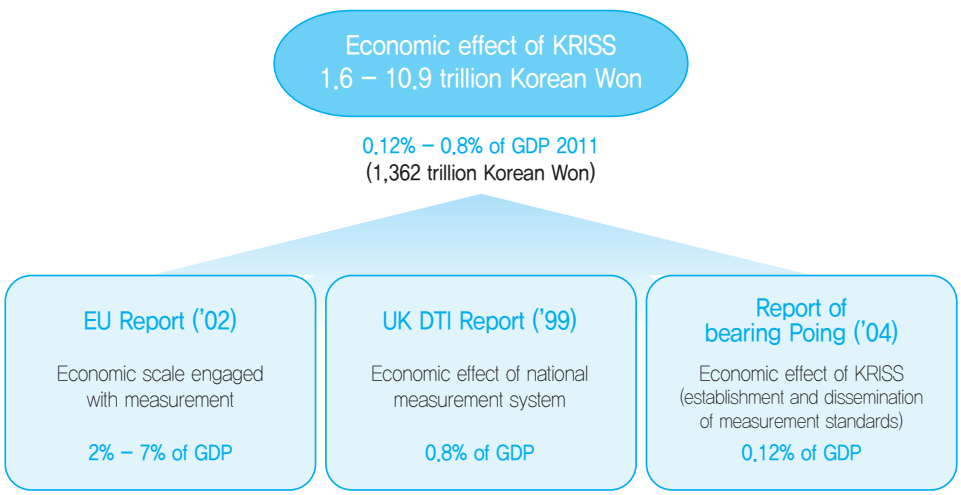
2. Economic Impact of National Standards System

2.1. Economic Value via the International Traceability of Measurement

The underlying function of national measurement standards is to assure that the results of all measurement activities throughout the nation are to be traceable to national measurement standards. National metrology institutes (NMIs) maintain their national measurement standards (NMS) to be compatible at the international level through international comparisons and then disseminate the NMS to their customers, including the industrial

sectors. However, it is difficult to make an accurate assessment of how much economic effect has been made on production, commercial transaction, and international trade by using measurement standards which are traceable to international standards. A study in an advanced country reports that the effect of measurement standards on the economy is around 0.12% - 0.8% of the GDP. According to a report by the Department of Trade Industry (DTI), UK (1999), the economic effect of national measurement system is around 0.8% of the GDP. The 2004 Bearing Point report suggested that the economic effect of measurement services provided by KRISS is 0.12% of the GDP. Another report of the EU (2002) says the economic scale of measurement-related activities is 2% - 7% of the GDP.

Table 1-3 | Economic Effect of Measurement Standards



Additional collections are given below, demonstrating the economic effect that the national standards system has had on the international trade and the growth of national economy.

Economic effects of standards	• 80% of international trade of goods, affected by standards	Donald Evans (cited from OECD report) - 34th Minister of Commerce, U.S. ('01 - '05)
	• 76% of the total trade volume in EU, affected by standards	OECD report (1999) - 21% affected by compulsory standards (regulatory standards)
	• Effects of standards on the German economic growth	DIN report - Capital (48.5%), **standards (27.3%),** licenses (15.2%), labor (6%), patents (3%)

Source: Gun-Woong Bahng, Economic impact of metrology and NMI (2012)

2.2. Effect of Measurement Standards on National Economy

Measurement standards bring confidence to national and international economic activities by providing reliability in measurement results that are applied to and obtained in the course of the production, distribution and consumption of products and services in all sectors. Reliable measurement results benefit transactions of all kinds as they help reduce the costs that might arise from data collection and analysis as well as disputes. They also greatly reduce social expenses that arise from checking health and analyzing food safety when reliable measurement standards are made available to their users. It is possible to reduce expenses from excessive clinical tests, prevent medical accidents resulting from incorrect diagnoses, and prevent safety incidents arising from food additives or pesticide residues. They are all possible only when reliable measurement standards are in place.

For international trade, an agreement can be reached only when the measurement certificate can guarantee its conformity to international standards. It is fair to say that the measurement capability of a NMI can determine the global competitiveness of the industry. When average income increases, people will look for better products or services in terms of quality. So the competitiveness of a product or service depends on quality, which can be evaluated through reliable measurements in various aspects.

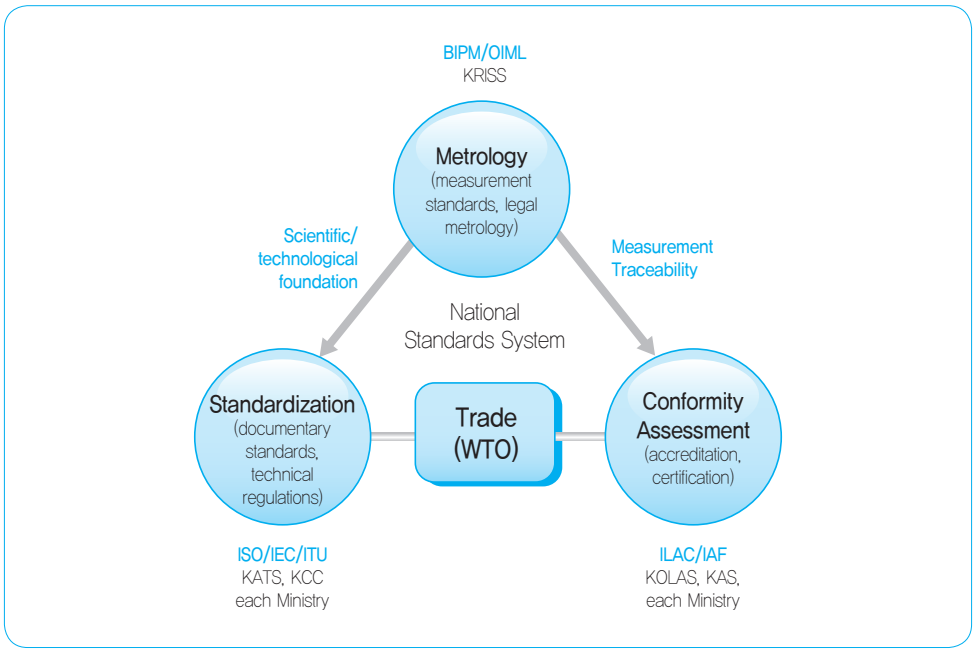
When it comes to the automobiles or aircrafts industries where hundreds of thousands of components have to be assembled, each part should be measured based on the same standards. Otherwise it is impossible to complete any products that can be operated as designed. It is even more critical in the case where a space shuttle must be docked on a space station. The accuracy of measurements is essential not only for the safety of the space shuttle but also the survival of the crew. More specific success stories of the economic benefits that KRISS has created and delivered to the nation's economy and to the selected Korean industries will be described in more detail in the following chapters.

3. National Standards System of Korea

3.1. National Standards System and Authorities in Charge

Different nations have developed various types of national standards systems in accordance with their industrial structure and historic backgrounds. [Figure 1-4] illustrates the national standards system of Korea and the relevant authorities, along with their roles. Korea has been operating a decentralized type of NSS, where different organizations are in charge of each of the three elements of national standards system.

Figure 1-4 | National Standards System of Korea and Authorities in Charge



• KRISS: Korea Research Institute of Standards and Science www.kriss.re.kr
• KATS: Korean Agency for Technology and Standards www.kats.go.kr
• KCC: Korea Communications Commission www.kcc.go.kr
• KOLAS: Korea Laboratory Accreditation Scheme www.kolas.go.kr

Source: Gun-Woong Bahng, NSS in Korea (2012)

Table 1-4 | Roles of Key Players in the National Standards System of Korea

Areas	Organizations in charge	Roles
(1) Metrology (Measurement Standards)	- Assigned to KRISS: National Metrology Institute (Framework Act on National Standards, §13)	- Establishment and dissemination of measurement standards through R&D activities in metrology
(2) Standardization (Documentary Standards)	- Assigned to different organizations, including Korean Agency for Technology and Standards (KATS), Korea Communications Commission (KCC), Ministry of the Environment, Ministry of Defense, Ministry of Health and Welfare, Korean Food & Drug Administration, and Ministry of Strategy and Finance, etc.	- Development and management of standardization and technical requirements (e.g., KS, KICS, technical guidelines and regulations set forth by various ministries)
(3) Conformity Assessment (Accreditation/ Certification)	- Assigned to different organizations, including Korean Agency for Technology and Standards (KATS), National Institute of Environmental Research (NIER), Radio Research Laboratory (RRL), Ministry of Defense, and Ministry of Health and Welfare, etc.	- Operating accreditation and certification system for conformity assessment of products and services - Programs include those operated by Korea Laboratory Accreditation Scheme (KOLAS), Korea Accreditation System (KAS), Korea Accreditation Board (KAB), Korea Society for Laboratory Medicine, Ministry of Defense's quality watchdog, Korean Food & Drug Administration, etc.

Source: Gun-Woong Bahng, NSS in Korea (2012)

Measurement standards, by providing measurement traceability for conformity assessment activities, guarantee the global recognition and reliability of quality reports, and provide a metrological foundation for standardization. Standardization (i.e. documentary standards, technical regulations) sets forth requirements and specifications required by agencies in charge of conformity assessment. As shown in <Table 1-4>, KRISS, the sole national metrology institute of Korea is authorized to take over the missions of metrology and measurement standards in Korea. Meanwhile, different ministries share other tasks involving standardization and conformity assessment, with each setting forth its own technical regulations and operating its own agencies in accordance with their specialties.

3.2. Laws Related to the National Standards System of Korea

Article 127 (2) in Korea's Constitution, as amended in October 1980, states "The State shall establish a system of national standards," committing the government to establish and manage the national standards system. In February 1999, the Korean government enacted the Framework Act on National Standards, which stipulates the legal requirements and policies regarding the national standards system. To put this framework into practice, its Enforcement Decree became effective in July 1999. The Industrial Standardization Act, which was first enforced in 1961, provides the legal basis for the standardization activities and conformity assessment activities in Korea.

In addition to this, different ministries have separately set forth the individual mandatory technical regulations and guidelines to secure the basis of standards-related activities in each area of work. This is identical to the operation conformity assessment. Different ministries of the Korean government have been operating separate programs of accreditation and certification of products and services in the areas under their administration. Such an individual legal framework has room for further improvement so that it complies with the provisions as set forth by the international standards of ISO 17011.[4]

Table 1-5 | Major Laws Governing the National Standards System of Korea

– The Korean Constitution (article 127, clause 2) – "The State shall establish a system of national standards."
– Framework Act on National Standards – Article 13: "Korea Research Institute of Standards and Science (KRISS) shall act as the national metrology institute (NMI)." Article 21: Establishment of conformity assessment system in Korea
– Industrial Standardization Act – Article 5 : Establishment of Korean Industrial Standards Article 13 : Designation of certification institution Article 32 : Establishment of Korean Standards Association (KSA)

Source: http://www.moleg.go.kr/lawinfo/engLawInfo

4. ISO/IEC 17011: Conformity assessment – General requirements for accreditation bodies accrediting conformity assessment bodies.

Chapter 2

Brief Overview of Standardization and Conformity Assessment in Korea

1. Overview of Standardization (Documentary Standards) in Korea
2. Classification of KS, Korean Industrial Standards
3. Development and Dissemination of KS
4. Core Task in Standardization: Harmonization with International Standards
5. Overview of Conformity Assessment in Korea

Brief Overview of Standardization and Conformity Assessment in Korea

1. Overview of Standardization (Documentary Standards) in Korea

Korean Industrial Standards (KS) are one of many documentary standards in Korea, and is most widely known to the public. The horizon of standardization grows wider to cover numerous areas such as communication, food, agriculture, fishery, laboratory medicine, and nuclear energy. There are various organizations responsible for developing and disseminating documentary standards in Korea for their own specific areas of work. The Korean Agency for Technology and Standards (KATS) is responsible for industrial standardization. In the areas of information and communications, Korea Communications Commission (KCC) is authorized to be in charge of the standardization activity. Standardization for food safety and toxicity analysis is under the administration of the Korean Food and Drug Administration (KFDA) and the Ministry of Food, Agriculture, Forestry and Fisheries. The Korean Ministry of Education, Science and Technology is in charge of standardization of radionuclide analysis. <Table 2-1> shows the major institutions in charge of standardization in each area.

Although Korea's national administration system concerning standardization is currently in transition towards a public-private balanced system, it has still been more public-sector-led or legislation-based, similar to most developing and newly developed nations unlike in the case of the developed economies in Europe and North America. The difference may have originated from its history and from the stage of industrialization of each country. For instance, the development of standardization and certification in Korea is legislated by the *Industrial Standardization Act* of 1961 while those of the United States and most Western European countries are based on private sector development.

Table 2-1 | Major Institutions in charge of Standardization in Korea

Areas	Korean Organizations in Charge	International Organizations concerned
Industrial Standardization	Korean Agency for Technology and Standards, Korean Standards Association	International Organization for Standardization (ISO), IEC (International Electrotechnical Commission)
Information and Communications	Korea Communications Commission	International Telecommunications Union (ITU)
Food safety, Toxicity Analysis	Korean Food and Drug Administration, Ministry of Food, Agriculture, Forestry and Fisheries	Food and Agriculture Organization (FAO)
Clinical Analysis	Korean Food and Drug Administration	International Federation of Clinical Chemistry (IFCC)
Radionuclide Analysis	Ministry of Education, Science and Technology	International Atomic Energy Agency (IAEA)
Bio Activity	Korean Food and Drug Administration	World Health Organization (WHO)

Source: Gun-Woong Bahng, NSS in Korea (2012)

2. Classification of KS, Korean Industrial Standards

Industrial standardization might be given priority in development in almost all countries in the course of their industrial advancement. In Korea, Korean Industrial Standards (KS) is a typical one in this area. At present KS is managed by the Korean Agency for Technology and Standards (KATS), whose responsibility has been delegated and entrusted by the Korean Ministry of Knowledge Economy (MKE) drawing on the *Industrial Standardization Act* and its *Enforcement Decree*. The Korean Standards Association (KSA) is responsible for publishing and disseminating KS according to the same law.

KS may be grouped into three types of standards as follows:

- "Product Standards," specifying the improvement, measurement and quality of products;
- "Procedure Standards," stipulating testing, analysis, inspection, measurement method and process standards; and

• "Horizontal Standards," specifying terminology, technical characteristics, unit and numerical progression, etc.

As of December 2011, there are 23,923 KS items. The list is composed of 7,576 product standards, 8,540 procedure standards and 7,807 horizontal standards. KS is also classified into 21 sectors. The sector codes include those (A) for basic standards, (B) for mechanical engineering, (Q) for quality management, (S) for services, to those (X) for the information sector. To give examples, in the case of developing KS in the sector of basic standards (A), the title of KS is named to KS A, while in the service sector (S), the number for the "Call Center for Services" standard is KS S 1006-1: 2006. Classification of KS is designed to help users better recognize and identify the sectors to which the subject KS belongs.

Table 2-2 | Classification of Korean Industrial Standards (KS) by Sectors

Sector		Sub-major
Basic Standards	(A)	General/Radiation · radioactivity management/Guide /Dependability management/Culture/Social system/etc.
Mechanical Engineering	(B)	General/Machine elements/Tools/Machine tools /Measuring instrument · physical apparatus/General machinery /Industrial machinery Agricultural machinery /Thermal apparatus · gas apparatus/Metrology · measurement /Industrial automation/etc.
Electrical &electronic engineering	(C)	General/Measurement & testing apparatus /Electrical &electronic materials/cable and conduit /Electrical machines/Electrical appliances Electrical · electronic · communication component/Lamp · lighting devices /Wiring · electrical accessories/Semiconductor · display/Others
Metals	(D)	General/Raw Materials/Steels/Cast Steel and Cast Iron /Copper Products/Castings/Wrought Products/Secondary Products /Methods of processing/Analysis/etc.
Mine	(E)	General/Mining/Security/Mineral/Transportation/etc.
Construction	(F)	General/Testing · inspection · measurement/Materials · elements of civil and building construction/Construction work/etc.
Necessities	(G)	General/Furniture · interior items/Stationery · office supplies /Household goods/Leisure · sports equipment /Musical instruments/etc.
Foodstuffs	(H)	General/Processed agricultural foods/Processed marine foods/etc.
Environment	(I)	General/Environmental assessment/Atmosphere/Water quality /Soil quality/Waste/Noisy and vibration/Malodor/Marine environment /etc.

Sector		Sub-major
Organism	(J)	General/Biological process/Bio-chemical · bio-fuel /Industrial microorganism/Bioassay · bio-information/etc.
Fiber	(K)	General/Clothing/Yarns · Knitted fabrics · Textile fabrics /Textile · Knitting machine/Industrial textile products/etc.
Ceramics	(L)	General/Glass/Refractories/Potteries · clay products/Cement /Abrasives/Machine structure ceramics /Electric · electronic ceramics/Ceramic materials/etc.
Chemistry	(M)	General/Industrial chemicals/Rubber · leather/Fats and oils · mineral oil/Plastics · photographic material/Dyestuff · explosives/ Pigment · paint · ink/Paper · pulps/Reagents/Cosmetics/etc.
Medical	(P)	General/General medical devices/Equipment used in medical practice/Materials for medical devices/Medical supplies · hygienic products/Technical aids for disables · elderly-considered products /Electronic equipment in medical practice/etc.
Quality management	(Q)	General/Factory management/Sensory analysis/System certification /Conformity assessment/Applied statistical method/etc.
Transportation machine	(R)	General/Testing and Inspect method/Common parts/Bicycle/ Engine and parts/Car bodies · safety/Electric &electronic system · instrument/Repair Tools/Railway/Motorcycle/etc.
Service	(S)	General/Industrial service/Consumer service/etc.
Logistics	(T)	General/Packaging/Storage · loading/Transport/Logistics information/etc.
Shipbuilding	(V)	General/Hull/Engine &parts/Electric equipment /Navigational instrument/etc.
Aerospace	(W)	General/Standard parts/Airframe · materials /Aviation screw propeller/Aviation electronic equipment /Ground support supplies/etc.
Information	(X)	General/Information technology application/Character set · coding · automatic identification/Software · computer graphics /Networking · IT interconnection/IT equipment · data storage media /Electronic documents · electronic commerce/etc.

Source: http://www.kats.go.kr/htm/business_01/standard_02_01.asp

3. Development and Dissemination of KS

Based on the Industrial Standardization Act, KATS organizes and manages a high-level 'Industrial Standards Council (ISC),' 52 technology councils composed of 543 experts at the next level, and 370 expert committees composed of 4,493 experts at the working level. The ISC may approve KS based on the recommendations from technology councils and expert

committees. Expert committees often function as mirror committees and counterparts to the technical committees (TC) or sub-committees (SC) of ISO[5] and IEC.[6]

Box 2-1 | COSD: Cooperation Organization for Standards Development

In 2006, KATS introduced the scheme of Cooperation Organization for Standards Development (COSD) in an effort to develop KS efficiently by improving the standardization capacity of the private sector. As of June 2011, there are 44 organizations designated to serve as COSD. They consist of interest groups and societies concernred. It is envisaged that the Korean government will focus on establishing the national policy of standardization while transferring its responsibility for standards development and management to the private sector to the extent of approximately 80% by the end of 2012.

In fact, there are many more emerging areas subject to standardization such as telecommunications, food, and aerospace industries. Compared to the number of KS in 2000 in these areas, its volume in 2007 most likely doubled: IT (3.3. times), Food (3.3 times), and Aerospace (2.1 times). COSD is assigned to carrying out surveys of standards in need and planning for the development of appropriate standards. In addition, COSD operates mirror committees and working groups which supply feedback from the stakeholder's perspective. Each COSD has technical expertise in their subject area; therefore, each COSD serves as a key player in the development of Korean industrial standards.

Table 2-3 | Number of Korean Industrial Standards (KS) by Sector

Total			23,923
Basic Standards(A)	744	Ceramics (L)	475
Mechanical Engineering (B)	4,149	Chemistry (M)	3,465
Electrical & Electronic Engineering (C)	3,832	Medical (P)	760
Metals (D)	1,633	Quality Management (Q)	123
Mining (E)	440	Transportation Machine (R)	1,067
Construction (F)	858	Service (S)	113
Necessities (G)	383	Logistics (T)	319

5. ISO: International Organization for Standardization www.iso.ch.

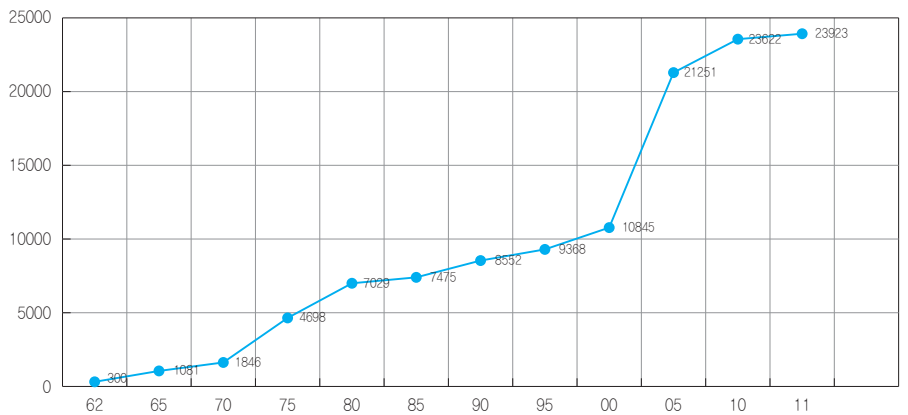
6. IEC: International Electrotechnical Commission www.iec.ch.

Total			23,923
Food stuffs (H)	526	Shipbuilding (V)	834
Environment (I)	672	Aerospace (W)	522
Organism (J)	78	Information (X)	2,039
Fiber (K)	891		

Source: http://www.standard.go.kr/code02/user/0A/07/StdInfoKind_statistics.asp?OlapCode=STAU010702

Table 2-4 | Number of Korean Industrial Standards (KS) from 1962 - 2011

Year	Number of KS	Year	Number of KS
1962	300	2005	21,251
1970	1,846	2007	22,760
1980	7,029	2009	23,372
1990	8,552	2010	23,622
2000	10,845	2011	23,923



Source: KSA

The KSA provides KS (Industrial Standards) both online (KSSN network) and offline (hard copy) for producers and consumers. To enable industries and consumers to gain a better understanding of KS and the KS mark certification system, the KSA publishes and distributes various types of information and makes efforts to broadcast the importance of its standardization program and the system on TV and radio as well as in newspapers. The Korean Standards Service Network (KSSN, www.kssn.net) is a standard information portal service which contains a vast amount of data-based standards information including

standardization (documentary standards), measurement standards, reference standards, conformity assessment, and trends in international and private standardization activities.

Box 2-2 | Korea, an Early Adopter of Industrial Standardization

The statistics of KS shown above tell a very interesting lesson concerning the Korean government's foresight of promoting standardization in Korea. It was 1962 when the Korean government introduced the KS system for the first time in the history of the Republic of Korea. The statistics reveal that there were already 300 KS registered during the very first year of KS. It was also the first year that the Korean government launched its first five-year economic development plan (1962~1966). Korea was then among the poorest countries in the world with no advanced industries at all. Nevertheless, the Korean government adopted the KS system despite being in an early stage of industrialization.

With no experience in standardization, there was no other way for Korea but to simply copy and translate Japanese industrial standards into Korean. In the field of agriculture, however, Korea developed its own KS to implement locally. Korea suffered greatly from a lack of food. Therefore, Korea was in desperate need to increase its food production. In contrast to advanced countries, in which large tractors were popular, Korea needed unique farming equipment such as cultivators suitable for working on small farms. It wasn't until the early 1970s that Korea could introduce farming equipment powered by electricity. The Korean government was an early adopter of industrial standardization such that the country could find areas and subjects for standardization from the beginning of its industrialization. As it is with nearly all other areas, standardization had to begin with the most urgent issues and had to be in step with the nation's industrial advancement.

4. Core Task in Standardization: Harmonization with International Standards

The core task in standardization is to establish the nation's documentary standards corresponding to the relevant international standards. All nations at present, whether industrialized or developing, are faced with this task, which should be effectively resolved to sustain their economic growth. It has become inevitable as all countries pursue their economic growth through international trade in the current globalized economic environment. It is much more significant for developing countries, in particular, as they are heavily dependent on international trade for economic advancement. As it is well known, any products or services which are not complying with the relevant international standards

cannot be granted reliability in terms of quality and are thus unable to access the global market.

Until 2001, KS, the Korean industrial standards, reached around 60% in consistency with the corresponding international standards of ISO and IEC. However, the rate had jumped to 99.9 % by the end of 2011, demonstrating that nearly all of the Korean industrial standards, which are subject to international consistency, are in agreement with international standards.

Table 2-5 | International Consistency of Korean Industrial Standards (KS)

Year	Total number of KS	KS subject to international consistency	Status of consistency			NEQ[7]	Rate of consistency (%, B/A)
			Sum (B)	IDT[8]	MOD[9]		
2001	12,006	5,469	3,453	2,378	1,075	2,016	63.1
2002	15,176	7,515	7,048	5,520	1,528	467	93.8
2003	18,014	9,856	9,784	8,227	1,557	72	99.3
2004	19,865	11,535	11,488	10,073	1,415	47	99.6
2005	21,251	12,691	12,669	11,262	1,407	22	99.8
2006	22,058	12,978	12,965	11,623	1,342	13	99.9
2007	22,760	13,969	13,957	12,714	1,243	12	99.9
2008	23,062	14,171	14,160	12,937	1,223	11	99.9
2009	23,372	14,675	14,661	13,397	1,264	14	99.9
2010	23,622	14,177	14,157	12,849	1,308	20	99.9
2011	23,923	15,384	15,365	14,225	1,140	19	99.9

Source: http://www.standard.go.kr/code02/user/0A/07/StdInfoNational_statistics.asp?OlapCode=STAU010703

5. Overview of Conformity Assessment in Korea

Conformity assessment is defined as a "demonstration that specified requirements relating to a product, process, system, person or body are fulfilled."[10] This may include any activity concerned with determining directly or indirectly that relevant requirements are fulfilled. Conformity assessment procedures provide a means of ensuring that the products, services, or systems produced or operated have the required characteristics, and that these

7. NEQ: Not Equivalent.

8. IDT: Identical.

9. MOD: Modified.

10. ISO/IEC 17000: 2004, Conformity Assessment – Vocabulary and General Principles.

characteristics are consistent from product to product, from service to service, or system to system. The purpose of conformity assessment is to provide confidence for users that the requirements applicable to products, services, and systems have been met. Such confidence, in turn, directly contributes to the market acceptance of those products, services, and systems. Such user confidence can be achieved through cooperation among conformity assessment bodies and/or accreditation bodies, resulting in the mutual recognition and promotion of each participant's work across borders.

5.1. Principal Components of Conformity Assessment

Conformity assessment includes sampling, testing, inspection, certification, quality management system assessment and registration. It also includes the accreditation of the competence of those activities and the mutual recognition of an accreditation program's capabilities.

5.1.1. Testing

Testing is perhaps the most common form of conformity assessment. It can include activities such as measurements and calibrations. It is the main technique used for product certification. Testing is defined as a technical operation that consists of the determination of one or more characteristics of a given product, material, equipment, organism, person's qualification, physical phenomenon, process, or service according to a specific technical procedure (test method).

5.1.2. Inspection

Inspection is defined in ISO/IEC Guide 2 (*Standardization and Related Activities – General Vocabulary*) as the "conformity evaluation by observation and judgment accompanied as appropriate by measurement, testing, or gauging." In the European Standard, EN 45004,[11] inspection is defined as the "examination of a product design, product, service, process or plant, and the determination of their conformity with specific requirements, or on the basis of professional judgment."

5.1.3. Certification

Certification is a type of third-party conformity assessment. Certification is the process of providing assurance that a product (including services), process, personnel, organization, or system conforms to specific requirements.

11. EN 45004: General Criteria for the Operation of Various Types of Bodies Performing Inspection.

a. Product Certification

Many variants exist. For example, product certification may consist of the initial testing of a product combined with an assessment of its supplier's quality management system. This may be followed by surveillance that takes into account the supplier's quality management system, plus testing of samples from the factory and/or the open market. Other product certification schemes are comprised of initial testing and surveillance testing, while still others rely on the testing of a sample product - this is known as type testing.

b. Quality Management System (QMS) Certification

QMS certification is the most well-known example of certification. There are more than 951,486 organizations in 175 counties that have been certified to the ISO 9001[12] standard (as of December 2007). It should be noted that ISO itself does not assess the conformity of quality management systems. ISO does not issue certificates of conformity to these standards or any other standard. QMS certification is carried out independently of ISO by more than 800 certification or registration bodies that are active internationally.

5.1.4. Accreditation

Accreditation is the procedure by which an authoritative body gives formal recognition that a body or person is competent to carry out specific tasks of conformity assessment. ISO/IEC 17000 (Conformity Assessment — Vocabulary and General Principles) defines accreditation as: "third-party attestation related to a conformity assessment body conveying formal demonstration of its competence to carry out specific conformity assessment tasks." Accreditation is the internationally accepted system that recognizes the competence of testing and calibration laboratories, inspection bodies, product certification bodies, and quality system certification bodies. Therefore, accreditation establishes the assurance of the test data and provides discipline and a sense of professionalism that is internationally accepted. This minimizes duplication of re-testing and re-certification, which in turn reduces the cost and eliminates non-tariff barriers to trade and market access delays.

12. ISO 9001: Quality Management Systems - Requirements.

Box 2-3 | Metrology for Conformity Assessment

Metrology Enabling Conformity Assessment

It should be noted that although metrology as it pertains to measurement standards is not generally considered a conformity assessment activity, we could not have conformity assessment without metrology. We could have laboratory accreditation, testing, and product certifications, for instance, only where there are the services of scientific and technological measurements made available for those conformity assessment activities. For this reason, conformity assessment on the certification orgnizations is composed of two parts; quality management requirements and technical requirements. The core of technical requirements is to evaluate whether or not they have kept traceability to the national measurement standards.

5.2. Scheme of Conformity Assessment in Korea

5.2.1. Characteristics of Conformity Assessment in Korea

Conformity assessments are directly related to industrial activities across sectors and to the daily lives of people. In Korea, numerous government ministries set up and implement conformity assessment schemes of their own. Each ministry, working in agriculture, labor, construction and transportation, science and technology, health and welfare, the environment, culture and tourism, information and communication, national defense, and industry, as examples, operates individual independent conformity assessment systems. Such a decentralized national system of conformity assessment has room to improve even more in view of the higher efficiency and competitiveness of Korea's conformity assessment activities.

"*The Framework Act on National Standards*" of Korea specifies the responsibilities of the Government to promote and the conformity assessment system.[13] In addition, there are a few more laws in effect that lay the legal foundation of the conformity assessment activities in different areas. "*The Quality Management and Safety Control of Industrial Products*

13. Framework Act on National Standards
    Article 21 (Establishment of Conformity Assessment System)
    (1) The government shall endeavor to promote projects for accreditation and certification of the conformity assessment system and to make the conformity assessment procedure conform to international guidelines andinternational standards.
    Article 22 (Product Certification)
    Article 23 (Accreditation of Testing and Inspection Institutes)
    Article 24 (Certification of Quality Management System and Environmental Management System)

Act" deals with conformity assessments concerning the ISO 9000 certification system. "*The Act on the Promotion of the Conversion into Environment-Friendly Industrial Structure*" serves as the legal basis of the conformity assessments on the ISO 14000[14] certification system. "*The Industrial Standardization Act*" also specifies the government's significant mission in the area of conformity assessments regarding product certification and system certification.[15]

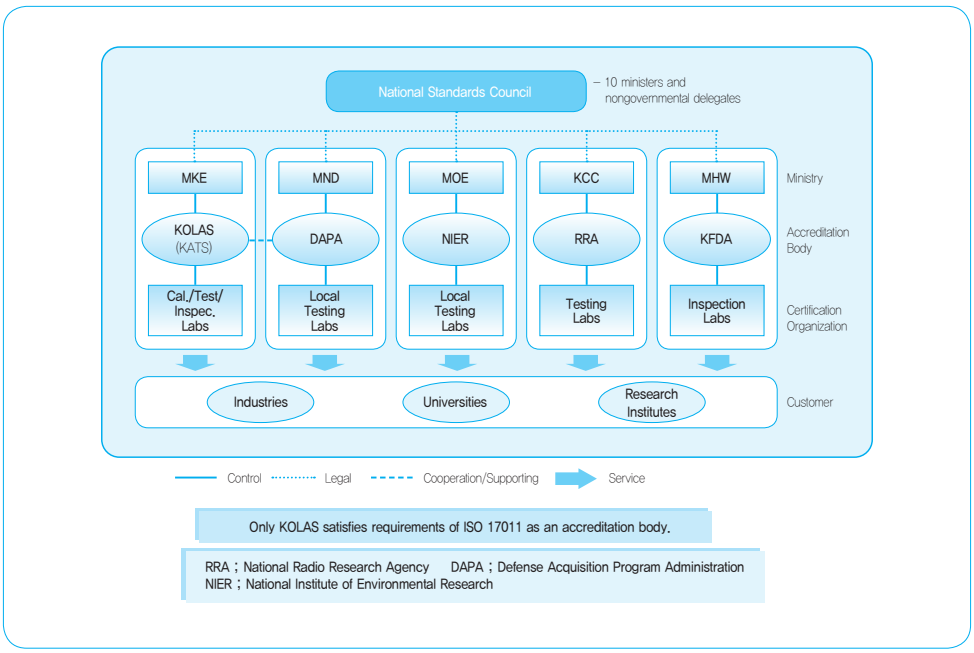
5.2.2. Accreditation System in Korea

Various accreditation programs in different areas have been in operation in Korea as authorized by specific Ministries of the Korean Government in charge. For example, the Korea Laboratory Accreditation Scheme (KOLAS) is the legal authority for the accreditation of calibration laboratories, testing laboratories, inspection bodies, and reference materials producers. It is operated under the administration of the Ministry of Knowledge Economy. In the field of national defense, the Defense Acquisition Program Administration (DAPA) has been authorized by the Ministry of National Defense (MND) to operate its own accreditation program for local testing laboratories. In addition, the Ministry of Environment (MoE) has authorized the National Institute of Environmental Research (NIER) to operate its own accreditation program for the local testing laboratories engaged in environmental testing and analysis. In the field of information and communications, the Radio Research Laboratory (RRL) has been authorized by the Korea Communications Commission (KCC) to operate a program of accreditation for the testing laboratories concerned. [Figure 2-1] illustrates the current accreditation system in Korea, in which there are various accreditation programs for specific areas of work. All programs are under the administration of different ministries.

14. ISO 14000: Environment Management Systems.

15. Industrial Standardization Act
    Article 13 (Designation of Certification Institutions)
    Article 15 (Certification of Products)
    Article 16 (Certification of Services)

Figure 2-1 | Accreditation System in Korea



Source: Gun-Woong Bahng, NSS in Korea (2012)

5.2.3. Korea Laboratory Accreditation Scheme (KOLAS)

The Korea Laboratory Accreditation Scheme (KOLAS) is the most widely known accreditation body in Korea. Established on December 8, 1992, KOLAS has the legal authority for the accreditation of calibration laboratories, testing laboratories, inspection bodies, and reference materials producers. It is operated under the administration of the Korean Agency of Technology and Standards (KATS). KOLAS actively participates in international activities related to testing and calibration in cooperation with the Asia-Pacific Laboratory Cooperation (APLAC) and the International Laboratory Accreditation Cooperation (ILAC). Meeting the requirements of ISO/IEC 17011, KOLAS is a signatory to the International Laboratory Accreditation Cooperation Mutual Recognition Arrangement (ILAC MRA). As of December 2012, there are 189 calibration laboratories, 418 testing laboratories, 49 inspection bodies, and 11 reference materials producers which have been accredited by KOLAS. The relevant international standards used for its accreditation consist of the following:

- Accreditation of Calibration and Testing Laboratories: ISO/IEC 17025 (General Requirements for the Competence of Testing and Calibration Laboratories)

- Accreditation of Inspection Bodies: ISO/IEC 17020 (Conformity Assessment – Requirements for the Operation of Various Types of Bodies Performing Inspection)
- For Accreditation of Reference Material Producers: ISO Guide 34 (General Requirements for the Competence of Reference Materials Producers)

5.3. Core Task in Accreditation System in Korea: Central Coordination Function

As described above, there are numerous accreditation programs in operation by different agencies in Korea. Besides the KOLAS, there are two more accreditation bodies which operate under the supervision of the Ministry of Knowledge Economy. They are KAB (Korea Accreditation Board) and KAS (Korea Accreditation System). KAB is the accreditation body responsible for management systems, while KAS is engaged in accreditation for product certification.

In addition, different governmental ministries have been running various accreditation programs in specific areas. To name a few, the National Institute for Environmental Research of the Ministry of the Environment has some 80 testing laboratories, and the Ministry of Health and Welfare is operating 950 testing laboratories. The Korea Food and Drug Administration (KFDA) manages 80 testing laboratories, and the Ministry for Food, Agriculture, Forestry and Fisheries operates 60 testing laboratories, accredited within the framework of their own accreditation programs.

However, it should be noted that a central function for coordinating all the above accreditation programs has been absent. In this context, Korea's conformity assessment system has room for further improvement of its efficiency and effectiveness by ensuring a central authority of nationwide coordination for assessment systems currently operated independently by different ministries.

Box 2-4 | Conformity Assessment and Trade

Harmonizing conformity assessment procedures around the world has far-reaching benefits for international trade in general. Agreements among nations or regions on the mutual acceptability of requirements, assessment methods, inspection or test results, for instance, can all help to reduce or remove technical barriers to trade. These are procedures or requirements related to importation and market access that vary from country to country and may bar a foreign product from entering a country.

The WTO's Agreement on Technical Barriers to Trade (TBT) was established to promote the recognition of others' conformity assessment results as a way of reducing barriers to trade. It emphasizes that confidence in the continued reliability of conformity assessment results is a prerequisite to the recognition of assessments. A practical example of trade facilitation is where a country exporting cheese to another country accompanies the product with a test report on the fat content to enable the importing country to classify the cheese according to its regulations on fat content. The importing country may accept the test report of the exporting country based on its level of confidence in the conformity assessment procedures used and are in place in the exporting country. Likewise, when trading partners adhere to similar or equivalent conformity assessment procedures and requirements, or recognize each other's conformity assessment results, then the costly problem of discriminatory, non-transparent and unnecessary obstacles to trade will disappear. Mutual recognition of conformity assessments can then facilitate the flow of goods and services in the global marketplace.

Chapter 3

Overview of Metrology (Measurement Standards) in Korea

Overview of Metrology (Measurement Standards) in Korea

1. Overview of KRISS Today: National Metrology Institute of Korea

1.1. Missions and Functions of KRISS

Operating under the Constitution of the Republic of Korea, article 127, §2, and the section 13 of the Framework Act on National Standards, KRISS sets forth its mission in Article 2 of its statute. The article states that "KRISS, as the national metrology institute of Korea, has been assigned to conduct its missions to promote industrial competitiveness of Korea by advancing measurement standards in science and technology in ways that enhance the nation's economic performance and secure a better quality of life for all." Its missions and main functions are given as below:

Table 3-1 | Missions and Functions of KRISS

Missions	Functions
○ To establish, maintain, and improve national measurement standards	■ Maintaining the seven SI base units including length, time, and mass; ■ Establishing traceability to ensure the international equivalence of national measurement standards; ■ Improving uncertainty in measurements and establishing new measurement fields; ■ Fulfilling requirements for the CIPM-MRA regarding mutual recognition of national measurement standards and of the calibration and measurement certificates issued by NMIs
○ To research and develop measurement science and technology	■ Advancing measurement science and technology as well as evaluation methods for emerging industries; ■ Pioneering measurement science and technology for convergence in the fields of NT, BT, IT, etc.
○ To disseminate national measurement standards	■ Offering calibration services and advancing measurement service systems; ■ Developing and supplying certified reference materials (CRMs) for testing and analysis; ■ Training on measurement technologies for industries.

Source: KRISS, Overview of KRISS, NMI of Korea (2012)

1.2. Personnel and Budget

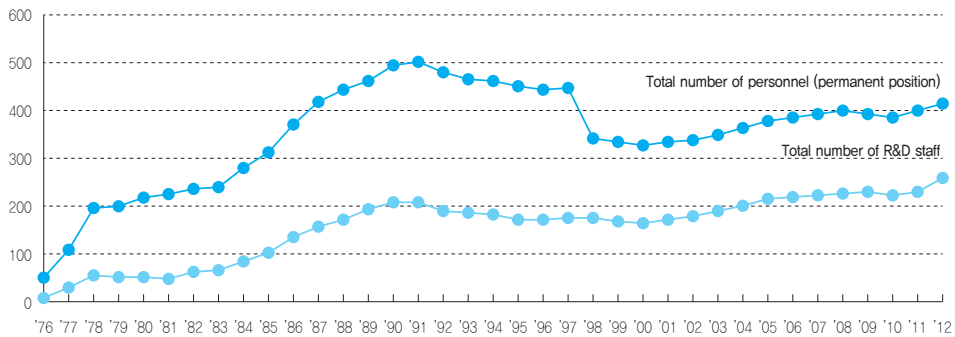
As of December 2012, KRISS had 414 regular employees. Approximately 360 of them are engaged in R&D activities in metrology, with more than 260 having doctoral degrees in different fields of science and technology. In addition, there are some 400 temporary employees working on a contract basis.

The budget for the fiscal year of 2012 was 139 billion Korean Won, 85 billion of which was directly funded by the government (i.e., approximately 60.8% of its entire budget). In addition, KRISS earned income via competitive bids to government R&D projects worth 29 billion KRW (20.8%). In total, the government's financial support for KRISS occupies around 80 % of its annual budget. The ever-increasing amount of the government's funding that has been invested in KRISS demonstrates that the Korean government has a high awareness and understanding of the important role of national measurement standards and NMI that are played in achieving the nation's goal of economic advancement. The table below tallies the personnel and budgets of KRISS.

Table 3-2 | Personnel and Budget of KRISS

Items	Executive	Researcher	Engineer	Administrator	Total
Number (Individuals)	1	256	152	47	414

Source: Personnel of KRISS as of December 2012



Source: Personnel of KRISS since 1976

(Unit: Million Korean Won)

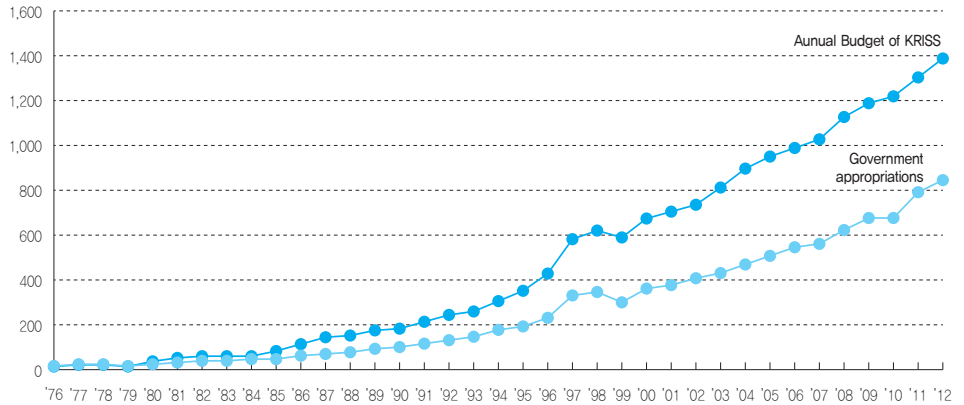
Revenue		Expenditure	
Items	Amount	Items	Amount
• Government appropriation	84,728	• Personnel expenses	33,199
• R&D and technical services	54,714	• R&D investment	73,885
		• Ordinary operations	6,444
		• Facility maintenance	14,673
		• Repayment of loans	388
Total	139,442	Total	139,442

Source: Budget of KRISS: FY 2012

(Unit: Million Korean Won)

Fiscal Year	Government appropriation	R&D contract (government)	R&D contract (private sector)	Technical services	Total
2011	78,863	25,512	13,592	12,618	130,585
2012	84,728	28,984	13,117	12,613	139,442

Source: Statement of Revenues of KRISS: FY 2011, 2012

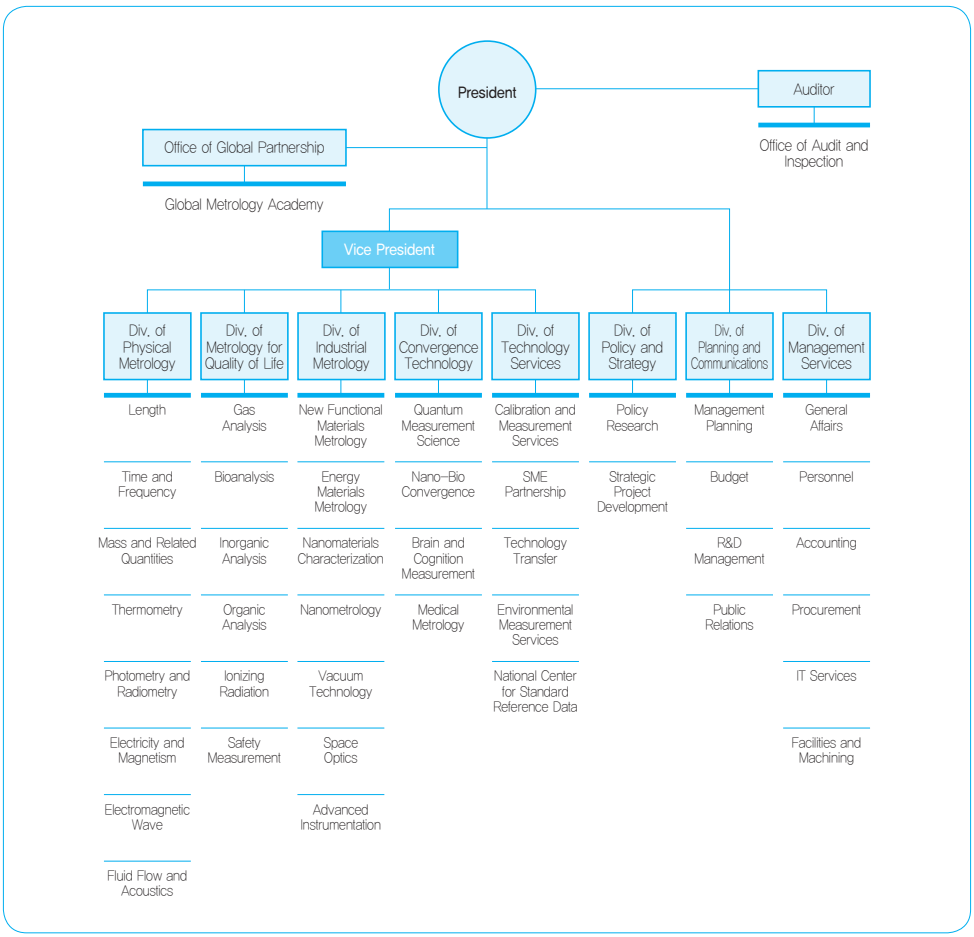


Source: Annual budget and government appropriations of KRISS since 1976

1.3. Organizational Structure

As of December 2012, KRISS operates 25 research centers under its four research divisions, each of which is assigned to carry out R&D activities regarding national measurement standards and advanced measurement science and technology. It also has four additional divisions in charge of daily operations and management, which provide support pertaining to the measurement services, strategic policies, planning and management. The following figure illustrates the organizational structure of KRISS as of December 2012:

Figure 3-1 | Organizational Structure of KRISS (as of December 2012)



Source: KRISS, Overview of KRISS, NMI of Korea (2012)

1.4. NMIs in Major Advanced Countries

Advanced countries have operated national metrology institutes from an early stage of their industrialization. Almost all of those NMIs have a history of more than 100 years. The 125-year-old Physikalisch-Technische Bundesanstalt (PTB), the German metrology institute for example, was established in 1887. The National Physical Laboratory (NPL) of the U.K. and the U.S. National Institute of Standards and Technology (NIST) were founded in 1900 and 1901, respectively. Although run by their governments, their operational independence is guaranteed, allowing them to work in a more creative and flexible environment. These NMIs have continuously yielded excellent performance, including Nobel Prize winners,

a fact that attests to the importance of independence and autonomy in their operations to encourage creative R&D activities by their research scientists.

Table 3-3 | Major Advanced National Metrology Institutes (NMI)

Country	NMI	Founded	Affiliated Ministry	Type (legal status)	Employee
Germany	PTB/BAM	1887	Economics & Technology	Federal agency	3,000
UK	NPL	1900	Business, Innovation and Skills	Government-owned, Contractor-operated	600
USA	NIST	1901	Commerce	Federal agency	2,900
Japan	NMIJ, CERI & NICT	1903	Economy, Trade and Industry	Independent administrative foundation	600
Australia	NMIA	1938	Innovation, Industry, Science and Research	Governmental Agency	350
Korea	KRISS	1975	Education, Science and Technology	Government-supported research institute	414[16]

Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

In spite of its rather short operation span, KRISS has grown to be on a par with those advanced NMIs in terms of its capabilities in national measurement standards. More details in this regard will be described later. The advanced NMIs are given similar functions for both national measurement standards and legal metrology, while KRISS takes charge of measurement standards alone. Different countries may have their own national standards systems fit for their own customs and circumstances. However, it is worth noting that the advanced NMIs are given authority of legal metrology based on their technical expertise in the area of measurement standards. It should be quite appropriate and desirable that agencies having professional competence in the subject area should be assigned with the pertinent responsibility and legal authority. This will allow them to serve the nation and its people better on a more efficient and effective manner.

16. The number (414) denotes the permanent staff of KRISS. There are also nearly 400 employees working on a contractual basis.

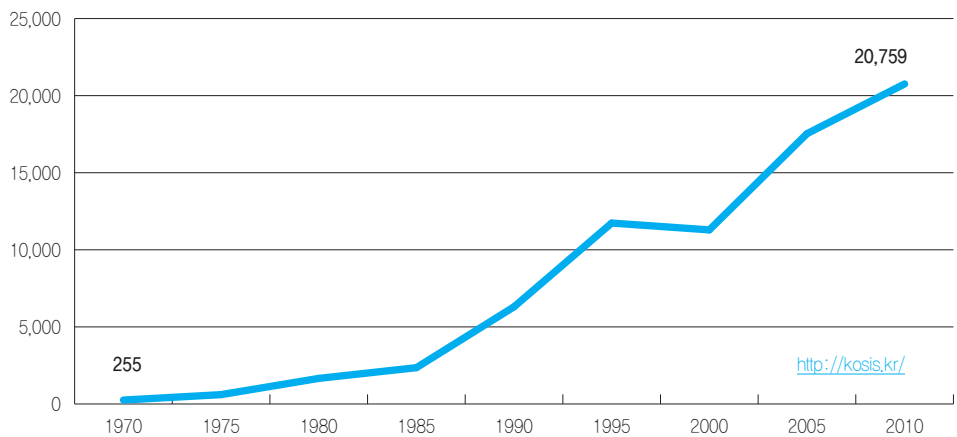
2. Foundation of KRISS

2.1. Korea's S&T for her Economic Growth

2.1.1. Success Factors for the Economic Growth of Korea

The unprecedented fast pace of the economic growth of the Republic of Korea since 1960 is often called a "miracle." The nation's GNI per-capita jumped to US $20,759 in 2010 from the meager US $79 in 1960 when the country was the second poorest in the world. The increase represents a rise of 250 times over 50 years, a feat that any other country has yet to achieve.

Table 3-4 | GNI Growth of Korea over Past Decades (1970 - 2010)



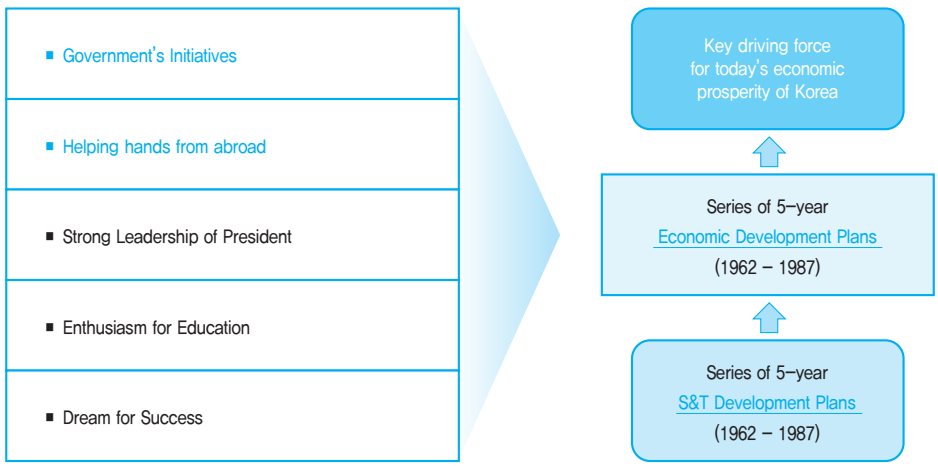
Year	'70	'75	'80	'85	'90	'95	'00	'05	'10
GNI per capita (US $)	255	607	1,660	2,355	6,303	11,735	11,292	17,531	20,759

1960's: US $79, Second to the lowest in the world → increased more then 250 times for 50 years: (1960-2010)
Source: http://kosis.kr

Studies have ensued to determine what made such miraculous growth possible. The answers lie in Korean people's diligence and enthusiasm for education, the nation's efforts to introduce advanced technologies and capital from around the world. Also as important were the roles and policies of the Korean government. During the period of rapid growth, the government implemented a series of five-year plans for the advancement of science and technology, along with and in support of its consecutive five-year economic development

plans. Realizing a miracle from the ashes of the Korean War, Korean people collaborated and worked in union to advance its national economic and scientific goals. Without this advancement, the government's efforts would not have blossomed.

Table 3-5 | Key Success Factors Contributing to Korea's Economic Growth

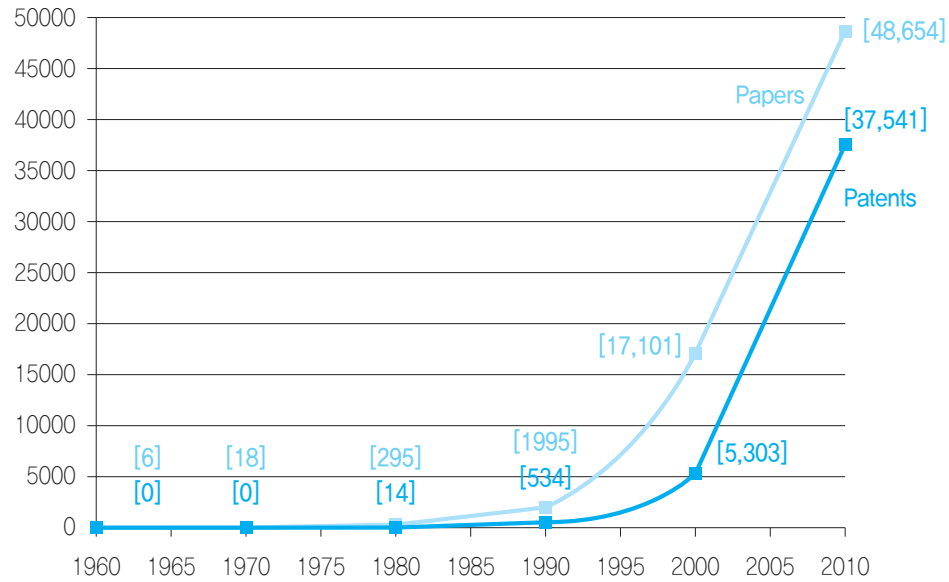


Source: Gun-Woong Bahng, Economic impact of metrology and NMI (2012)

2.1.2. Korean Government's Strategy to Advance S&T in Korea

The following table chronologically sums up the increasing numbers of academic papers in the areas of science and technology, as well as patents in Korea over the past 50 years. This simple comparison may not carry much significance; nonetheless, the figures clearly show a pattern. The GNI rise does not match that of papers and patents issued, which are the two major indicators of scientific and technological capacity of a nation. However, the pattern clearly demonstrates that Korea's scientific and technological capacity played a key role in sustaining its economic growth.

Table 3-6 | Numbers of Papers and Patents Produced by Korea (1960 - 2010)
(Indicators of Korea's Progress in Science and Technology)



Source: http://www.scopus.com

The Korean government adopted a series of strategies for scientific and technological development as a means to meet the goals set forth in its Five-Year Economic Development Plans. These strategies, introduced in the 1960s and 1970s, were centered on four strategic areas. First, science and technology development plans were implemented in addition to economic plans. The importance of science and technology has not diminished at all in the 21st century. Indeed, they are the key force of driving its economic growth. In this light, it is surprising that the Korean government became aware of the importance of these two tenets decades ago. Next, one can also note that the Korean government founded research institutes. The government funded the establishment of numerous research institutes, which number 26 as of 2012. They have grown to be the global leaders in their specific professional fields. These institutes have truly contributed to the successful completion of the five-year economic plans and have advanced national scientific and technological growth. In addition, the Korean government has offered exceptional incentives (e.g., salaries and benefits) to overseas Korean scientists to recruit them back to Korea. This has also guaranteed independence to the government-supported research institutes (GRIs) so as to promote an autonomous and creative working environment, while all budgets of the institutes are funded by the government.

Figure 3-2 | Key Driving Forces Enabling Korea's Progress in S&T

Source: Gun-Woong Bahng, Economic impact of metrology and NMI (2012)

2.2. Foundation of Government-supported Institutes in Korea[17]

2.2.1. Background

The Korean government endeavored in earnest to develop technologies and, thereby, to meet the goals set forth in the Five-Year Economic Plans with an special emphasis on industrialization and exports. These efforts required, as a prerequisite, the development of quality human resources. Initially, Korea relied on foreign technologies and paid heavy royalties as exports rose.

In 1963, which was the year the first five-year economic development plan (1962 - 1966) was instigated, Korea had only 83 research institutes nationwide. Mostly government-run organizations, along with a handful of executive agencies of corporations and universities, the institutes faced structural problems. Therefore, it was almost impossible to meet the nation's demand for innovation. At that time, government-run institutes were not guaranteed in terms of autonomous research activities. Even worse, the researchers in these institutes received humble salaries (forty dollars per month on average) - a fact that made it impossible to hire quality researchers. Moreover, factors that worsened the situation were insufficient budgets, a shortage of research instruments and facilities, and poor literature

17. PARK, Seung-Duk, "Winning the Future with Science and Technology," (*The Myung Hyun*).

and information. To tackle these issues from the root, the government established KIST[18] in 1966, and the Ministry of Science and Technology (MOST) in 1967, allowing them to be free from government intervention in the formation and administration of their science- and technology-related policies.

KIST has functioned as a model prototype of Korea's government-supported research institutes. The government incorporated these organizations as independent entities to secure their autonomy away from bureaucracy and government intervention. The government has also funded their budgets in the form of contribution so that they are free from government intervention in budgetary affairs. Deemed wise, the policies reflected the Korean government's commitment to promoting scientific and technological R&D efforts, and succeeded in fostering a creative and efficient research environment.

One of the ambitious goals of the Third Five-Year Economic Plan (1972 - 1976) was to promote and advance heavy and chemical industries. For that purpose, it was necessary to establish specialized research institutes that were capable of facilitating the advance of five major strategic industries (i.e., machinery, steel, chemical engineering, shipbuilding, and electronic engineering). In the end, the government enacted the "Supports of Specific Research Institutes Act" in December 1973. Under the Act, it became possible for the government to make investments, to assign government assets to the institutes for free, and to offer exceptional salaries and benefits to the research staff, along with tax exemption and other benefits. The government began to provide priority to them in allowing participation in government-run R&D activities, and they granted waivers to some young researchers from their mandatory military service. The institutes were allowed to have an autonomy in implementing their annual R&D plans and budgets upon approval by their respective board of directors and by the Minister of Science and Technology. All of these initiatives have led to the formation of relevant legal authority and principles of autonomous operations centered on their boards of directors.

2.2.2. Expansion of Government-supported Research Institutes

These government-supported research institutes (GRIs) have continuously grown and now number 26, as of 2012. The GRIs have led national scientific and technological advancement. With their outstanding competence as internationally recognized, these institutes have played global leaderships in various fields such as nuclear energy, maritime, metrology, chemistry, machinery, electricity, resources, energy, construction, bio-engineering, astronomy, food, aerospace, and nuclear fusion. Their outstanding roles will allow them to remain as key players in the nation's advancement in science and technology throughout the 21st century.

18. KIST: Korea Institute of Science and Technology.

<Table 3-7> summarizes the years when each of the government-supported research institute was founded.

Table 3-7 | Foundation of Korea's Government-supported Research Institutes

1960s (2)	Korea Institute of Science and Technology Information (1962) Korea Institute of Science and Technology (1966)	**1980s (7)**	Korea Institute of Construction Technology (1983) Korea Research Institute of Bioscience and Biotechnology (1985) Korea Astronomy and Space Science Institute (1986) Korea Food Research Institute (1987) Korea Basic Science Institute (1988) Korea Aerospace Research Institute (1989) Korea Institute of Industrial Technology (1989)
1970s (9)	Korea Atomic Energy Research Institute (1973) Korea Ocean Research & Development Institute (1973) Korea Research Institute of Standards and Science (1975) Electronics and Telecommunications Research Institute (1976) Korea Research Institute of Chemical Technology (1976) Korea Institute of Machinery & Materials (1976) Korea Electrotechnology Research Institute (1976) Korea Institute of Geoscience and Mineral Resources (1976) Korea Institute of Energy Research (1977)	**1990s (2)**	Korea Institute of Oriental Medicine (1994) Korea Railroad Research Institute (1996)
		2000s (6)	Korea Institute of Toxicology (2002) Korea Polar Research Institute (2003) National Institute for Mathematical Sciences National Security Research Institute (2005) National Fusion Research Institute (2005) Korea Institute of Materials Science (2007)

Government-supported Research Institutes (GRIs) in Korea (26 GRIs: as of 2012)

Source: Gun-Woong Bahng, Economic impact of metrology and NMI (2012)

2.3. Foundation of KRISS

2.3.1. Background

In 1965, President Park Chung Hee and U.S. President Lyndon B. Johnson issued a joint statement that the two countries would cooperate in the advancement of science and technology. In 1966, President Johnson visited Koera and announced practical measures to follow up the joint statement, which led to the creation of KIST. During his visit to Korea, Mr. Johnson presented a set of measurement standards prototypes (for length and mass), symbolizing the cooperation of the two countries in science and technology. The gift was simply not a souvenir; rather, it gave Korea the direction where to go forward. It presented the important lesson of why national measurement standards should be given priority as they play a key role in underpinning the industrial and economic growth of Korea and advancement of science and technology. Calibrated by the National Bureau of Standards (NBS), the national metrology institute of US, the prototypes were ready to be used for measurement services in Korea immediately. The incident awakened Korea's awareness of the necessity of a national metrology institute, and led to the foundation of KRISS in 1975 as the NMI of Korea through assessment and feasibility studies over three occasions.

The urgent necessity of an internationally recognized national measurement standards system encouraged the Korean government to found KRISS as the national metrology institute in charge of establishing national measurement standards. The Korean government became aware of the significant role of national measurement standards that were acceptable at an international level as the key factor underpinning the industrialization and economic development of Korea, with the recommendations by GE TEMPO consultant team.

Figure 3-3 | US President Visited Korea Carrying Measurement Standards (1966)

* Mr. Johnson, then the US President donated two sets of national measurement standards (Length and Mass)
Source: 30 years of KRISS (2005)

Figure 3-4 | Length and Mass Measurement Standards Presented by US President (1966)

Source: 30 years of KRISS (2005)

2.3.2. Feasibility Studies for Founding KRISS

An important turning point was set forth through the mutual visits of the presidents of the Republic of Korea and the U.S. in 1965 and 1966 so that Korea could advance in science and technology. Follow-up measures were taken for national measurement standards. Three NBS[19] delegates stayed in Korea for four weeks from October 8 to November 3, 1967 to study Korea's measurement standards and relevant systems. Their findings were described in a report, whose key points are summed up in the following table.

Among other things, the report stressed the necessity of national systems pertaining to physical measurement standards, a recommendation that necessitated the presence of a single national metrology institute like the U.S. NBS so as to reach the golas of Korea's economic development plans. The report also pointed out that it was the Korean government's responsibility to establish national measurement standards and to provide calibrations and technical advisory services applicable to industries and the nation's scientific community. Unfortunately, however, the delegation's recommendations did not prompt any action. It was only ten years later when an independent national metrology institute was founded in Korea.

Table 3-8 | Overview of the Activities of the First NBS Delegation to Korea (1966)

Delegates	Dispatching Organization	Findings and Recommendations
Mr. H. Steffen Peiser Mr. Forest K. Harris Mr. Ronald K. Eby	NBS (National Bureau of Standards, US)	· Absence of national standards infrastructure · Lack of awareness about a national physical standards system · Emphasis on the government's responsibilities for national measurement standards · Strong recommendation for the foundation of a national metrology institute

Source: 30 years of KRISS (2005)

Five years later in 1972, NBS sent its second delegation to Korea. The delegation was to assess issues related to a national measurement standards system, and to find solutions in order to facilitate Korea's pursuit of industrialization. At that time, Korea's economy was continuously growing, realizing the "Miracle of the Han River." In spite of this, however, Korea was faced with a serious problem. Korean products were not receiving due recognition in the global market because of the low quality. The situation provided the government an opportunity to rethink and reevaluate Korea's industrialization plans.

19. NBS (National Bureau of Standards); an internationally recognized U.S. national metrology institute, currently known as the NIST (National Institute of Standards and Technology) ⟨www.nist.gov⟩.

Amidst these circumstances, the second NBS delegation carried out survey and analysis in Korea to help find the best way to establish a national measurement standards system most conducive to the industrialization of Korea.

The Korean government, along with diverse experts, made relevant preparations for the second visit. Backed by full-hearted support from the Korean government, the delegation engaged in various activities, which finally led to more specific follow-up measures. The actions taken thereafter included, for example, identification of the processes and tasks to be undertaken by the government in the fields of national measurement standards and standardization. The efforts resulted in the foundation of the Office of Industrial Promotion (OIP) to be in charge of the tasks. The key activities and findings of the second delegation are summarized in <Table 3-9>.

Table 3-9 | Major Activities by the Second U.S. NBS Delegation (1972)

Delegates	Dispatching Organization	Findings and Recommendations
Mr. H. Steffen Peiser Mr. Thomas D. Coyle Mr. Ronald K. Eby	NBS (National Bureau of Standards, US)	· Issues in 19 categories identified to be addressed · Solutions proposed in 20 categories · Foundation of a national body in charge of standardization and measurement standards

Source: 30 years of KRISS (2005)

Despite the foundation of the OIP in 1973 and some progress in terms of industrial standardization, actions did not follow pertaining to national measurement standards in contrast to the original recommendations. As a result, the founding of KRISS was postponed once again.

The executive body of the OIP, the National Industrial Standards Testing Institute (NISTI) conducted surveys for three months starting in 1973 to understand the national circumstances pertaining to the establishment of national standards system. It conducted surveys on 6,350 organizations including colleges, testing and research institutes, and manufacturing plants, along with field surveys on 560 additional entities. The study found that Korean industries retained a very poor understanding of the necessity of precision and accuracy in measurement, and that most of them seemed unaware of how precise or accurate their equipment was. There were no calibration intervals designated on the measuring instruments which were already in use. Almost all measuring instruments were not receiving calibration services, which were only available for a few kinds of measuring instruments under legal enforcement.

To address these problems and the urgent need to set up a national standards system, the NISTI made suggestions regarding the need to establish a national calibration service network, securing qualified researchers, and securing financial resources to be borrowed from overseas. Accepting these proposals, the Korean government decided to take out loans from the USAID[20] and to invest in the foundation of a national metrology institute in Korea.

In response to the findings of NISTI, the Korean government invited the GE-TEMPO feasibility study team of General Electronics in September 1974, and had it examine the national standards systems in Korea. The study team began its work in September 1974 to determine whether or not it was feasible to set up such an organization in Korea. This work ended in August 1975. The final report was published in six volumes. Consisting of substantial content and feasible recommendations, most parts of the report were adopted by the Korean government. It also played a decisive role in the creation of the Korea Standards Research Institute (KSRI), the predecessor to KRISS. The following tables sum up the GE-TEMPO report by volume, along with its final conclusions:

Table 3-10 | Summary of GE-TEMPO Report Concerning the Foundation of KRISS

Vol. No.	Title of Volume	Main Contents
1	Organizational Structure of the National Standards System	Proposal of building national standards system in Korea
2	Organization of the Korea Standards Research Institute (Organization, Staff, Legal Framework)	Proposal of creating Korea Standards Research Institute (organization, human resources and legal authority)
3	Organization of the Priority missions of Korea Standards Research Institute (Mobile Calibration Service, Training, Information Requirements, and Suitability Analysis)	Korea Standards Research Institute (Mobile calibration services, education and training, provision of information and conformity assessment)
4	Organizational Surveys	
5	Recommended Laboratory Equipment for the National Standards System of Korea	List provided 704 items of measuring equipment
6	Executive Summary	

Source: 30 years of KRISS (2005)

20. USAID: U.S. Agency for International Development.

Table 3-11 | Conclusions in GE-TEMPO Report Concerning the Foundation of KRISS

Items	Main Contents	Remarks
Final Conclusions	- Korea's plan to improve national standards systems deemed highly valid; - Recommended to take action to raise national awareness of the importance of quality; - Recommended to take action to strengthen education programs on the importance and applications of advanced measurement capabilities; and - Stronlgy recommended to establish and operate an advanced national measurement standards system to enhance global competitiveness	

Source: 30 years of KRISS (2005)

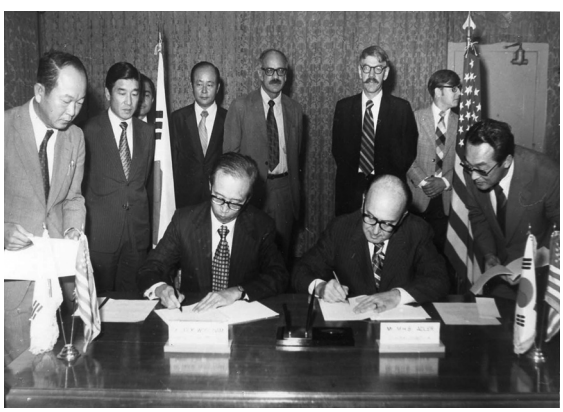
Based on these diagnoses, the GE-TEMPO team proposed major recommendations which contained vital elements to augment and improve the national standards sysem in Korea. The team stressed the importance of implementing the recommendations on a timely manner. In fact, most of these recommendations were adopted and put into practice during the course of establishing KRISS. The GE-TEMPO report also proved useful as a starting point, as it contained detailed lists and information of which equipment to be purchased as well as instructions on how to formulate and implement the basic operation plan of the institute. <Table 3-12> shows the details of the GE-TEMPO report, which are directly related to the creation of KRISS.

Table 3-12 | Recommendations in GE-TEMPO Report on the Foundation of KRISS (Excerpts pertaining to KSRI)

Category	Main Contents of Recommendations	Remarks
1	Establish an autonomous national metrology institute in Korea - Korea Standards Research Institute (KSRI) to be founded	
2	Modify functions of the NISTI of the OIP - Transfer functions concerning measurement standards to KSRI - Change name to "National Industrial Testing Institute (NITI)"	
3	Assign 12 functions to the KSRI - Maintaining the national measurement standards of the SI base units; - Maintaining the international traceability of the national measurement standards; - Providing technical support to government regulators; - Providing technical support to secondary calibration laboratories; - Manufacturing and supplying standard reference materials; - Maintaining and supplying standard reference data; - Conducting R&D on measurement and calibration technologies; - Conducting advice and education/training on metrology; - Providing information on measurement standards and technologies; - Designing, repairing and maintaining measurement instruments; - Providing advice on technology transfers; - Conducting studies on industrial standardization	

Source: 30 years of KRISS (2005)

Figure 3-5 | Signing Ceremony of USAID Loan for the Establishment of KRISS (1975)



Source: 30 years of KRISS (2005)

2.3.3. KRISS and its Implications for the Korea's Economy

The creation of KRISS had given rise to significant implications for the economic growth of Korea from a couple of perspectives. In 1975, when KRISS was born, Korea was near completion of its third five-year economic development plan (1972-1976). The volume of its yearly exports was soaring, at around US $5 billion. Such a rapid increase in exports called for the strict quality assurance of the products made in Korea. Quality assurance of exported goods was at the top of the national agenda of Korea as exports increased and was the key strategic task required for achieving the goal of its economic growth and sustaining national advancement. KRISS took an essential role in establishing the national standards system of Korea on an international level. Their efforts allowed the quality of Korean products to be accepted in the global marketplace. Quality assurance of products led to continued and rapid increase of exports, which in turn contributed to the realization of the nation's economic development plans.

In the middle of the 1970s, Korea was improving its industrial structure, shifting its focus from light to heavy industries as well as the chemical industry. Manufacturing under such new industrial circumstances required much larger capabilities of measurement services than ever before. KRISS was carrying out research and development activities across wide sectors of metrology in physics, chemistry, and materials. It was made possible as KRISS took the US NBS as its model of development; NBS was engaged in more comprehensive functions covering wide areas in metrology comprising metrology in physics, chemistry, and materials, while most of the NMIs in Europe were mainly focused on physical metrology. The resuls of R&D in metrology allowed KRISS to provide service of high-precision measurements that were internationally recognized so as to meet the need of Korean industry. Furthermore, KRISS has made it possible for Korea to stand firm as it is today with strong international competitiveness based on its advanced national standards infrastructure in Korea.

3. Progress of KRISS toward a Leading NMI

3.1. Early Stage (1970s - 1980s)

3.1.1. Key Issues: How to Secure Equipment and Human Resources

The Korean government has not spared resources for government-supported research institutes with a view to strengthen its national scientific and technology capacity and enhance its global competitive edge. For example, the government has constantly funded these efforts through budgetary appropriations and with overseas loans to help the

institutes strengthen their facilities, research equipment, and human resources. Starting as an independent foundation in December 1975, KRISS set out its priority of investment in securing facilities, equipment and human resources. As mentioned above, the institute received USAID loans that the government took out for that purpose.

The USAID loans were used to purchase equipment, and to recruit Korean scientists staying abroad. Starting with only three buildings - Administration, Physics and Mechanics, KRISS's compound has been enlarged to encompass more than 20 buildings by 2012, and has established itself as a world-leading national metrology institute. The continuous efforts of the government led to a fruitful harvest. Out of the US $5 million USAID loans, 60% (i.e., US $3 million) was spent on the purchase of high precision measuring equipment and systems. With a limited budget, the institute had to prioritize its choices of instruments to purchase. Priority was given to the purchase of measuring equipment in the fields of base units such as mass, time, electricity, temperature and luminous intensity.

Three million dollars did not suffice for the institute to carry out R&D activities and procure various types of equipment needed to provide measurement services to industries and others. To relieve some of the burden, the Korean government decided to take out an US $8 million loan from the Asia Development Bank (ADB). While the USAID loans were mainly used to purchase instruments pertaining to the base units of measurement, ADB loans were spent on the establishment of national measurement standards in applied measurement fields with focused on procuring measuring equipment in chemistry, acoustics and materials.

Regarding human resources, the government endeavored to recruit renowned Korean scientists who were staying abroad. When hired, these scientists, before returning to Korea, were sent to the National Bureau of Standards (NBS) for an orientation training program which lasted six months to one year. This preparatory step was to ensure that these elites effectively fulfilled their duties in Korea with the knowledge acquired at the NBS about national measurement standards. The NBS's training was partly designed to train the scientists how to use the equipment to be purchased in Korea and thereby to maximize their productivity by enabling them to effectively use the equipment once it became available. The same approach is taken by KRISS in helping developing countries; as such an approach makes it possible to get higher efficiency and effectiveness of HRD in metrology, in particular. Technical training programs once coupled with donations of the relevant measuring equipment allow the trainees to get better ready to perform measurement services more effectively.

3.1.2. Contribution by the US Government and NBS, the NMI of US

Born on paper in Korea in December 1975, KRISS physically settled into the Daedeok Science Town in March 1978. During the following May, the first group of U.S.-educated Korean scientists, who returned to Korea upon the completion of the NBS orientation, used the new systems and began to provide calibration services. The assistance of the NBS enabled this efficient progress, which ranged from feasibility studies on whether it was necessary or not to found a national metrology institute for economic growth to securing loans. Furthermore, NBS was also directly involved in the implementation process of the loans and offered the Korean government assistance in the construction of buildings and lab facilities, the selection and purchase of the relevant measuring equipment, the training of Korean scientists on measurement standards, and the provision of on-the-job training, and commissioning experts to Korea to offer professional advice. The U.S. government and the NBS made critical contributions to the successful establishment of KRISS as the national metrology institute of Korea through financial and technological support.

Table 3-13 | U.S. Government's Contributions to the Establishment of KRISS

Area of assistance	Details	Remarks
Feasibility Study	Attested to the necessity of KRISS as an independent national metrology institute	Dispatched study teams three times
Loans	Provided USAID loans	US $5 million
Construction	Supported the construction of the administration, physics and mechanics wings of the KRISS	Consulted on the design, based on the use of the loan
Measuring Equipment	Invested US $3 million of USAID loans	List of 705 items w/specifications
Education/ Training for Researchers	Educated the first group of 16 Korean scientists on measurement standards (6 months – 1 year) * Local training of 63 researchers including those hired in Korea	Educated a total of 63 researchers (1976 - 1979)

Source: 20 years of KRISS (1997)

3.1.3. Features of Mission and Organizational Structure of KRISS

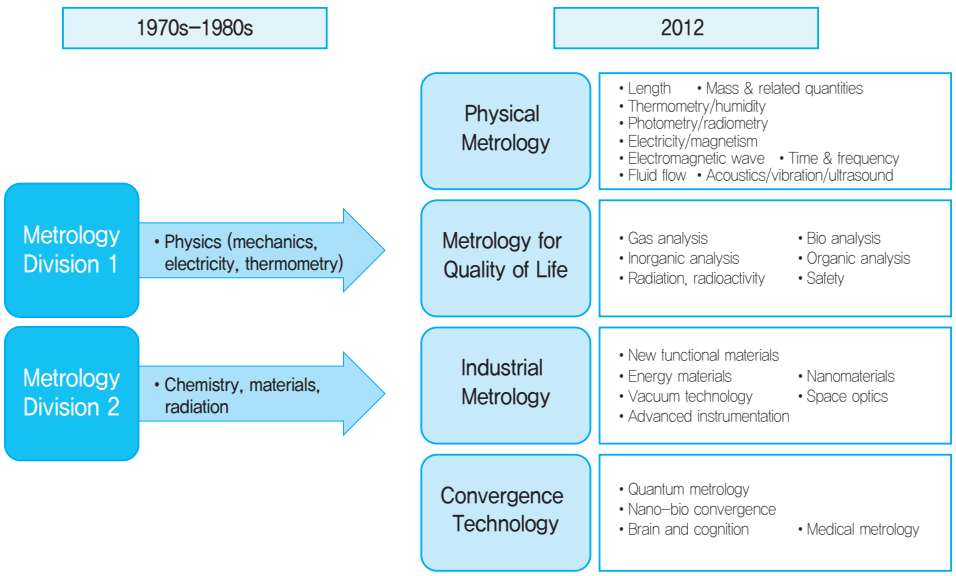
As the national metrology institute of Korea, KRISS has been recognized for its world-class capability in metrology. It is to be noted that KRISS has had a wide scope of R&D and services since its beginning that it covers almost all areas of metrology such as metrology in chemistry and materials as well as fundamental physical measurements. In almost all of

the developing countries, however, the work scope of their NMIs is much too narrow to be focused mainly on a few fields in physical measurements. To make things worse, the mission of metrology has been taken over by different laboratories in some countries, which causes lower efficiency and productivity in the operation of national standards system. The greatest contributor to the foundation of KRISS was the NBS (currently the NIST), the NMI of the US. It has been carrying out R&D activities in multidisciplinary themes including all areas of metrology. This structure of NBS became a model for KRISS. The close partnership with the NBS from early stage enabled KRISS to get started with its mission covering all areas of metrology, which has brought KRISS to be recognized as one of the leaders in such wide areas of metrology today.

In this respect, it is recommended that developing countries have one single NMI whose mission is comprehensive to the extent that it covers metrology in chemistry, materials, radiation as well as physics. For that purpose, it is necessary to set up and implement strategies so that the NMI could have, from the beginning, an organizational structure and secure human resources as appropriate to accommodate such a comprehensive mission in metrology.

In addition, borrowing loans from overseas might also be taken into account as a strategic approach to make up for its shortage of financial resources. It is highly recommended to find as many opportunities for loans and donations as possible from international organizations and advanced countries. To carry out a large-scale project like the establishment of a government-run institute, in particular, it might be wise to use long-term loans with low interest rates. It may also be helpful to form close partnerships with advanced NMIs who have ample experience in assisting developing countries.

Table 3-14 | Organizational Structures of KRISS in 1978 and 2012



Source: 20 years of KRISS (1997), Overview of KRISS, NMI of Korea (2012)

3.2. Growth Stage (1980s - 1990s)

3.2.1. Globalization of R&D Capability

Launching its calibration services in 1979, KRISS began to pursuing boosting its research capacity to the global level from the mid-1980s. The institute started participating in joint research projects with the institutes of major developed countries. In carrying out these programs, the Korean government took up important roles as a decision-maker or sponsor. Among others, the government succeeded in continually securing financial assistance and resources as a means to overcome the financial limits it was faced with. In the 1980s, the government arranged a loan from the Japanese OECF[21] to get it invested in the promotion of the R&D capacity of KRISS. The OECF loans between 1986 and 1987 amounted to US $6 million, which was mostly spent on the purchase of state-of-the-art measuring equipment for KRISS, along with training programs for its researchers.

The OECF loans differed from other loans. The OECF loans focused on the purchase of advanced equipment conducive to the enhancement of the capability of KRISS in already-established measurement standards areas. Therefore, the targeted equipment cost

21. OECF: Overseas Economic Cooperation Fund.

more, but operated better. The OECF loans helped KRISS to upgrade its capacity to a global level, offering an opportunity to augment the equipment pertaining to the radiation and flow measurement area, and to significantly improve its capabilities in the relevant national measurement standards. Purchasing an electron microscope, the institute began analyzing materials properties, and paved the way for the establishment of a new R&D unit of Materials Properties Evaluation Center at KRISS. With its upgraded functions and sophisticated capabilities, the advanced equipment enabled KRISS to advance to a whole new level.

3.2.2. Joining Consultative Committees of CIPM

The Convention of the Meter is the diplomatic treaty providing the basis of international agreement on units of measurements. Adopted in 1875, the Convention of the Meter was to lay scientific and technological foundations to secure reliability in international economic activities, as the Industrial Revolution sparked and enormously expanded industrial production and international trade. The Convention created the International Bureau (BIPM)[22] on the outskirts of Paris, an intergovernmental organization under the authority of the General Conference on Weights and Measures (CGPM). The BIPM works under the supervision of the International Committee for Weights and Measures (CIPM). The principal task of the CIPM is to promote world-wide uniformity in units of measurement and it does this by direct action or by submitting draft resolutions to the CGPM.

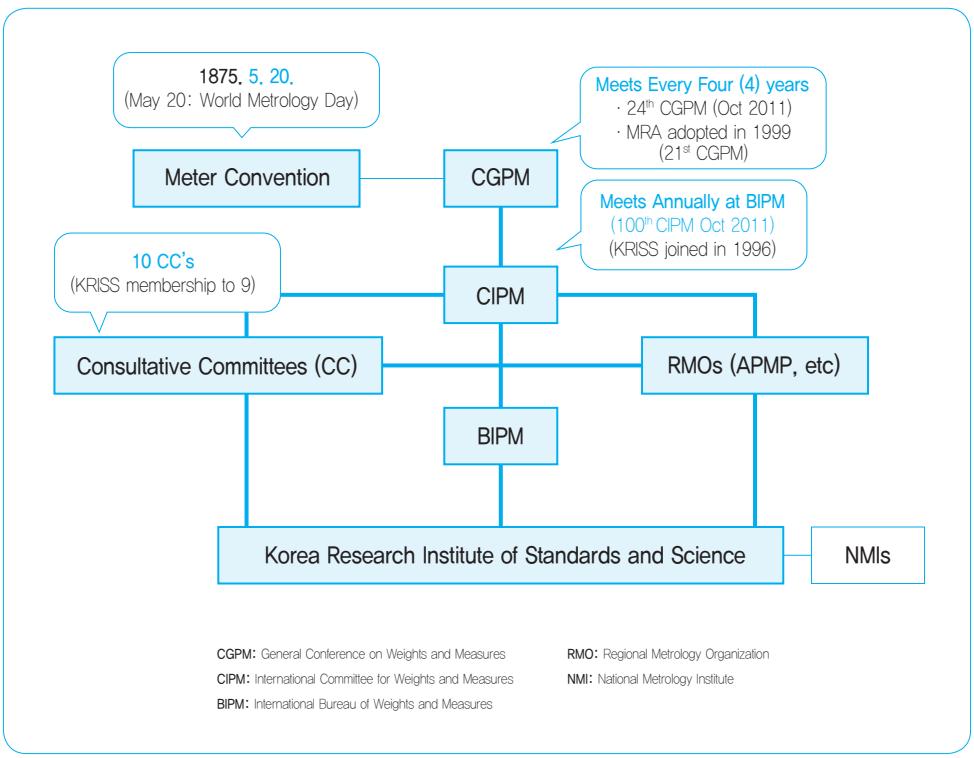
Consisting of eighteen metrology specialists from around the world, the CIPM operates ten consultative committees (CC). Nine of them deal with international issues in specific areas of metrology like Acoustics, Ultrasound and vibration (CCAUV); Electricity and Magnetism (CCEM); Length (CCL); Mass and Related Quantities (CCM); Photometry and Radiometry (CCPR); Amount of Substance - Metrology in Chemistry (CCQM); Ionizing Radiation (CCRI); Thermometry (CCT); Time and Frequency (CCTF), while the remaining one works on issues concerning the international system of units (SI). Obtaining a membership of each CC requires screening and approval by the CC and the CIPM of the candidate institute's capability in the subject field of metrology. Founded in 1975, KRISS acquired membership in the three CCs in 1988, including CCL, CCT, and CCPR. It has been rare so far that an institute from a developing country obtains the membership of three CCs at a time only within ten-plus years after its foundation. This achievement implies that KRISS's capability in metrology gained global recognition very quickly, keeping in good pace with Korea's economic growth.

22. BIPM: International Bureau of Weights and Measures www.bipm.org

The CIPM and the BIPM remain as the global authority in the fields of national measurement standards and metrology even in the 21st century. In order to secure advanced capability in metrology, it is a prerequisite for any NMI to promote active participation in both the CIPM and the BIPM activities. It provides the participating NMIs with opportunities to learn up-to-date information and trends of R&D in metrology and to set up and implement strategies to effectively respond to such trends. This is true for both advanced and developing countries. The following figure illustrates the scheme of global metrology community under the Convention of the Meter.

a. Structure of International Metrology Community under the Meter Convention

Figure 3-6 | Scheme of the Global Metrology Community under the Meter Convention



Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

b. Brief Overview of the General Conference on Weights and Measures (CGPM)

o History

- The CGPM (Conférence Générale des Poids et Mesures) was authorized by the Meter Convention, which had been adopted by 17 nations during the final session of the diplomatic Conference of the Meter held in Paris on May 20, 1875.
- Agreed by the governments of different nations, the Meter Convention was conceived to guarantee international uniformity in units of measurements, and led to the establishment of the BIPM (Bureau International des Poids et Mesures). As of October 2012, a total of 56 countries, including most industrially advanced countries, adopted the Convention (Upon the inclusion of its 37 associate members, the CGPM stands as the largest international metrology organization with 93 member states).
- The BIPM is operated under the supervision of the CIPM (Comité International des Poids et Mesures). The CIPM, in turn, is directed by the CGPM consisting of representatives of the member states of the Meter Convention (Article 3).
- CGPM is the highest decision-making body in global metrology community, where the representatives of member states of the Meter Convention discuss and find solutions to issues in metrology.

o Major tasks

The General Conference receives the report of the CIPM on its activities; it discusses and examines the arrangements required to ensure the propagation and improvement of the International System of Units (SI); it endorses the results of new fundamental metrological determinations and various scientific resolutions of international scope; and it decides all major issues concerning the organization and development of the BIPM, including the donation (membership fee) of the members. The CGPM meets in Paris usually once every four years; the 24th meeting was held from 17-21 October 2011.

- Republic of Korea's participation in the CGPM
  - Joined the Convention of the Meter on July 28, 1959, Korea began to participate in the CGPM at its 11th session held in October 1960; As the NMI of Korea, KRISS is representing Korea to the CGPM.

c. Brief Overview of the International Bureau of Weights and Measures (BIPM)

The BIPM was created up by the Metre Convention. The BIPM has its headquarters near Paris, France in the ground of Pavillon de Breteuil. It is financed jointly by its Member States, and it operates under the exclusive supervision of the CIPM. It has an international staff of over 70 and its budget for FY 2013 is over ten million euros.

o Major tasks

- Its mandate is to provide the basis for a single, coherent system of measurements throughout the world, traceable to the International System of Units (SI). This task takes many forms, from the direct dissemination of units (as in the case of mass and time) to coordination through international comparisons of national measurement standards (as in electricity and ionizing radiation);
- To establish fundamental standards and reference scales for the measurement of a number of principal physical quantities and maintain the international prototypes;
- To carry out comparisons of national measurement standards maintained by its member states;
- To ensure the coordination of the development of appropriate measurement techniques;
- To carry out and coordinate measurements of the fundamental physical constants relevant to these activities.

d. Brief Overview of the International Committee for Weights and Measures (CIPM)

o Membership and meetings

The CIPM is made up of eighteen individuals, each from a different Member State under the Meter Convention. Its principal task is to promote world-wide uniformity in units of measurement and it does this by direct action or by submitting draft resolutions to the General Conference (CGPM). The CIPM meets annually at the BIPM and, among other matters, discusses reports presented to it by its Consultative Committees. Reports of the meetings of the CGPM, the CIPM, and all the Consultative Committees, are published by the BIPM.

o Functions and activities

- Functioning as a standing committee of the CGPM, the CIPM indeed plays a key role in its worldwide metrological activities;
- Supervising research and other activities of the BIPM upon the relegation of authority from the CGPM;
- Supervising and receiving reports from 10 consultative committees on how major activities have been performed in each area;
- Submitting agendas to the CGPM regarding its decisions based on the matters determined by it; and

- Studying the future needs of metrology and promoting international collaborations among member NMIs.

o Topical issues

- Coordinating major comparative activities in accordance with the CIPM-MRA, selecting relevant fields for measurement activities, approving the produced results, and determining whether to publish them;
- Identifying and recommending the necessity of R&D in a new area of measurement standards;
- Promoting research and collaborations on measurement standards pertaining to the emerging areas, such as nanotechnology, bio-science, medicine, food, the environment, and materials; and
- Studying on the potential redefinitions of the SI units of mass, electric current, thermometry, and amount of substance.

o Criteria for membership of the CIPM

The principles currently followed by the bureau and the CIPM in making elections are as follows:

- Persons proposed for election are always of a high scientific standing and have experience which qualifies them to take part in the work of the CIPM.
- In accordance with the discussion at the 17th CGPM, the CIPM should – in general – take all possible steps to assure itself that each of its members is acceptable to his/her government at the time of provisional election. The bureau encourages the members of the CIPM to continue to maintain this relationship throughout their membership of the CIPM.
- Care is taken to ensure an appropriate spread of scientific disciplines.
- Members should be prepared to make a significant contribution of time and effort to the work of the Meter Convention.
- Efforts are made to maintain a reasonable balance between regions and also to ensure the presence of a small number of members from those States paying the minimum contribution.
- Candidates from Member States three of more years in areas with their payments to the BIPM are not considered for election.
- One member of the CIPM is always of French nationality. This recognizes the role of France as the originator of the metric system and the depository of the Meter Convention.

• One member comes from each State paying the maximum contribution.

• Particular consideration is given to candidates from States which pay a contribution of 2 % or more.

o CIPM Membership distribution by region (18 members as of October 2012)

• EURAMET (8): Germany, the Netherlands, UK, Denmark, France, Italy, Switzerland, and Turkey

• COOMET (1): Russia

• APMP (4): South Korea, China, Japan, and Australia

• SIM (4): Canada, US, Mexico, and Argentina

• SADCMET (1): South Africa

o Procedure of election and re-election of the CIPM members

• Half of the members are (9 members) reappointed at the general meeting held every four years;

• Priority is given to the member selected due to a vacancy after the previous general meeting;

• Discretionary power is given to the CIPM in choosing the other members;

• Opportunity of confidence vote is given to member states' representatives; and

• Filling a vacancy: Votes cast, in-person or via mail, by committee members on the candidates submitted to CIPM

e. Brief Overview of the CIPM Consultative Committees

Over the years, the CIPM has set up a number of Consultative Committees, which bring together the world's experts in their specified fields as advisors on scientific and technical matters. Among the tasks of these Committees are the detailed considerations of advances in physics that directly influence metrology, the preparation of Recommendations for discussion at the CIPM, the identification, planning and execution of key comparisons of national measurement standards, and the provision of advice to the CIPM on the scientific work done in the laboratories of the BIPM.

The Committees meet at irregular intervals. The president of each Committee is appointed by, and is normally a member of, the CIPM. The Members (institutions and other bodies) of the Committees are agreed upon by the CIPM, and Members then send delegates of their choice.

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

[Note]

※ Participation in the consultative committees: Committee members are mostly from the NMIs of developed countries who have advanced expertise in the subject metrology areas. Thus, it is very important to secure the relevant technical capability in order to take the leading role in each committee.

※ Participation of Korea (i.e., KRISS): Currently, KRISS participates in the activities of 9 consultative committees with a full membership (except CCU).

3.3. Take-off Stage (1990s - 2000s)

3.3.1. Expanding New Partnership with the NMIs of Germany and Japan

In retrospect, KRISS received help from invaluable partners during different stages of its growth. As mentioned above, the USAID and the NBS played a critical role in the establishment of the institute and its expansion with their financial and technological support. While making continuous efforts to promote its measurement capacity (e.g. taking out ADB and OECF loans), the institute met invaluable partners such as the national metrology institutes in Germany and Japan. The German PTB and the Japanese NRLM (presently NMIJ) made significant contributions to KRISS's advance to its present level of global recognition.

3.3.2. Collaboration with Germany

Germany has made great contributions to the growth of KRISS through technical cooperation projects between the two countries. Germany, acting through its NMI of PTB,[23] provided a total of 7.24 million DM of official development assistance to Korea over three stages during a 12-year period from the late 1970s to the mid-1990s. The project was to help Korea improve its industrial measurement capabilities by advancing the capability of KRISS. Specifically, the PTB donated 106 pieces of precision measuring equipment, along with technical advice by dispatching 43 German professional experts in metrology, and inviting 44 researchers of KRISS for their technical training in Germany.

The German government and the PTB should be much appreciated as the project has made significant contributions to promoting the capability of KRISS in terms of human resources and advanced measuring equipment. They also played a key role in assisting KRISS to acquire full membership of three consultative committees of the CIPM in 1988 and another three in 1992. Thanks to the Korea-Germany technical cooperation, KRISS could establish national measurement standards in wider areas, which in turn enabled KRISS to enhance its capabilities in industrial measurements, contributing to the sustainable growth of Korean industries. In 1988, the Korean government awarded an Order of Civil Merits to Professor Dr. Dieter Kind, the then President of PTB, to express its appreciation to such excellent contributions made by the PTB and the German government.

3.3.3. Collaboration with Japan

In the 1990s, Korea and Japan were expanding their collaborative programs in various areas including science and technology. One such program was a project to establish a materials property evaluation center, where major national metrology and materials institutes of both countries participated.

The project was agreed in 1990 at a Korea-Japan summit. Using the funds provided by the JICA (Japan International Cooperation Agency), the main organization in charge of official development assistance in Japan, the two countries successfully worked out the specific details for the project during the JICA research team's two separate visits to Korea in 1991. The project was launched in October 1991 and was successfully implemented over a five-year period until its completion in October 1996. Details of the project included providing financial aid for the purchase of cutting-edge measuring equipment (100 items/1 billion yen) as required to study new material properties; the dispatching of Japanese specialists to Korea (46 professionals/46 man-weeks); and the training of KRISS researchers

23. PTB (Physikalisch-Technische Bundesanstalt): The national metrology institute of Germany, well known as the world's first of its kind.

in Japanese institutes (21 professionals/105 man-months). KRISS could successfully implement this project thanks to the fact that KRISS had expanded its capabilities in not only physics but also in metrology, chemistry and materials science since the beginning by continuously securing professionals and advanced measuring equipment. It has contributed to the strengthening of its capabilities in almost all relevant areas of metrology. Areas of metrology. The partners of this project was National Institute for Research in Inorganic Materials (NIRIM), Japan Fine Ceramics Center (JFCC), National Research Institute of Metals (NRIM), Electrotechnical Laboratory (ETL), and RIKEN since this project was designed to expand KRISS's capabilities in characterization of materials properties.

The Japanese national metrology institute, NRLM[24] did not participate in the project as a partner at that time. However, NRLM continuously promoted the scope of cooperative activities with KRISS concerning national measurement standards. Both organizations have continued their efforts to develop collaboration opportunities through the annual Korea-Japan Metrology and Measurement Standards Cooperative Committee meetings, which are held to the present day to consolidate their ties and cooperation.

During this period, KRISS provided its service as a founding member of the CCQM (Consultative Committee for Amount of Substance - Metrology in Chemistry) of the CIPM in 1994. The contribution symbolized the institute's efforts to secure professionals in the area of metrology in chemistry, and its continuous strategic efforts for expanding its R&D capabilities. By this time, KRISS had already established itself as an internationally recognized national metrology institute in physical measurement standards, and was subsequently gaining global recognition in the fields of materials and chemical measurement standards as well.

3.3.4. Korean Government's Support of KRISS

KRISS became a representative national metrology institute with the help of U.S. loans in the beginning, and thanks to the official development assistance and loans from abroad. The Korean government provided aggressive support to KRISS, including two IBRD loans that helped promote the nation's capacities in metrology. The first IBRD loan of US $6 million was invested in purchasing the cutting-edge measuring equipment of KRISS to advance into new areas such as laser technology, measurements in extreme environment, surface analysis, and failure prevention technologies. The second loan of US $10 million was spent on the procurement of equipment for chemical analysis to augment the environmental measurement capabilities. Close cooperation between the Korean government and KRISS

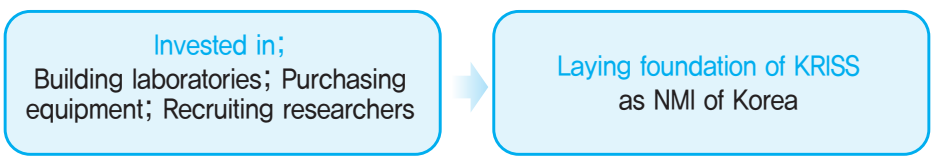
24. National Research Laboratory of Metrology (NRLM): The Japanese national metrology institute until April 2011; it was then renamed NMIJ (National Metrology Institute of Japan), incorporating other metrology-related institutes.

fueled the promotion of a customer-oriented service paradigm and the successful expansion of capabilities in wide areas of metrology. The strategic support of the Korean government that was accompanying continued financial support of KRISS in a timely manner made it possible for Korea's capability in metrology to receive global recognition. <Table 3-15> sums up the various loan projects, along with donations from German and Japanese governments, which were invested in promoting the capabilities of KRISS.

Table 3-15 | Summary of Loan and ODA Projects Offered to KRISS

Resources	Main Project Activities Invested	Amount (US $)
USAID (1975-1980)	· Construction, Equipment, · Orientation of researchers	5,000,000
ADB (1979-1981)	· Equipment	8,000,000
OECF (1986-1987)	· Equipment, Training	6,000,000
IBRD (1990-1991)	· Equipment	6,000,000
IBRD (1994-1995)	· Equipment	10,000,000
* PTB (1979-1996)	· Equipment, Training, Advice	1,952,000
* JICA (1991-1996)	· Equipment, Training, Advice	8,401,000

* donation for technical cooperation



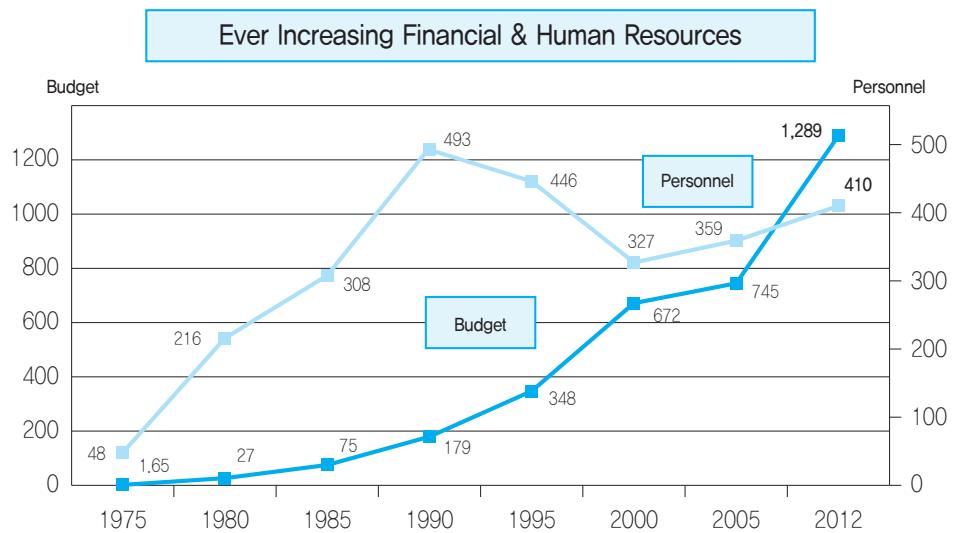
Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

The Korean government funneled into KRISS US $35 million in loans and official development assistance (ODA) in the sum of US $10 million to construct research facilities, upgrade measuring equipment, and foster qualified human resources in metrology. This support is deemed to have contributed to the advancement of KRISS's world-leading metrological capabilities and to the growth of the measurement capacity of Korean industry.

Furthermore, the Korean government did not spare its budget and support. These factors were essential to the successful operation of KRISS. From 1975 to 2012, the annual budget scale for KRISS was never downsized amidst instances of global economic turbulences such as the foreign currency crisis in 1997, thus underpinning the sustainable economic growth of Korea in the long run. This fact attests to how great an insight the Korean government had into its own responsibilities and how strong its commitment was to the execution of its

policies. During this era, the Framework Act on National Standards was enacted to grant legal authority to KRISS, and formally designated KRISS as the national metrology institute (NMI) of Korea. The Act served as a significant step forward for further advancement of national standards infrastructure in Korea, as part of the effort to affirm and implement the government's constitutional duties. The Act defines the roles and responsibilities to be carried out by the government and relevant organizations in order to improve the national standards system of Korea, such as the establishment of the basic plan of national standards system that is to be renewed every five years and the operation of national standard council.

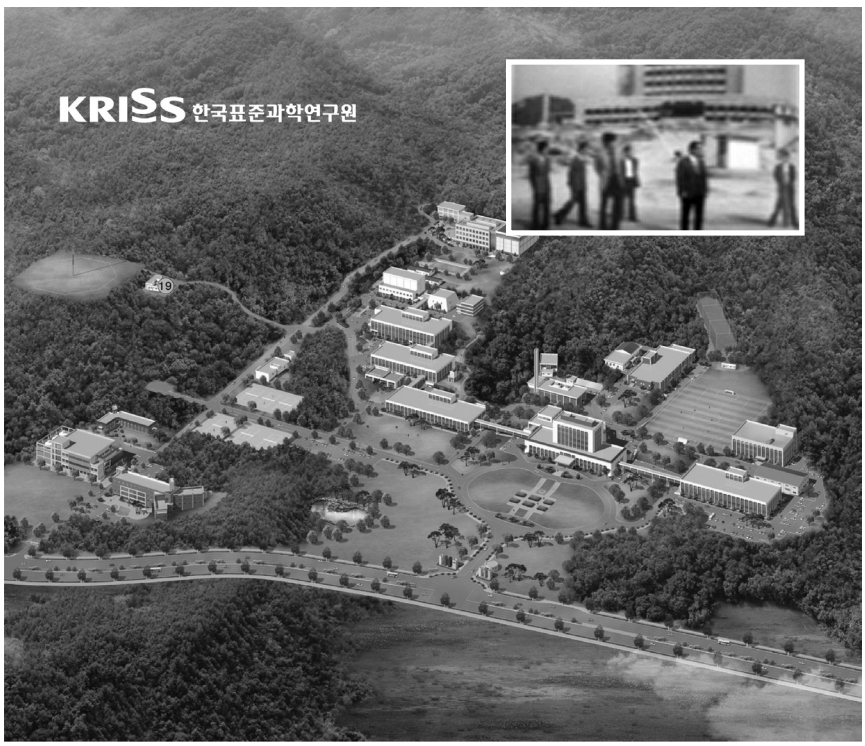
Table 3-16 | Trends of KRISS Budgets and Human Resources (1975-2012)



ACCOUNT	'75	'80	'85	'90	'95	'00	'05	'12
GNI per capita (US $)	607	1,660	2,355	6,303	11,735	11,292	17,531	20,759
Budget (100 Mil Won)	1.65	26.5	75.1	179.4	347.5	671.7	744.9	1,289
Personnwl (Permanent)	48	216	308	493	446	327	359	410

Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

Figure 3-7 | Map of KRISS Campus



* Small frame: early stage of the construction of KRISS
Source: KRISS, Overview of KRISS, NMI of Korea (2012), 20 years of KRISS (1997)

3.4. Maturing Stage (2000s - present)

3.4.1. Strategic Development of Global Partnerships in Metrology

Since the dawn of the New Millennium, KRISS has grown to the status of a world leader, and now receives numerous requests for cooperation and assistance from partners around the world. As a result, KRISS succeeded in forming a global network of cooperation. For promoting its global partnerships in international metrology community, KRISS set up its strategic approaches by classifying its partners into three groups: international metrology organizations, advanced metrology institutes, and the NMIs of developing countries. This is to promote its global partnership activities to be more effective so as to share the benefits of shared efforts with those partners. The following table shows the featured strategies of the global partnerships of KRISS tailored for each partner group.

Table 3-17 | Strategic Approaches of the Global Partnerships of KRISS

Items	Strategic Objectives
○ Philosophy of global partnerships of KRISS	■ To share the fruits of shared efforts with partners in metrology by being a most friendly and productive partner in metrology
○ Strategy for collaboration with international metrology organizations	■ To promote global leadership in global metrology organizations such as the CIPM, IMEKO, and APMP
○ Strategy for collaboration with advanced countries	■ To expand strategic R&D collaborations on global issues such as energy, climate change, safety, and the environment
○ Strategy for collaboration with developing countries	■ To provide programs of HRD in metrology and to share knowledge and experience of KRISS in advancing its capability in metrology

Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

As a result, KRISS has taken up major posts serving as chair of major international metrology organizations such as the APMP, CIPM and the IMKEO. To take the leadership in the global community, there should be harmonized efforts made by individuals and the institute. First of all, individual researchers should be recognized of their excellent achievements in the subject field of metrology. Also, they need to be cultivated with the qualifications required to be leaders in the global metrology community. Moreover, the institute should provide support for potential leaders so that they can continuously participate in the activities of international metrology organizations.

To boost cooperation with developed countries, KRISS set forth its goal of strengthening strategic cooperation in R&D activities. Particularly, it has beefed up joint studies with national metrology institutes of advanced countries to develop technologies concerning the environment, health, safety and food for sustainable global growth. In this context, it is important to specialize in the areas in which its partners show strength, such as cooperation in nanotechnology with the US NIST, the frequency standards of the next generation with the Japanese NMIJ, medical instrumentation with the German PTB, and food safety systems with the British LGC. It is also necessary to enlarge the scope of cooperation and research by expanding partnership with academia and research laboratories as well who have outstanding capabliities in the relevant R&D activities.

KRISS approaches cooperation with the developing world with the notion of sharing in mind. As discussed above, Korea received various forms of support from the advanced world. Now, it is time for Korea to pay back the favor by helping countries in need just as

it had once been decades ago. Indeed, Korea joined the OECD's Development Assistance Committee in 2010 and has accelerated its engagement and investment in ODA activities across wide sectors including science and technology. Metrology has been regarded as having great potential to be Korea's representative ODA program in science and technology. It is because metrology serves as the core infrastructure underpinning the sustainable economic growth of developing countries.

3.4.2. Promotion of Strategic R&D Capabilities

In addition to its unique mission as the national metrology institute of Korea, KRISS has been engaged in developing cutting-edge measurement technologies as one of the government-supported research institutes of Korea. KRISS's excellent capability of R&D on precision measurements is laying the basis on which the national measurement standards of Korea can gain global competitiveness. In this context, KRISS has set up and implemented its mid- and long-term strategic development plans, focused on promoting its performance in R&D activities. While carrying out its major laboratory programs of metrology in physics, chemistry, and materials, KRISS has also been operating a few more strategic R&D programs as listed below.

Table 3-18 | Strategic R&D Programs of KRISS

Programs	Characteristics
○ National Agenda Program (NAP)	■ Government's initiative of S&T research ■ To provide solutions for national/global agenda items such as climate change, safety, energy, and the environment
○ World Class Laboratory (WCL)	■ To pursue higher performance of R&D focused on cutting-edge areas, such as brain cognition, nano-bio convergence, and space optics ■ Large scale of funding for a long project period (up to nine years)
○ Creative Research Program (CRP)	■ To encourage collaboration among young scientists ■ To be focused on subjects of high- risk but of high potential of impact ■ In pursuit of novel measurement technologies, leading to new definitions/new principles of measurements

Source: KRISS, Overview of KRISS, NMI of Korea (2012)

3.4.3. Strengthening Global Partnerships

The first step of a mutually beneficial partnership begins with laying a foundation of cooperative relationships between the institutes. KRISS has been committed to entering into partnerships with the metrology institutes and research organizations of developing countries as well as those advanced countries. This effort resulted in the execution of memorandums of understanding and the formation of partnerships with about 50 institutes around the world. Partnership may facilitate a variety of cooperative activities such as joint research, exchanges of experts, seminars, information, and international comparison. Memorandums of understanding must be considered not as an objective but as a means. Therefore, in this sense, it is necessary to have deep understanding of the partners in terms of competence in metrology and needs of cooperation for the successful implementation of collaborative projects.

In the meantime, cooperation among neighboring partners is economically beneficial and may have a higher potential of success. Korea is located in Northeast Asia with neighboring countries of China, Japan, and Chinese Taipei. It is the region in which highly competent players in metrology participate in cooperative activities. KRISS has established close partnerships with the NMIs of these economies. With China and Japan, the institute collaborates in research activities, and exchanges information about management. They also exchange opinions on current issues in the international metrology community trying to deduce solutions so that they may cope jointly with related developments. In this way, a regional partnership's greatest merit comes from the ability to share resources and to share the findings of collaborative R&D activities.

An exemplary case is the Asian Collaboration on Reference Materials (ACRM)[25] joined by the national metrology institutes of Korea, China and Japan. Launched upon a proposal by KRISS in 2004, this program has significantly contributed to the advancement of the R&D of Asian countries' capacities pertaining to reference materials, a field led by the U.S. and the EU. At the same time, it allows the participating NMIs to enjoy higher efficiency of resources through joint investments of human and physical resources in the development of certified reference materials (CRMs). The partners hold annual joint seminars for the cooperative development of CRMs focused on four specific areas of common interest: food, gas analysis, hazardous materials, and biomaterials, while boosting cooperation in their activities around international metrology organizations. It is encouraging to expand regional cooperation in science and technology as such regional collaboration has a ripple effect on spreading close partnerships around the globe. The NMIs of Korea, China, Japan, and

25. A cooperative program of developing of certified reference materials, proposed by KRISS in 2004 with the participation of national metrology institutes of three neighboring countries: Korea, China and Japan.

Chinese Taipei have recently launched a new cooperative program in the field of materials measurements.

3.4.4. Customer-oriented Services: Close Network with Customers

The return on investment in national measurement standards can scarcely be achieved in a day. Its benefits are intangible and its performance difficult to measure. Nevertheless, the Korean government has been providing financial support for the operation of its national metrology institute. As [Figure 3-9] (page 93) illustrates, it was in 1993, almost 20 years after its foundation, that the benefits created by KRISS came into balance with the government's annual investment in KRISS. Twenty years of investment has enabled KRISS to create benefits and performance greater than the investment made by the government at that time, and this trend in benefits and performance has continued the same to date.

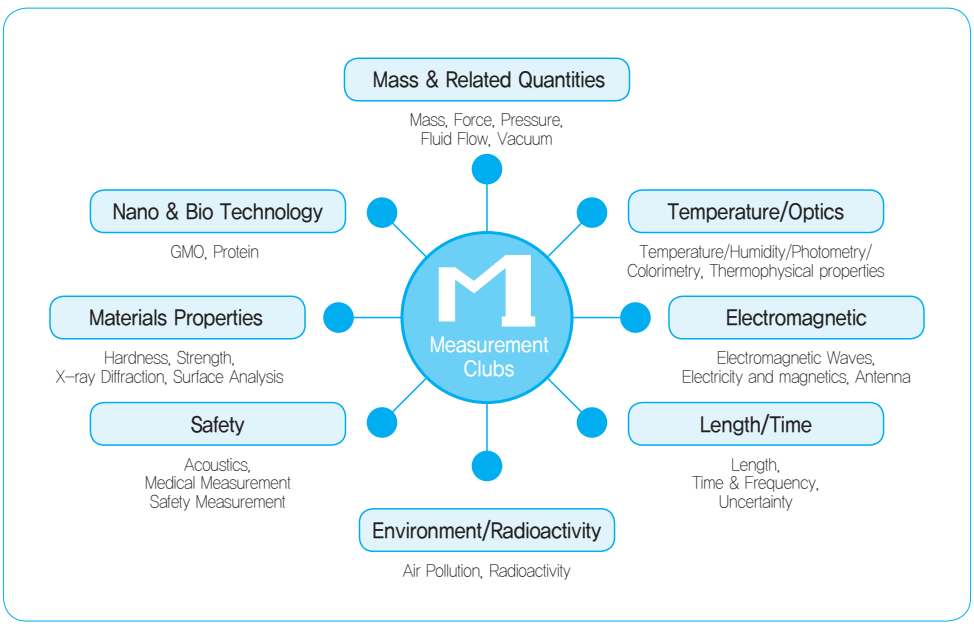
The performance of the national metrology institute (NMI) should be made available to its customers of industry, government and its agencies, academia, and laboratories. Furthermore, delivering services in an effective manner is a prerequisite to supply what customers expect from KRISS, the NMI of Korea. In the early stage of Korea's industrialization, manufacturers were the priority customers of metrology. As the Korean economy was advancing, the scope of its customers grew wider across different sectors creating new customers from emerging areas. The government is one of the key customers as well as the most significant sponsor of metrology. The core mission of KRISS, as the national metrology institute of Korea, was and has been to establish national measurement standards of international traceability. More important is to make available the performance to be used by its customers through various means of close and effective networking with the wide range of its customers. KRISS has been operating a portfolio of networking to better serve the needs of its customers. A couple of unique programs that KRISS operates for customer service are the "Measurement Club program" and the "Home Doctor Program," brief descriptions of which are provided below.

a. Measurement Club Program

With the purpose of learning more clearly about the technical hurdles faced by its customers, and then finding substantial solutions capable of clearing such hurdles, KRISS has been operating its measurement clubs since 2004. Originally, this idea was borrowed from the metrology club operated by NPL, UK. Participants are from customers of KRISS including industry, governmental agencies, academia, and calibration and testing laboratories. At present, there are 25 measurement clubs where some 6,000 members are working together. Each club is led by professional metrologists of KRISS who deal with individual specific areas of fundamental physical measurements of mass, temperature, optics, electromagnetics, length, and time. The horizon of the measurement clubs has been

expanded to accommodate new emerging areas of measurements, such as chemistry, safety, materials, nano-bio, and the environment. Each club meets on- and off-line, and KRISS organizes an annual workshop at KRISS where all of the individual clubs get together at the campus of KRISS. Tutorials are offered by selected clubs to meet the needs of customers mostly from academia and industry who need more practical knowledge and techniques required on site. In 2012, five tutorials were offered in the fields of hardness, gas analysis, surface analysis, and x-ray diffraction, and more than 200 participants joined.

Figure 3-8 | Measurement Clubs of KRISS (as of Dec 2012)



Source: Myungsoo Kim, How NMIs benefit global enterprises (2009)

b. Home Doctor Program

Just like medical home doctors who take care of individual patients through in-depth services, the Home Doctor Program of KRISS seeks to take care of small and medium-sized industries by providing custom-tailored technical services. One or a couple of professional experts of KRISS are assigned to each customer. They visit the customers four to six times a year, offering technical advice and assistance on site by finding solutions to break though the bottlenecks their customers are facing. Currently there are 40 customers who are enjoying the benefits of this program. Networking takes place in the laboratories of KRISS as well. Customers are given the opportunity to come to KRISS to carry out experiments under the supervision of their home doctors using the advanced measuring facilities at the

laboratories of KRISS. Beneficiaries are from industries that require the advanced services of KRISS in such areas as mechanical measurements, electrical and magnetic measurements, semiconductor manufacturing devices, materials evaluation, and optical measurements.

After less than five years of its operation, though, the KRISS Home Doctor Program began to write success stories in different forms of performance. They include higher sales, improvements of the quality management system, the creation of new jobs, the commercialization of equipment, and the development of national R&D projects, just to name a few.

Table 3-19 | Outline of the Home-Doctor Program of KRISS (as of Dec 2012)

One expert for one business

Visiting customer companies (4–6 times/year)
– To find technical problems and to provide consulting on site

Inviting customer companies to KRISS
– To conduct experiments with KRISS facilities

Providing education/training for customer companies

On–line communication offering recent technical news

40 KRISS experts
Serving 40 companies

Major fields	Consulting technologies
• Mechanical measurements	• Ultrasonic flowmeter, Thermometer, Laser technology for length measurement
• Electricity & magnetism	• Current transformer, Oscilloscope, Switches for rail–road system, Amplifier for audio system, Hard disk driver, Antenna
• Semiconductor manufacturing facility	• Vacuum pump, Chemical vapor pressure, Precursor materials
• Material evaluation • Optics	• Non–destructive test, Bridge safety test, Concrete hardness test • Optical photometer

Source: KRISS, Overview of KRISS, NMI of Korea (2012)

4. Analysis of the Economic Impact of KRISS

4.1. Enabling Infrastructure for the Industrial Development of Korea

Measurement standards are the bedrock supporting the domain of standardization and conformity assessment. They serve as the most fundamental infrastructure of science and

technology and enable the economic activities of people to work properly. Korea has set up testing laboratories whenever needed in the process of promoting the national economy or developing a specific industry.

The list of testing organizations established in the 1960s, a period of witnessing an export boom, is shown in <Table 3-20> below. It shows that a test organization was introduced whenever the nation's core industrial products were newly developed. As was noted earlier, the Korean government established KRISS in 1975 to provide services for national measurement standards because of the need to support the testing laboratories which were expanded as the export volume of Korea was constantly rising.

Table 3-20 | Establishment of Selected Testing Organizations in Korea

Name	Year	Remarks
Korea Textile Inspection & Test Institute (KOTITI)	1964	Founded as a textile text lab under Spinners & Wears Association of Korea (1961); renamed Korea Textile Technology Promotion Center (in 1981); KOTITI (1990)
Korea Apparel Testing Research Institute (KATRI)	1969	Installed as a test dept., in Korea Knitting Industry Federation (1964); Knit Quality Inspection Institute (1979) ; KNITI (in 1981); KATRI (1994);
FITI Testing and Research Institute	1965	Test dept. of Korea Textile Industry Cooperative Association (1964); Korea Fabric Inspection & Testing Institute (1969); Korea Fabric & Garment Inspection Testing Institute (1979); Korea Yarn & Fabric Inspection Testing Institute (1981); FITI Testing and Research Institute (FITI, 1994); FITI Testing and Research Institute (2005)
Korea Testing and Research Institute (KTR)	1969	Korea Rubber Products Testing and Inspection Institute (1969); Korean Chemical Products Testing and Inspection Institute (1971); Korean Chemical and Metals Testing and Inspection Institute (17979); Korea Institute of Chemical Analysis, Testing and Inspection by incorporating Korea Mining Product Testing & Inspection Institute (1980); Korean Chemical Inspection Test Institute (1988); KOTRIC (1994); KTR (2006); Incorporating Korea Electromagnetic Engineering Institute (2010)
EMI Research Institute (ERI)	1997	Korea Electromagnetic Engineering Institute (2003); merged with Korea Testing and Research Institute (KTR, 2010)
Korea Petrochemical Testing Foundation	1969	Korea Petrochemical Testing Institute (1984), Meter and Petrochemical Testing and Research Institute (MPI, 1991); Korea Testing Certification (KTC, 2010) by incorporating Korea Electric Testing Institute (KETI)

Name	Year	Remarks
Korea Testing Certification (KTC)	1970	Korea Electric Inspection Institute (1978); Korea Electric Testing Institute (KETI in 1994); Korea Testing Certification (KTC, 2010)
Korea Environment Merchandise Testing Institute (KEMTI)	1971	Korea Inspection Institute of Exporting Merchandise (1971); Korea Merchandise Inspection and Test Institute (1983); Korea Environment Merchandise Testing Institute (KEMTI, 2010) to be merged with KICM to be KCL (2010)
Korea Institute of Construction Materials(KICM)	1994	Merged with Korea Environment & Merchandise Testing Institute (KEMTI) to be the Korea Conformity Laboratories (KCL, 2010)

Source: Gun-Woong Bahng, Economic impact of metrology and NMI (2012)

The test reports issued by these many testing organizations in Korea are internationally accepted in the 21st century global economic environment because KRISS has established and disseminated national measurement standards that are internationally recognized.

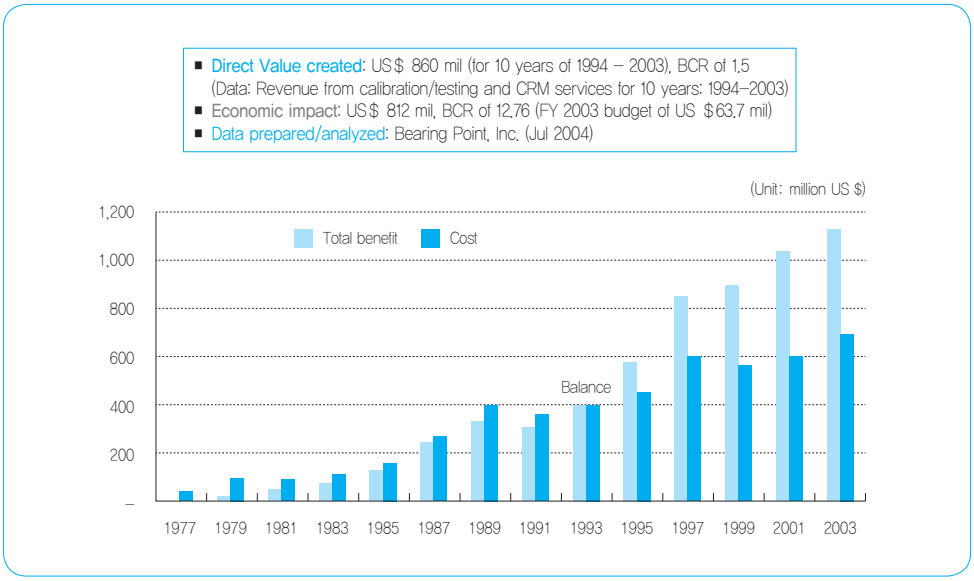
4.2. Economic Benefits Delivered to Korean Industries

KRISS, the national metrology institute of Korea established in 1975, is a government-funded organization. In 2004, just ahead of its 30th anniversary, KRISS requested Bearing Point to conduct a study for analyzing how much economic effect it had made on the Korean society. The findings were quite amazing and are presented here.

The BCR (benefit-cost ratio) was 1.5 when only the calibrations, tests, and certified reference materials (CRM) services provided for domestic customers for 10 years from 1994 to 2003 were taken into account. This means the investment resulted in a return of 150%. Because the services provided for Korea by KRISS accounts for a small portion of all similar types of services combined, the BCR value may be even greater, if all direct and indirect effects are taken into consideration. For example, the BCR for the year 2003 including all direct and indirect effects of the activities of KRISS is 12.76, according to the report of Bearing Point.

What we learn from [Figure 3-9] below is that the Korean government's supports of KRISS is not a failure at all. When only the calibrations, tests, and certified reference materials (CRM) services are considered, KRISS did make a loss on the investment before 1993, but in 1993, it reached the break-even point, and since then it has created more benefits for society than the initial investment made. This shows that the government's investment in national measurement standards should be made with a long-term perspective.

Figure 3-9 | Economic Impact Analysis of KRISS



Source: Myungsoo Kim, How NMIs benefit global enterprises (2009)

In 2008 KRISS requested that STEPI, a research institute for policies on science and technology, analyze the economic effect that KRISS had created for the industrial sectors which enjoyed the measurement services provided by KRISS. The result showed the practical effects that KRISS delivered to specific industries which benefitted from the metrological service offered by KRISS. For example, the report showed that KRISS helped the failure rate sharply reduce in the assembly of automobiles in Hyundai Motors by improving the accuracy of torque measurement standards. As another example, it was revealed that KRISS had contributed to the import substitution effect and faster product development through a 1 nm thin film measurement technology used in vacuum and film measurement – essential in the semi-conductor industry, which resulted in 15 times of investment efficiency.

Table 3-21 | Economic Benefits Delivered to the Automobile Industry by Improving Accuracy of the Torque Measurement Standards of KRISS[26]

Items	Details
Summary	■ Torque is a physical quantity indicating the tightening of nuts or bolts ■ 90% of automobile engine assemblies involve the tightening process ■ Precision measurement of torque is essential for safety and quality
Problems	■ Poor capacity for torque measurement leads to weak quality competitiveness (fraction defective of 35.1%)
KRISS's contribution	■ Improved accuracy in torque measurement results in quality improvement and reduces error rates ※ Accuracy of KRISS torque standards: 0.1 % ('99) → 0.005 % ('10) ※ Torque error rates for Hyundai Motors: 35.1 % ('99) → 0.5 % ('10)
Financial benefits delivered	■ Total cost of KRW 16.4 billion – creates benefits amounting to KRW 36.2 billion ('99-'11) ☞ Investment efficiency of about 22 times ※ Grand Prize (Presidential Citation) in precision measurement technology

Source: Gun-Woong Bahng, Economic impact of metrology and NMI (2012)

26. Analysis of Economic Impact of KRISS's Key Research Achievements, STEPI, May 2008.

Table 3-22 | Economic Benefits Delivered to the Semi-conductor Industry by Developing Vacuum/Film Measurement Technology of KRISS[27]

Items	Details
Summary	■ Quality assurance based on vacuum and thin film measurement technologies is important to win more contracts
Problems	■ Poor vacuum technology infrastructure of Korea cost USD 6.0 billion annually for the import of high-end vacuum equipment ■ Lack of thin film thickness measurement technology causing delays of R&D projects
KRISS's contribution	■ KRISS contributed to the quality improvement and market expansion efforts by Samsung Electronics, sdi, and others with the world's top vacuum and thin film technology. ※ KRISS developed 1 nm ultra-thin film thickness measurement technology for Samsung Electronics, SDI, and other companies
Financial benefits delivered	■ Total cost of KRW 10.3 billion; creates benefits of about KRW 149.0 billion ('03-'12) ☞ Investment efficiency of about 15 times ※ Grand Prize (Presidential Citation) in precision measurement tech

Source: Gun-Woong Bahng, Economic impact of metrology and NMI (2012)

27. Analysis of Economic Impact of KRISS's Key Research Achievements, STEPI, May 2008.

2012 Modularization of Korea's Development Experience
National Standards Infrastructure
Underpinning the Economic Growth of Korea

Chapter4

Challenges in Metrology and Strategies

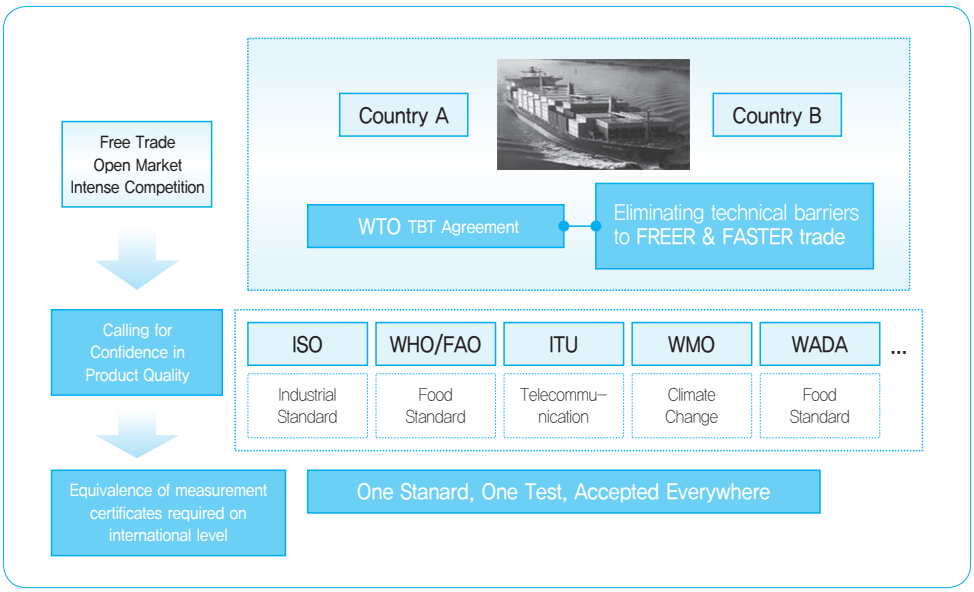
Challenges in Metrology and Strategies

1. WTO and National Measurement Standards

1.1. WTO TBT Agreement

To establish a more prompt and robust environment of trade across borders, WTO members agreed on the Technical Barriers to Trade (TBT), which was aimed at eliminating technical barriers in trade. National standards are one of these barriers. Therefore, the WTO recommends that every nation adopt and implement standards that can be internationally accredited. In other words, equivalence of standards between different nations may guarantee better confidence in the quality of products and faster flow in the global market places with products "tested once and accepted everywhere."

Figure 4-1 | National Standards System Making WTO TBT Agreement Workable



Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

To keep up with the needs of the times, therefore, developing countries are required to do their best in advancing the national standards system and measurement (test/analysis) capabilities at the international level. Furthermore, they are supposed to build the technological and institutional infrastructure of a national standards system to the extent that they can to be internationally recognized. For both advanced and developing countries, it is equally essential to establish national measurement standards that can be accepted by the international metrology community, so that it can play an important role in the sustainable economic growth of their countries.

2. CIPM-MRA: Mutual Recognition Arrangement of National Measurement Standards

2.1. Background of the CIPM-MRA

The purpose of the CIPM-MRA is to provide the scientific and technological infrastructure required for the implementation of the WTO's TBT agreement. It could also help NMIs not to waste time and resources in unnecessarily making a number of bilateral agreements between NMIs. WTO's TBT agreement indicated that gaps in the national standards systems, including conformity assessment system, between countries serve as a critical technical

barrier to trade. This is because the incomparability of national measurement standards and conformity assessment systems between different nations and regions becomes a significant obstacle to the fast and transparent flow of goods and services in the global market. Underlying the adoption of the CIPM-MRA in 1999 is the belief that the effective implementation of the TBT Agreement requires a metrological foundation.

Before the CIPM-MRA was officially adopted, NMIs of different countries maintained the equivalence of national measurement by exchanging written agreements on a bilateral basis. For example, Korea has exchanged an agreement on mutual accreditation for national measurement standards with the NMI of Australia, which sparked its plans for one-to-one exchange with Germany and the U.S. This type of bilateral recognition is a source of significant waste as it requires a considerable amount of effort for each case. The CIPM-MRA is a universal version of this one-to-one agreement, which is commonly applied to every agreement between different metrology institutes. In other words, the NMIs that have signed the CIPM-MRA might be able to secure the global equivalence of their national measurement standards by meeting the requirements of the MRA.

2.2. Overview of the CIPM-MRA: Key Comparisons

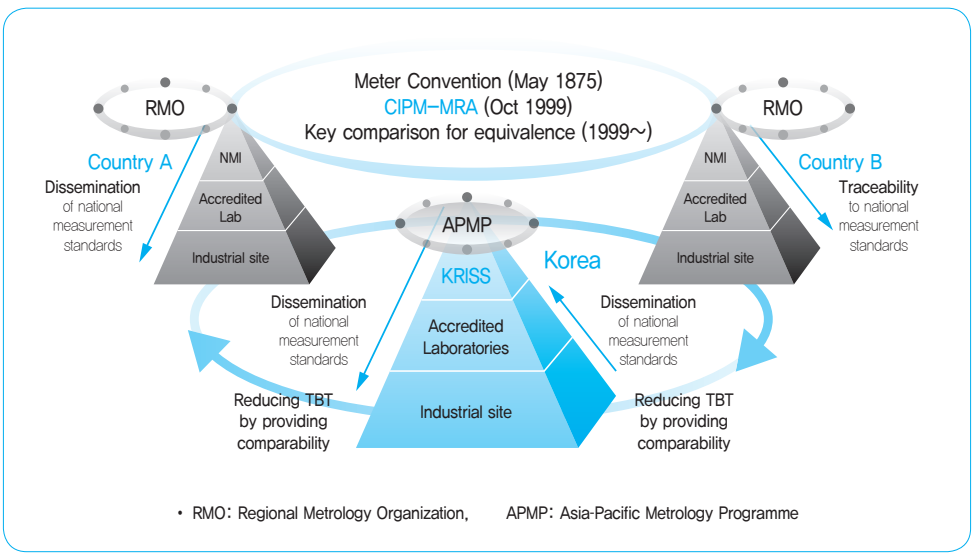
The CIPM-MRA was adopted in October 1999, under the initiation of the CIPM. As of December 2012, 87 nations and four international organizations[28] signed the MRA. NMIs who are signatory to the MRA are eligible to participate in the key comparisons (KCs), which are organized to provide the international equivalence of national measurement standards among the participating NMIs. Another important aspect of the CIPM-MRA is its requirement for a quality management system. Under this requirement, all NMIs are supposed to establish and operate quality management systems based on the relevant international standards such as ISO 9001. They must meet the requirements specified in applicable international standards such as ISO/IEC 17025 and ISO Guide 34. Therefore, the CIPM-MRA is given the top priority on the activities of every NMI whether it is from a developed or developing country. NMIs are required to secure their capability in metrology enough to take part in the key comparisons, while operating their quality management system and meeting the international standard.

The KC is coordinated by the nine consultative committees of the CIPM. One NMI is selected to serve as the pilot laboratory to coordinate each KC. The pilot laboratory is assigned to write up protocols, process the KC and write reports. The coordinator for each item of KC is selected among NMIs with the world's top-class capability of measurement in the subject KC. in the pertinent area of measurement. There is another type of KC conducted by the regional

28. IAEA: International Atomic Energy Agency, WMO: World Meteorology Organization, IRMM: Institute of Reference Materials and Measurement (JRC of EU), ESA: European Space Agency.

metrology organizations on the regional level. This type of KC is designed to allow institutes who cannot participate in the original version of the KC to get into the unbroken chain of traceability and global equivalence of national measurement standards. In other words, an NMI which participated in a KC of the consultative committees will, in turn, organize a KC on the regional level so that the NMIs in the region can take part in the KC. This aspect of the KC enables the equivalence of the national measurement standards to be recognized throughout the world. The concept of global recognition for national measurement standards, based on the CIPM- MRA, is shown in the figure below.

Figure 4-2 | Scheme of International Equivalence of National Measurement Standards under the CIPM-MRA



Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

NMIs participating in the CIPM-MRA make efforts to obtain good scores in as many items of KCs as possible, in order to make their national measurement standards accredited internationally. For this, they are carrying out R&D activities to improve the accuracy of the existing measurement standards, to expand the range of measurements, and to develop new ones. The three elements that the NMIs are supposed to secure for their successful participation in the CIPM-MRA consist of: the quality management system, competent human resource, and high-end measuring equipment. The results of KCs and calibration and measurement capabilities (CMCs) of the NMIs participating in the MRA are made

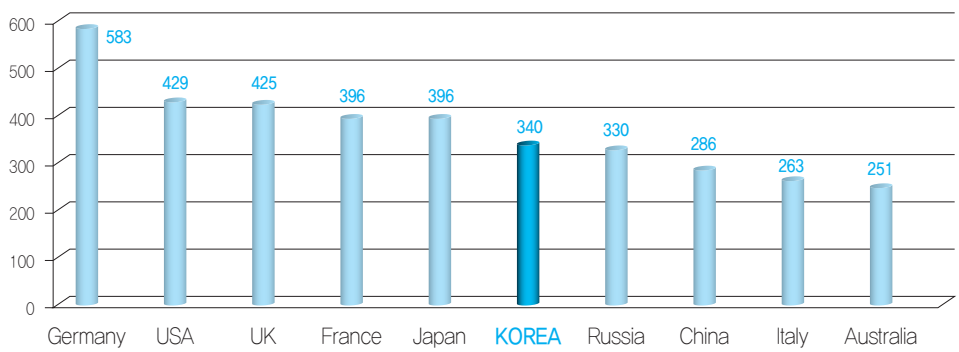
public in the KCDB[29] posted on the internet website of the BIPM. As of November 2012, a total of 1,144 KC items are registered in this DB system.[30]

3. KRISS's Activities for the CIPM-MRA

3.1. Joining the CIPM-MRA with Excellent Performance

KRISS became signatory to the CIPM-MRA in October 1999 and has participated in key comparisons (KC) to prove its excellent performance in national measurement standards. From the early stage of the MRA, KRISS, with a clear approach, has been committed to promoting its global competitiveness by focusing on the three key elements of competent human resources, high-end precision measuring equipment and a quality management system that complies with the requirements of the international standards. As of October 2012, KRISS participated in the KCs on 340 items, and registered 1,069 items of its CMCs (Calibration and Measurement Capabilities) to the KCDB operated by the BIPM. KRISS is ranked the sixth of the world in terms of the number of KC items it has participated in.

Table 4-1 | Participation in KCs by Selected National Metrology Institutes (October 2012)



Source: http://kcdb.bipm.org/kcdb_statistics.asp

29. KCDB: Key Comparison Data Base, a database system operated by BIPM which provides the result of KCs and the registration of CMCs.

30. This includes 818 items of KCs and 326 items of SCs (Supplementary comparisons).

Table 4-2 | KC Participation and CMC Registration by KRISS

Measurement Fields	AUV	EM	L	MRQ	PR	QM	RI	T	TF	Total
KC	16	49	22	64	19	93	55	21	1	340
CMC	41	141	28	49	41	473	214	59	23	1,069

Source: http://kcdb.bipm.org/default.asp (as of October 2012)

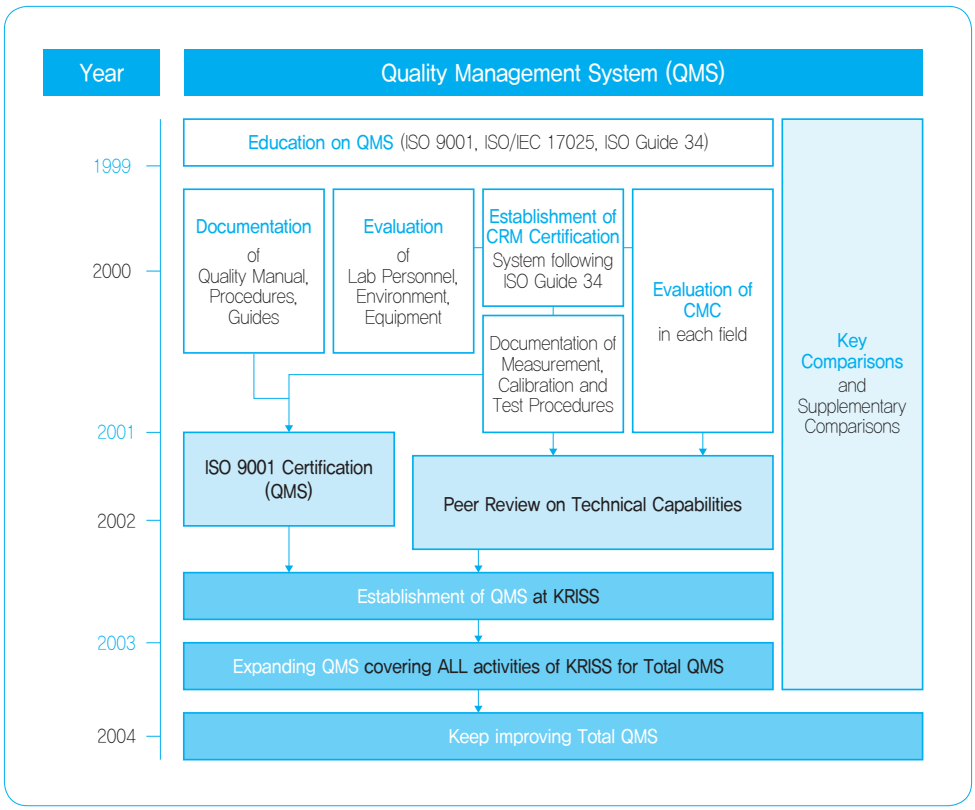
3.2. Preparations for Meeting the CIPM-MRA Requirements

3.2.1. Roadmap to the QMS

Before signing the CIPM-MRA introduced in October 1999, KRISS identified the requirements for the MRA and prepared for future activities promptly. First, it formed a task force who was assigned to draw up a roadmap in order to obtain a certification of its QMS and acquite outstanding achievement in the CIPM-MRA activities.

The institute initially established a roadmap toward the CIPM-MRA. While introducing the new concept of its quality management system (QMS), KRISS set up a plan to strengthen its R&D activities that were designed to help get excellent achievements in KCs. The roadmap KRISS drew up to establish its QMS is shown below:

Figure 4-3 | Roadmap of KRISS toward QMS under the CIPM-MRA



Source: Myungsoo Kim, How NMIs benefit global enterprises (2009)

As shown in the figure, KRISS planned an education program among others to broaden awareness and consensus among KRISS members concerning the newly adopted quality management system, followed by the development of various quality documents and evaluation on the manpower, its calibration and measuring equipment, and the environmental conditions of laboratories. It also established a CRM certification system based on the requirements of ISO guide 34. These efforts allowed KRISS to be certified to ISO 9001 in 2001. KRISS used peer review as a process verifying whether the institute had metrological capabilities appropriate for an organization providing calibration services.To meet the requirements specified in ISO/IEC 17025, a number of experts from foreign national metrology institutes were invited to conduct peer reviews, and KRISS could finally obtain international approval in regards to its technical capability in all areas of measurement standards covered by the consultative committees. In late 2002, KRISS was finally qualified for all requirements of the CIPM-MRA. KRISS has been organizing the “peer reviews” every five years and, thus far, it has successfully completed the program three times.

3.2.2. Operation of the QMS Task Force

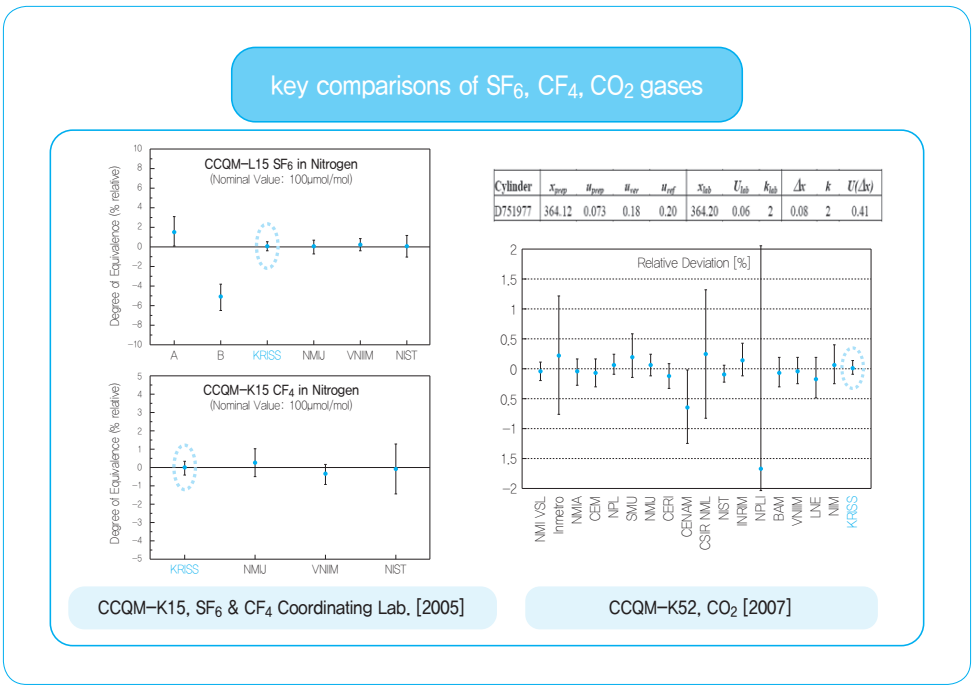
KRISS has established and been operating organizations for a Quality Management System (QMS) by making use of the structure for existing R&D and management organizations, which include; a Quality Assurance Committee (QAC) that is responsible for reviewing and making decisions on all activities required by the CIPM-MRA; and a Committee on Uncertainty in Measurement (CUM) who is responsible for discussing issues regarding uncertainty in measurement. The QAC is chaired by the Vice President and, the latter CUM by the Director of Technology Services. The institute formed a technical committees under each of four research divisions, which is responsible for deliberating and making decisions on the matters and functions regarding the QMS of each division. In addition, it operates a unit which is responsible for managing the institute's quality managements system by means of developing and refining the documentations and process regarding QMS, maintaining certification to the QMS as well as coordination of the peer reviews in close cooperation with research divisions and top management of the institute.

3.2.3. R&D for Improving Capability in National Measurement Standards

To acquire good scores in KC activities and develop new calibration and measurement capabilities, KRISS has been committed to strategic R&D activities. They are aimed at establishing new national measurement standards, to improve the uncertainty in measurements and to expand the ranges of measurements. All of these efforts are focused on reaching the ultimate goal of the institute to become the world leader in metrology. KRISS has continuously participated in R&D activities for the MRA by selecting annually an average of 10 research projects and extensively supporting them for 2–3 years. Such well-designed preparation and coordinated efforts have enabled KRISS to obtain excellent achievements in its activities for the CIPM-MRA as illustrated in <Table 4-1> and <Table 4-2>. They are the harvest of KRISS's incessant efforts combined with the cooperation of the Korean government (Ministry of Education, Science and Technology) who has unsparingly provided strategic and financial support for KRISS, the national metrology institute of Korea.

The following is selected out of a number of excellent results of key comparisons in which KRISS has participated. It is posted on the website of KCDB and is made available to the public.

Figure 4-4 | An Excellent Result of KRISS in Key Comparison Activities (Measurement of Global Warming Chemicals)



Source: http://kcdb.bipm.org/kcdb_statistics.asp

3.3. Korea's CIPM-MRA Success Stories Written by KRISS

As a result of its participation in the key comparisons and the registration of its calibration and measurement capabilities, KRISS has made splendid achievements in the CIPM-MRA activities. As discussed above, its performance in the KCs and CMCs have placed the institute on the top level of NMIs in the world. In addition, KRISS has written very interesting success stories of the CIPM-MRA in ways that Korea's famous private companies could enjoy tremendous economic benefits. The institute played a critical role in providing solutions to difficulties encountered by the companies in the course of implementing international business contracts. The beneficiaries include many well-known private companies of Korea: Daewoo Shipbuilding & Marine Engineering Co., Ltd. (DSME), Samsung Heavy Industries Co., Ltd. (SHI), Korean Air Lines (KAL), and Pohang Iron and Steel Co., Ltd. (POSCO). The selected success stories written by the KRISS related to the CIPM-MRA are described below.

3.3.1. Daewoo Shipbuilding & Marine Engineering (DSME, 2012)

a. Overview

- DSME became the winner of an international bid in 2010 invited by ENL (Exxon Mobil Neftegas Limited) in Russia, which is one of subsidiaries of Exxon Mobil, the world's top oil company. It was called "Arkutun-Dagi Project" to construct an off-shore platform (45,000 tons) to be used for oil and gas mining at Sakhalin, Russia(at US $5.5 billion).
- The Russian Law requires DSME to secure calibration certificates for the measuring devices to be mounted on the platform as issued by the Russian institution.
- To fulfill the terms as set forth in the contract, DSME needed to take more than 300 items of its measuring instruments to Russia to be recalibrated by a Russian laboratory. This would inevitably result in a waste of time and financial resources for DSME.
- KRISS was able to provide a solution for DSME thanks to the fact that the NMIs of the two countries were signatory to the CIPM-MRA, and the national measurement standards were internationally recognized.
- DMSE enjoyed economic benefits by saving resources.

b. Problems to be Solved

- The Russian Law on "Metrological Uniformity" required DMSE to get all of the measuring instruments to be mounted on the platform recalibrated by a Russian laboratory.
- In order to meet the requirement, DSME had to spend three months to bring more than 300 items of instruments to Russia for their recalibration, causing waste of resource for transportation, calibration, and purchasing new instruments to be used during they were recalibrated. It was estimated to amount to around US $800,000.
- Delay in delivery of the platform was subject to liability to be paid by DSME.

c. Solutions Provided by KRISS

- In July 2012, the senior management of the VNIIMS paid a visit to DSME and confirmed that the calibration pertaining to the DSME's instruments were recognizable in view of the fact that the two NMIs of both countries were signatories to the CIPM-MRA.
- The Korean calibration laboratories who offered calibration services for the DMSE were accredited by KOLAS (the Korean Laboratory Accreditation Scheme), which was a signatory to the ILAC MRA.

- It demonstrated that the calibration certificates pertaining to the "Arkutun-Dagi Project" were all recognizable as their calibration standards were traceable to KRISS, the NMI of Korea and calibration laboratories were duly accredited.

- VNIIMS and KRISS agreed to conclude a protocol stating mutual recognition of the calibration certificates issued by both NMIs, including those measuring instruments to be mounted on the platform.

- The protocol was duly signed in October 2012, and DSME was ready to make the delivery in time, without having to pay additional expenses.

d. Economic Benefits to Customers

- DSME was able to complete the project in time without wasting any additional resources.

- It is estimated that DSME saved approximately US $800,000, at least, for the calibration fees, logistics, and purchasing additional measuring equipment: (* DSME paid about US $70,000 for the calibration of the instruments in Korea.)

3.3.2. Korean Air (KAL, 2008)

a. Overview

- Under the US Repair Station Act, the Federal Aviation Administration (FAA) designates repair service stations in foreign countries which are eligible for offering repair and maintenance services for the US aircrafts.

- The Act requires that the measuring instruments used for services by the designated repair stations should be traceable to the NIST, the NMI of US.

- To fulfill the requirement, Korean Air was supposed to take all of the measuring instruments used in its repair station to the NIST for recalibration there. It would take quite some time and incur additonal expenses from recalibration in the US.

- The NMIs of the two countries worked together and provided Korean Air a solution so that Korean Air did not have to waste resources thanks to the CIPM-MRA to which the NMIs of both countries are signatories to the MRA.

- Korean Air enjoyed a huge amount of economic benefits by saving resources.

b. Problems to be Solved

- In order to meet the above requirements of the Act, Korean Air had to spend around three months to have more than 200 items of its measuring equipment recalibrated by the NIST (including its transportation to and from the NIST and calibration).

- Services had to be suspended for three months, and Korean Air had to pay the calibration fee to the NIST. Also, they had to purchase another sets of more than 200 items of measuring devices to be used for offering services for three months. The costs were estimated up to US $9.9 million.

c. Solutions Provided by KRISS

- KRISS and the NIST are signatory to the CIPM-MRA, keeping their national measurement standards equivalent.

- The measuring instruments of Korean Air were kept traceable to KRISS through the calibration services offered by KRISS.

- The NIST provided the FAA a statement in this regard, and the FAA accepted that certificates traceable to KRISS as traceable to the NIST.

d. Economic Benefits to Customers

- Korean Air could save approximately US $9.4 million, including calibration fee, cost for purchasing new instruments, and additional facilities and operations.
  - Calibration fee at the NIST: US $0.4 million
  - Cost for purchasing new equipment: US $4.0 million
  - Cost for additional facility, maintenance, transportation: US $5.0 million

- Korean Air paid US $40,000 for calibration in Korea

3.3.3. Pohang Steel and Iron Company (POSCO, 2004)

a. Overview

- In 2004, POSCO received an order from a Mexican automobile parts manufacturer, on the condition that POSCO should provide the demonstration of the reliability of POSCO steel.

- In the same year, an Indian buyer of POSCO steel required that POSCO's products should have certification from the BIS (Bureau of Indian Standards).

- An Indian iron importer requested that POSCO acquire the certification of India's Industrial Standards for the materials to be supplied by POSCO in 2004.

- KRISS was able to provide POSCO a solution thanks to the fact that POSCO's testing laboratory was accredited by KOLAS, and that KRISS was a signatory to the CIPM-MRA.

b. Problems to be Solved

- Additional testing and transportation costs if the materials were to be tested again by the testing laboratories of the importers in Mexico or India

- Potential for paying a liability for delayed delivery from retests at local laboratories

c. Solutions Provided by KRISS

- POSCO has its own testing laboratory, which was accredited by KOLAS who was a signatory to ILAC MRA.
- The testing laboratory of POSCO was keeping its standards traceable to the national measurement standards maintained by KRISS, who was a signatory to the CIPM-MRA.
- The two customers accepted the test certificates as traceable to the NMI of KRISS whose national measurement standards and measurement certificates were recognized as having international equivalence under the scheme of the CIPM-MRA.
- POSCO did not have to have secure test certificates from the two countries, which led to saving resources of the company.

d. Economic Benefits to Customers

- It was estimated that POSCO enjoyed around US $5.0 million in the year of 2004 alone, as POSCO did not have to get its materials retested in other countries of its customers around the world.
- The return-on-investment was more than 70 as POSCO invested US $70,000 for calibration in 2004.

3.3.4. Samsung Heavy Industry (SHI, 2003)

a. Overview

- Sakhalin Energy Investment Company Ltd (SEIC), funded jointly by Gazprom in Russia, Mitsui and Mitsubishi in Japan and a multinational corporation, Shell in UK/Holland, awarded SHI the world's largest project for building the second unit of an offshore platform for mining of oil and gas in 2003 as part of the Skhalin-2 Project. The platform was designed to be equipped with over 10,000 pieces of devices measuring temperature, pressure, water level, flow, density, etc.
- According to a Russian Law on "Metrological Uniformity," SHI was supposed to have those measuring instruments recalibrated by a Russian laboratory. It could waste of time and money for recalibration, transportation, potential liability for delay in delivery of the construction.
- The NMIs of the two countries worked together to find a solution based on the fact that they were both signatories to the CIPM-MRA.
- SHI did not have to get their equipment recalibrated in Russia, and was able to enjoy a huge economic benefits.

b. Problems to be Solved

- The Russian Law required that the measuring devices pertaining to the project be recalibrated by a Russian laboratory, which might have caused SHI to waste a huge amount of resources.
- It would take three months to have more than 10,000 pieces of measuring instruments recalibrated in Russia.
- It might cause delay in delivery of at least three months, for which SHI would be subject to liability around US $16.0 million.

c. Solutions Provided by KRISS

- The directors of KRISS and VNIIMS discussed these matters matters in the meeting of the directors of national metrology institutes held at the BIPM, France.
- Both NMIs came to an agreement that the calibration reports could be mutually recognizable under the requirement of the CIPM-MRA. For this a separate documentation was required to meet the provisions of the Russian law.
- The directors of the two NMIs worked out and signed a protocol stating the mutual recognition of the equivalence of the national measurement standards of the two countries, and of the calibration certificates that were traceable to the NMI of each country.
- The calibrations were offered by the two calibration laboratories whose standards were calibrated by KRISS. Also, the calibration laboratories were accredited by KOLAS (the Korea Laboratory Accreditation Scheme), which was a signatory to the ILAC MRA.
- The facts mentioned above demonstrated that the calibration certificates were to be recognized, as they were keeping traceability to the KRISS who was the signatory to the CIPM-MRA, recognizing the equivalence of certificates issued by the signatory NMIs. And the two calibration laboratories were duly accredited by KOLAS, which means their services were meeting the requirements for conformity assessment set forth by the relevant international standards regarding the QMS.
- SEIC acknowledged that the calibration certificates pertaining to the numerous measuring devices were traceable to the Russian national measurement standards.

d. Economic Benefits to Customers

- SHI was able to enjoy an economic benefit of around at least US $16.0 million, as it did not have to pay for liabilities, nor additional costs for recalibration and transportation of the measuring instruments to and from Russia.
- SHI paid about US $140,000 for the calibration fee of the instrument.

3.3.5. DSME (2002)

a. Overview

- DSME was awarded a project by British Petroleum in the US to build a huge off-shore structure.
- The terms of the project required that DSME secure calibration certificates traceable to the NIST for all measuring devices to be used.
- Meeting the requirements would take quite some time, causing delay in the delivery of the constructed structure. It might cause DSME to be subject to quite a large amount of liability accordingly.
- The NMIs of the two countries were able to find a solution thanks to the fact that they were both signatory to the CIPM-MRA.
- DSME was able to save more than US $10 million of its financial resources.

b. Problems to be Solved

- In order to meet the terms as required by British Petroleum, DSME had to take more than 130 kinds of measuring instruments to the NIST for recalibration.
- Calibrating the instrumentations at the NIST may have led to two months or more of equipment shut-down.
- Additional expenses of US $1 million would have been wasted on paying calibration fees and for purchasing additional 130 more pieces of equipment for substitution while the instruments were recalibrated at the NIST.
- It might have caused DSME to pay a liability of US $10 million due to delay in delivery.

c. Solutions Provided by KRISS

- Both KRISS and NIST had signed the CIPM-MRA on mutual recognition of equivalence of national measurement standards and of the certificates issued by the NMIs.
- Accordingly, the calibration certificates issued by KRISS were recognized as equivalent to those issued by the NIST.
- British Petroleum in the US accepted that the calibration certificate traceable to KRISS was equivalent to that traceable to the NIST.

d. Economic Benefits to Customers

- It allowed DSME to enjoy economic benefits as it could save around US $11.0 million including the cost of US $1 million for calibration, logistics, and additional equipment

and US $10 million for potential liability due to delayed delivery. It was estimated to be 360 times the calibration fee (US $30,000 million) that DSME paid in Korea.

The above cases were reported to the CIPM and the BIPM, and the CIPM invited KRISS to present these success stories in front of representatives of national metrology institutes and international metrology organizations at a symposium held in celebration of the CIPM-MRA's tenth anniversary in October 2009. These stories are introduced as splendid success stories for the CIPM-MRA. They are available on the BIPM website.

Figure 4-5 | Symposium in Celebration of the Tenth Anniversary of the CIPM-MRA (October 2009, Paris)

Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

4. Official Development Assistance (ODA) in Metrology

4.1. KRISS's Experience of ODA Activities

4.1.1. Portfolio of ODA in Metrology

It was as early as 1983 that KRISS began to offer an ODA program starting with a group training course of "National Standards System and Precision Measurement." Established in December 1975, KRISS had its first three buildings completed in 1978 and began calibration services in 1979. Therefore, it was only four years after its foundation that KRISS set out on a cooperative journey with the developing world. The Korean Ministry of Science and Technology was responsible for ODA in the fields of science and technology including metrology. In this annual program, around 15 technicians from standards

institutes in developing countries have been invited to KRISS and stayed for about two weeks to participate in technical training on precision measurements in the areas of length, mass, electricity, temperature, time, and other areas. Since it was launched in 1983, it has helped many foreign NMIs to improve their measurement capabilities and understanding on the role of metrology institutes in global scene as well as on Korea's contribution to the development of the measurement capability of developing countries. The program benefits both KRISS and participating countries as it has encouraged various opportunities of cooperation in metrology.

In addition, KRISS has delivered ODA programs in metrology for its partners in developing countries. The programs involve training courses offered at the KRISS laboratories, technical advice by KRISS experts on site of the partner NMIs in developing countries, and calibration services of their national measurement standards at KRISS. These programs are summarized in <Table 4-3> below.

Table 4-3 | ODA Portfolios of KRISS

Programs	Details	Remarks
Group training	National measurement standards and precision measurement workshops - Annually since 1983 - 2-week course with approx. 15 participants (around 600 people from some 40 countries participated)	Funded by Korea International Cooperation Agency (KOICA)
Individual training	Custom-tailored mid/long-term courses - Customized to the needs of the metrology institutes of developing countries - Includes Master's/Doctoral courses (an average of 10 students in progress)	
Calibration service	Calibration, test, and reference materials services - Excellent quality - Prompt service (complete within four weeks of receipt)	
Technical advice	Consulting by experts dispatched on site of customers - "Peer review" experts dispatched - Consulting service on challenges in each area	

Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

The achievements of KRISS's ODA activities for the recent three years are shown below.

Table 4-4 | Achievements of Recent ODA Activities of KRISS (2009-2011)

Programs	2009	2010	2011	Remarks
Invited training	71	73	79	UST Master's/Doctoral course; about 10 students
Calibration service	53	96	166	Malaysia, Philippines, Vietnam, Sri Lanka, etc.
Technial consulting	26	30	25	Philippines, Vietnam, Ethiopia, Columbia, etc.

Source: Annual performance report of KRISS (2009, 2010, 2011)

4.1.2. Key Elements of ODA in Metrology

- Human Resources Development, Measuring Equipment, QMS

KRISS has set goals of ODA activities of metrology based on its own experiences. It defines "human resource development," "measuring equipment," and "QMS (quality management system)" as the three essentials of its ODA in metrology. The first goal is to share the experience of KRISS with the developing world so as to help them to advance their capabilities enough to participate in the CIPM-MRA. The ODA in metrology serve for developing countries to enhance their scientific and technological foundations which are needed to build their trade capacity. It will surely serve as the engine for their sustainable economic growth in the long run as it has been proven by what KRISS has achieved.

The capacity of NMI is called the indicator of the nation's industrial competitiveness because it is an indispensable element to ensure customers' confidence in products and services. KRISS and UNIDO (United Nations Industrial Development Organization) recently have developed a joint ODA project in metrology which will provide a two-week course in metrology four times during the period of September 2011 to June 2013.

Figure 4-6 | UNIDO-KRISS Training Program in Metrology
(third workshop, October 2012)

Source: KRISS, Report of UNIDO-KRISS training workshop 3 (2012)

4.2. Global Metrology Academy (GMA)

4.2.1. A New Initiative of HRD in Metrology for Developing Countries

KRISS launched a short-term basic measurement standards training program as a part of its ODA activities in 1983. This program helped the participating institutes to establish close partnership with KRISS and other metrology organizations in developing countries, leading to opportunities to develop a range of cooperative initiatives. In line with this pr ogram, KRISS launched a new initiative of ODA program in December 2012, Global Metrology Academy (GMA). GMA is aimed to offer quality services of HRD in metrology. KRISS carried out surveys and analyses of similar programs offered by domestic organizations and foreign NMIs and educational institutions. The primary goal of GMA is to upgrade and operate the existing metrology training programs in a more organized fashion. As shown in the survey results, the GMA of KRISS might be able to offer short-term training courses on 25 individual modules that can be categorized into 10 areas of measurement technology. Features of the GMA are summarized in the table below.

Table 4-5 | Brief Overview of Global Metrology Academy
(launched in December 2012)

Programs	Main Subjects	Potential Participants	Lecturers
Metrology **General**	VIM (Vocabulary in Metrology) SI (International System of Units) Uncertainty in Measurement	Open to All Partners At Home & From Abroad	Senior Professional Metrologists of KRISS
Metrology **Technical**	Measurement and Calibration Techniques (25 Modules covering 11 fields)		
Quality Management System	CIPM-MRA ISO 9001, ISO/IEC 17025, 17043 ISO Guide 34		

Source: KRISS, Global Metrology Adacemy (2012)

Courses of GMA are open to anyone at home or abroad. Each course will be instructed in English by senior researchers who are experts with rich experiences in R&D and international cooperation in metrology. The success of GMA depends on the quality of instructors, the quality of the curriculum, and a favorable environment of training and education. KRISS has been making great effort to find resources in close cooperation with the Korean Ministries in charge and international organizations concerned.

4.3. Plan of KRISS ODA in Metrology: Underpinning Sustainable Economic Growth

4.3.1. Justification

In merely 30 years, KRISS has become an organization comparable with other national metrology institutes in advanced parts of the world who have more than 100 years of history. The knowledge and lessons learned in these years can serve as a role model for developing countries.

Korea could have never reconstructed the country after the Korean War without the Korean people's enthusiasm for education, and the efficient planning and execution of the Korean government. Also, it should be reminded that if it had not been for the helping hands from abroad, such rapid economic growth of Korea could not have been achieved.

It is told that ODA in metrology lays the scientific and technological foundation on which developing countries could build their trade capacity, which will lead to their sustainable economic growth. In this sense, ODA in metrology could serve to attain the MDG's[31] proclaimed by the United Nations. ODA in metrology serves for eliminating the extreme poverty suffered by developing countries around the globe as it plays the key role in advancing the industry and economy of a nation. It is certain that it will help attain the ultimate goal of the MDGs[31] so that all of the people in every corner of the globe can enjoy prosperity in the long run.

In this context, KRISS will push forward a plan for ODA in metrology for the "establishment of national standards infrastructure underpinning the sustained economic growth." It will put emphasis on the development of human resources, improvement of measuring equipment and quality management systems in compliance with international standards, to make it Korea's number one ODA in science and technology.

First, the plan aims to support developing countries in establishing fundamental capabilities in measurement services with international traceability. From a long-term perspective, KRISS plans to help these nations to improve their metrological capability enough to participate in the CIPM-MRA, which is the top priority for all NMIs. Most developing nations around the world could not be ready to join the CIPM-MRA, and even those who have joined do not have the capacity enough to fully participate in the CIPM-MRA activities. KRISS is going to help them to make a difference. The CIPM-MRA was introduced to realize the aims of eliminating Technical Barriers to Trade, an initiative of the WTO; however, it is rather another obstacle for the developing world. Thus, metrology institutes in the advanced world are called to come forward to provide all possible resources so that the NMIs in the developing world might improve their technical capabilities in metrology and be ready to be admitted to the CIPM-MRA.

4.3.2. Outline of Project

a. Background

o Global environment

- WTO: calling for the removal of technical barriers to trade (TBTs)

The global, WTO-driven economy, seeking more liberal and fast flows of transactions, requires each nation to eliminate technical barriers to trade, as well as to establish transparent national standards system, based on international standards, which can be recognized across the globe. Ultimately, it requires a measurement standards system to guarantee

31. MDGs: Millennium Development Goals.

the acceptance of a product or service (*One Standards, One Test, Accepted Everywhere*), anywhere in the world through a one-stop test of the product or service. The developing world may have to secure a world-class national standards system and test/analysis capacity and, based on this, the technological and strategic infrastructure to assure the reliability of their products and services.

- CIPM-MRA: global recognition of national measurement standards

In response to the needs above, the CIPM introduced MRA in 1999, an agreement on the mutual recognition of national measurement standards, to secure worldwide equivalence of national measurement standards. Most developed nations including Korea, signed the MRA. As of October 2012, MRA has 51 regular and 36 associate members and is participated in by the four international organizations of IAEA,[32] IRMM,[33] WMO,[34] and ESA.[35]

However, while most developing countries do not have the capacity to participate in the CIPM-MRA, this may impose a rather adverse effect on them, due to its strict requirement for technological capacity. MRA membership status of selected developing countries and their activities for the MRA are as follows.

Table 4-6 | CIPM-MRA Membership of Selected Developing Countries (October 2012)

Regions	Membership to Meter Convention		Membership to CIPM-MRA		Registration of Calibration and Measurement Capabilities (CMC)		Participation in Key Comparisons (KC)	
	Yes	No	Yes	No	Nations	No. of items	Nations	No. of items
Asia (11)	2	9	6	5	2	131	9	130
Africa (8)	1	7	1	7	0	0	6	21
Middle East, CIS (2)	0	2	0	2	0	0	1	2
Central & South America (4)	0	5	3	2	2	89	4	82
Total	3	23	10	16	4	220	20	235
Korea	Yes		Yes		1,069 items registered		340 items reported	

Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

32. IAEA: International Atomic Energy Agency.
33. IRMM: Institute for Reference Materials and Measurements (JRC of EU).
34. WMO: World Meteorological Organization.
35. ESA: European Space Agency.

At present, countries in the developing world are in a situation in which they cannot upgrade their economies or standards of living if they do not secure the required capacities for science and technology and national measurement standards. A national infrastructure for standards, tests, quality and globalization is essential for sustainable growth. KRISS plans to deliver a science and technology ODA program representing Korea, in measurement standards, from the judgment that the developing world can achieve sustainable growth only when they have joined the CIPM-MRA and their national measurement standards are internationally recognized.

o Domestic environment

- The Korean government: expanding ODA for the developing world

Korea, who gained membership in the Development Assistance Committee (DAC) of the OECD in 2009, has been seeking opportunities in various domains under an initiative to raise its investment in ODA up to 0.25 % of GNI by 2015. Science and technology are not apparently classified in the OECD's or Korean government's ODA programs, but they are serving as the significant tool enabling other ODA programs identified from wide categories. The basic philosophy of the Korean government's ODA strategy is focused on "teaching how to catch fish," i.e., independent growth, where the developing countries work their way toward sustainable growth with technological support from the advanced world. In that, metrology is an essential scientific and technological foundation needed to ensure the prompt and transparent flow of goods by securing the reliability of products and services. In this context, the ODA in metrology has sufficient value, justifications, and potential to be developed into the major ODA program of Korea.

- Time to share Korea's experience in science and technology

The economy of Korea has rapidly grown through a quantum leap, and it has become a role model for many developing countries. One of the important contributors to this rapid growth is the country's strong scientific and technological power. Developing countries are paying growing attention to cooperation with Korea in various fields of science and technology, including metrology with higher priority. In 37 years, KRISS has grown to be comparable with those in advanced countries including Germany, the US, the UK, and Japan. This has been demonstrated by the excellent performance that KRISS has achieved in the two key activities of the CIPM-MRA; Key comparison (KC) and the calibration and measurement capabilities (CMC).[36]

Taking note of this, from Asia to the Middle East to Africa and South America, many NMIs in developing countries are making requests for the help and support of KRISS.

36. Korea is ranked sixth in KC participation and CMC registration (see ⟨Table 4-1⟩ and ⟨Table 4-2⟩).

Countries benchmarking the success story of KRISS include Columbia, Ethiopia, the Philippines, Vietnam, Mongolia, Indonesia, Saudi Arabia, Uzbekistan, and Kazakhstan. KRISS is facing a rush of requests for training and education, calibrations, consultations, and other services focused on the establishment of national standards infrastructures as well as requests for development cooperation regarding the three essential elements of human resources, measuring equipment, and a quality management system. It is certain that the ODA in metrology of KRISS would provide opportunities to share knowledge and experience of Korea's development of metrology and the NMI of Korea. In particular, the Philippines and Columbia, who participated in the Korean War but remain thus far developing countries, are eager to advance their national standards infrastructure setting priority on national measurement standards.[37]

KRISS is willing to share its experience in the development of its capability of metrology to the world-leading level with the developing world, in close cooperation and in line with the Korean government's policy on ODA.

b. Objectives and Project Activities

o Objectives

This program aims to help the NMIs in the developing world to promote their national measurement standards to a level that can be internationally recognized. Specifically, the goals are as follows:

- Assist the partner NMIs in establishing human, material and institutional infrastructures, to secure their industrial competitiveness in the global economic environment, and eventually to improve the people's quality of life through sustainable economic growth of the country;
- Transfer and share the knowledge and experience of Korea obtained in the course of promoting national measurement standards in Korea; and

o Project Activities

The ODA in the metrology will produce higher performance when it is implemented as a package-type project embracing the development of the competence of human resources (Software), upgrading of measuring equipment (Hardware), and establishment of QMS and a national standards system (System). It has been proven by the findings of a study conducted by STEPI, which suggested specific strategies and plans for ODA programs and stressed that a packaged-type ODA program is more effective in terms of performance of aid

37. Plan Nacional de Desarrollo (2010-2014) of Columbia and Philippine Development Plan (2011-2016) of the Philippines.

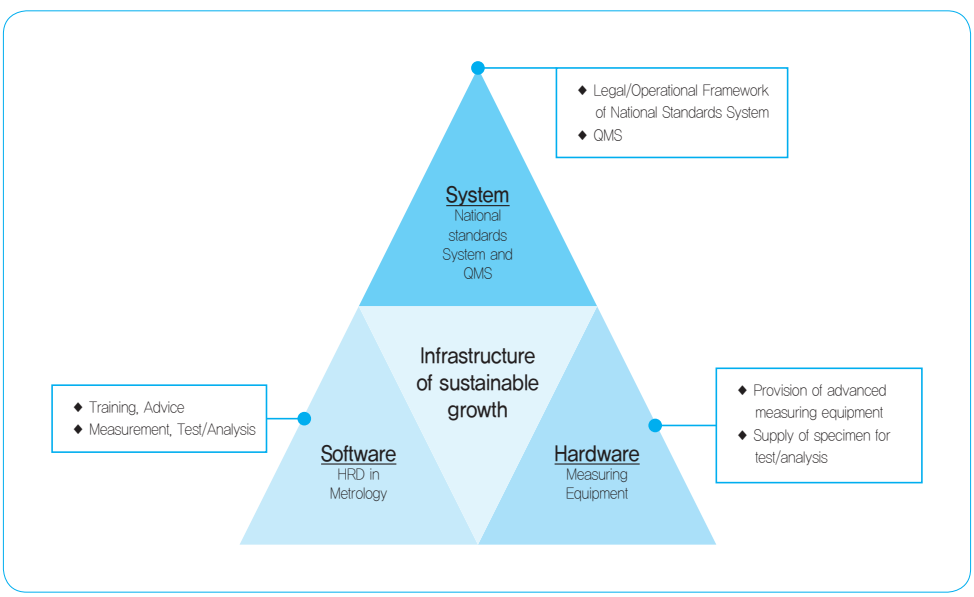
and efficiency in investment. Therefore, KRISS has been designing its ODA in metrology program within such an integrated package-type framework.

Table 4-7 | Descriptions of Three Key Components of ODA in Metrology Project

Components	Activities	Remarks
Development of human resource	- Technical advice by dispatching experts - Training/education in metrology for technical staff	[SW]
Precision measuring equipment	- Precision measuring equipment for key metrology areas - Measurement and calibration service	[HW]
National Standards System & QMS	- Consulting for the establishment and improvement of QMS - Technical advice on strategies for establishing advanced national standards system - Providing information and materials concerned	[SYSTEM]

Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

Figure 4-7 | Scheme and Components of ODA in Metrology: Building an Infrastructure of Sustainable Growth for Developing Countries



Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

c. Anticipated Effect: WIN-WIN through Sharing the Fruits of Shared Efforts

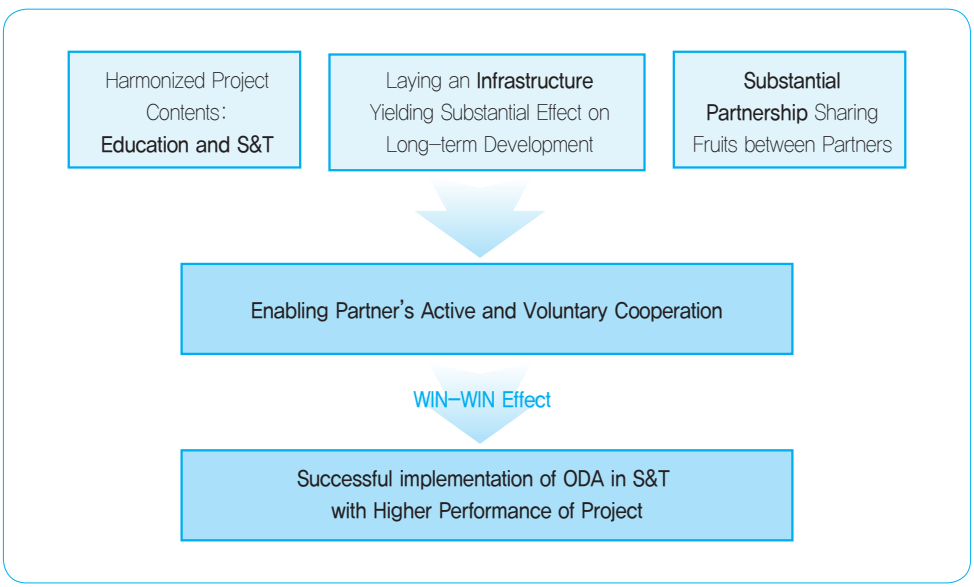
o Partners: Enhancing industrial production driving sustainable economic growth, through;

- Developing high-quality human resources in metrology;
- Securing a scientific and technological foundation for the international recognition of the nation's measurement standards;
- Ensuring the international reliability on test reports and inspection certificates issued by the nation; and
- Establishing an advanced national standards system serving for the sustainable economic growth of the nation;

o Korea: Promoting the global partnership of Korea by;

- Sharing Korea's experience in the establishment and advancement of national measurement standards; and
- Contributing to realizing common prosperity of all of the people in the world

Figure 4-8 | Sharing Benefits of ODA in Metrology
(* well balanced combination of SW+HW+System)



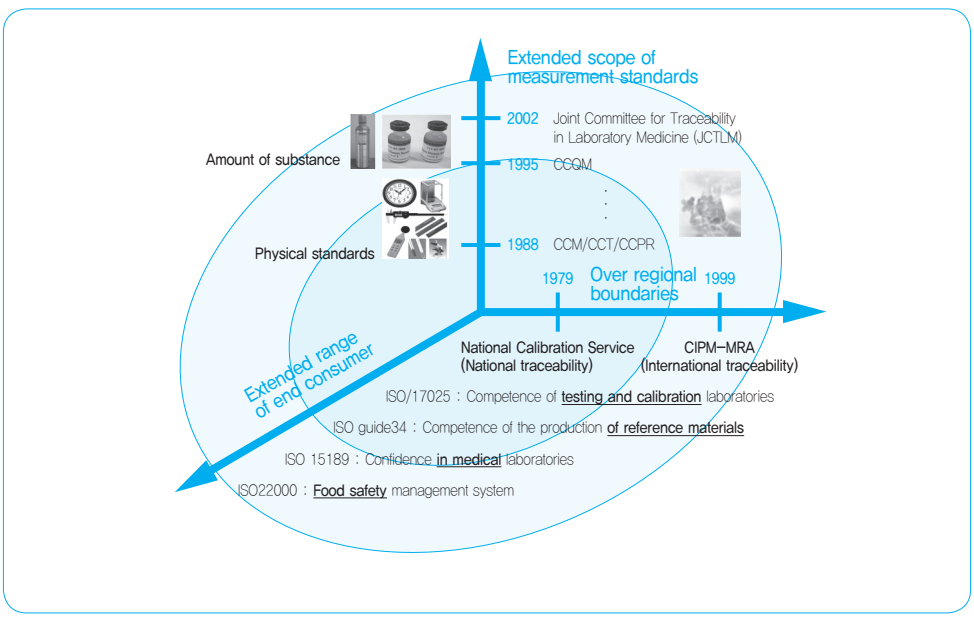
Source: Sangwook Seo, CIPM-MRA, prerequisite for trade capacity building (2012)

5. Challenges and Strategies

5.1. Effective Response Meeting Evolving Needs for Metrology

Needs of measurement standards have continued to increase in line with industrial development and the advancement of the human society. As the desire for a higher quality of life grows, it gives rise to various forms of better capabilities of measurements across new emerging sectors where confidence in measurement matters. The metrology community should be ready to respond to such evolving needs for better service of measurements. The situation calls for national metrology institutes (NMIs) to keep enhancing the capacities and scope of their services so that they can meet the new and evolving needs from its customers. Serving customers of traditional manufacturing industries and commercial transactions remains unchanged as one of the core missions of NMIs. Furthermore, NMIs are invited to play a crucial role in underpinning and enabling the sustainable growth of human society by providing measurement solutions to such challenging issues as: how to promote the quality of life (e.g., health, food, and the environment); and how to address energy problems and climate change. In brief, the primary mission of NMIs is, as ever, to secure and provide the technical foundation of confidence in all types of measurements, analyses, and tests. This will, in turn, lay the basis of finding solutions of those challenging global issues.

Figure 4-9 | Evolving Needs for Metrology, Measurement Standards



Source: Gun-Woong Bahng, Economic impact of metrology and NMI (2012)

To respond to the ever evolving needs and challenging issues in metrology effectively, KRISS has made constant efforts to foster high-quality human resources in new metrological areas, to refine its organizational structure to create better performance in R&D, to operate strategic R&D programs with appropriate funding, and to promote a cooperative research environment among partners within and outside of KRISS. In addition, much more efforts have been put forth for efficient and systematic monitoring to remain aware of the activities of advanced NMIs and international metrology organizations.

5.2. Fostering World-leading R&D Capabilities

KRISS, with less than 40 years of operation, takes pride in the fact that it is now on par with advanced national metrology institutes around the world, most of whom have more than a one hundred-year history. Nevertheless, there is still a long way to go until KRISS can reach the top of the global metrology community in terms of its R&D capability. A strategic approach should be taken, as it may not be possible or necessary for KRISS to be the world leader in all areas. Based on a strict analysis of its capacity and potential for development, KRISS should instead identify and promote priority areas which are found to have a higher potential for top-tier global competiveness.

For this purpose, KRISS has set up and been operating strategic R&D programs so that its competent research scientists, both experienced and young, can make a commitment carrying out R&D on forward-looking subjects in the areas of science and technology. World-class laboratory programs, creative research programs, and national agenda programs are in operation. They are invested in by a major amount of funding on an extended basis in consideration of the fact that they are striving to reach the top in their specific areas of science and technology. They are designed to provide measurement solutions for concerns on national and global agendas such as climate change, safety, energy, and the environment.

Table 4-8 | Major Projects of Strategic R&D Programs of KRISS in Progress (2012)

Programs	Major Project in progress	Areas
○ National Agenda Program (NAP: 3)	■ Measurement technology for solving climate change issues ■ Advanced sensing Technology for intelligent surveillance ■ Measurement technology for safety in hydrogen conversion and storage	climate change, safety, energy
○ World Class Laboratory (WCL: 5)	■ Measurement technology for the brain and cognition ■ Nano-bio convergence and nano-material safety technology ■ A pulsed laser uniform source (PLUS) and an electrostatic container-less levitation instrument for physical state evaluation ■ Time and space metrology laboratory ■ Large aspheric optical mirror based on advanced metrology	health, convergence, photometry/ radiometry, time/ frequency, space optics
○ Creative Research Program (CRP: 6)	■ Development of the KRISS Watt balance ■ Multi-spectral infrared technology using surface plasmon resonance ■ Revealing atomic-scale cluster formation in a levitated medium via time-resolved coherent light scattering ■ Nano-scale energy conversion ■ Quantum measurement using superconducting quibits ■ Matter-wave interferometer using ultracold atoms	New definitions of mass, hyper-spectral infrared imaging, thermal transport, quantum standards, etc.

Source: KRISS, Overview of KRISS, NMI of Korea (2012)

2012 Modularization of Korea's Development Experience
National Standards Infrastructure
Underpinning the Economic Growth of Korea

Chapter5

Challenges in Metrology and Strategies

1. Key Factors in the Successful Operation of a National Metrology Institute
2. Recommendations

Challenges in Metrology and Strategies

1. Key Factors in the Successful Operation of a National Metrology Institute

1.1. Legal and Institutional Foundation

1.1.1. The Constitution and Framework Act on National Standards

The Korean government established the Korea Research Institute of Standards and Science (KRISS) as the national metrology institute representing Korea in matters concerned with the Convention of the Meter since the early stage of Korea's export-led economic development. The Constitution of the Republic of Korea stipulates the nation's commitment to the establishment of a national standards system. In addition to this, the government enacted the Framework Act on National Standards (FANS) in order to provide the legal foundation on which the national standard system of Korea could properly operate. FANS designates KRISS as the national metrology institute (NMI) of Korea. Thus, the Korean government clearly recognizes the significance of the national standards system and has laid down the necessary legal and institutional foundations for setting up the national standards system and for establishing and advancing an institute for national measurement standards.

1.1.2. KRISS, Founded as a Government-supported Research Institute: Promoting Autonomy and Creativity in R&D Activities

In order to preserve the all-too-important characteristics that define an ideal research institute, such as creativity and autonomy, the Korean government has again demonstrated wisdom by establishing KRISS as a government-supported research institute, being an

independent legal foundation, not as a governmental organization. Fostering an environment of creativity and autonomy is crucial for the unhindered R&D activities of science and technology research institution in the long run. The Korean government allowed KRISS a status of GRI, non-government organization, it might be free from bureaucracy and potential limitations which government-run national research institutes would have.

1.2. High-quality Human Resources

1.2.1. Recruiting Korean Scientists from Advanced Countries

In the 1960s, while the Korean government established a series of Five-Year Economic Development Plans, it displayed remarkable insight by simultaneously establishing and promoting plans for the development of science and technology required for economic development. As part of these latter plans, early on the Korean government made it top priority to actively recruit both prominent and promising Korean scientists with doctorate degrees who had been educated abroad in the US, Europe, or in other countries back to Korea to work at these newly-established, government-supported research institutes.

In line with these aggressive plans to secure such prominent scientists, the Korean government offered these scientists competitive salaries that were three times higher than that of university professors. Also offered were free housing and other diverse benefits, including the opportunity to serve their nation through their expertise and to lead research activities in the newly-formed institutes. The first generation of these scientists made great contributions to the advancement of these government-supported research institutes (GRIs). Today there are 26 GRIs in operation, and they have received international recognition for their professional capabilities in their professional areas.

1.2.2. Offering Opportunities to be Trained as Metrologists

Though these scientists were experts in their fields with doctorates earned from advanced countries such as the U.S. or different countries in Europe, the Korean government foresaw the need of additional training to assist them in absorbing knowledge in metrology, which was necessary to transform them into scientists with metrological approaches. Thus the government arranged for them to have opportunities to receive on-site training at the National Bureau of Standards, NBS (presently known as National Institute of Standards and Technology, NIST) in the U.S. for a period of six months to a year before returning to Korea. Each of them was assigned to receive training in a specific area of measurement standards. This arrangement was to allow these scientists to initiate the establishment of national measurement standards right after their return to Korea at an expert level from the beginning.

The government also utilized loans from overseas sources into providing adequate training for R&D personnel in the foreign advanced metrology institutes. Such policies and arrangements are seen as the foundation which enabled KRISS to achieve outstanding results in various fields of metrology and to grow and become an internationally recognized NMI in such a short period of time.

The research scientists who were recruited in that period was comprised of not only physicists but also chemists and material scientists as well, who together laid out the comprehensive base of KRISS on which it has advanced to a leading national metrology institute as it is. In countries such as Japan, Australia, and Italy, the missions related to national measurement standards had been delegated to diverse institutes, and they were restructured into one in the early 21st century to promote efficiency in the operation of their NMIs. The task was said to be not that easy. In this respect, the Korean government and the first generation of scientists of KRISS had remarkable insight on many different aspects down the road from its very early founding stages.

1.3. Advanced Measuring Equipment

1.3.1. Effective Investment for NMI Using Loans and ODA Funding

For R&D in science and technology, advanced state-of-the-art research equipment and facilities are essential. The cost is especially extremely high when it comes to top performance precision measurement and analytical equipment. The Korean government successfully secured overseas loans on a continuous basis and invested them into purchasing such state-of-the-art research equipment and building the facilities needed for proper R&D in the government-supported research institutes. Upon the founding of KRISS, the government secured overseas loans equivalent to the total amount of 35 million US dollars—the first from the U.S. Agency for International Development (USAID), and later followed by Asian Development Bank (ADB), Japan's Overseas Economic Cooperation Fund (OECF), and the International Bank for Reconstruction and Development (IBRD). The Korean government also obtained over 10 million US dollars of the Official Development Assistance (ODA) funds from Germany and Japan, most of which was effectively invested in purchasing precision measuring equipment.

1.4. Quality Management System

1.4.1. Effectively Meeting the Requirements of CIPM-MRA: Ensuring International Equivalence of Measurement Certificates

All laboratories providing measurement services must establish and operate a Quality Management System (QMS) to meet the requirements of appropriate international standards. When measurement capability is not accepted by international review and the QMS of its calibration or measurement service is not adequate to be accredited, then the certificate issued by the laboratory cannot be recognized anywhere. National metrology institutes, which serve at the top of their nation's metrological traceability chain, thus must establish an QMS in compliance with ISO 9001, ISO/IEC 17025, and other relevant ISO Standards to carry out their important role in accordance to international practices to adequately support the national standards system. This is the core requirement presented by the CIPM-MRA whose objectives are to establish equivalence among the national measurement standards and services provided based on equivalent standards.

1.5. International Partnership

1.5.1. International Cooperation is Essential in Metrology

When it comes to measurement standards, cooperation is esteemed much more highly than competition. Today, the arena of measurement standards is global as economic activities are expanding across borders. Both advanced and developing countries are called on to participate actively in various international activities organized by international metrology organizations and are encouraged to continuously seek more opportunities for cooperation.

The U.S., whose expertise in metrology undoubtedly ranks among the top in the world, provided KRISS with much-needed cooperation at its founding stages. Such cooperation was the crucial element that enabled KRISS to grow in such a short time period and to become what it is today—a national metrology institute sharing its place among the top ranks in the world. Cooperation with Germany and Japan, thereafter, helped continue to nurture the institute's growth and development.

Strategic cooperation for R&D among neighboring national metrology institutes should be encouraged. Such collaborations with neighboring countries allow the partners to enjoy sharing the advantage of strengthening capabilities through collaborating resources. Furthermore, cooperation in science and technology serves to promote a spirit of friendly environment in the region.

1.6. Customer-oriented Services

1.6.1. Close Networking for Serving Customers Better

National metrology institutes could be fully valued when their outcomes of national measurement standards are made available for the effective use of their customers in industry, government, academia, and calibration and testing laboratories. Calibration, testing, technical advice, and education/training are among the basic tools of technical services delivering national measurement standards with international traceability to customers. Such tools of services are common to almost all national metrology institutes around the globe. As mentioned earlier, the needs of customers of metrology have always been evolving. This expands the scope and depth of the needs of metrology services, creating new customers from emerging sectors such as health, energy, safety, the environment, and the quality of life, coupled with its primary customers from the manufacturing industries. Therefore, NMIs are required to prepare by means of close networking with its customers so that better quality services can be effectively offered in a timely manner.

KRISS has developed and has been operating its unique tools of customer service, such as the "Measurement Club" and the "Home Doctor" programs. Members of the measurement clubs are technical experts of metrology coming from government, industry, academia, calibration and testing laboratories. This practice allows KRISS to communicate closely with its customers across wide sectors. It enables KRISS to listen to the voices of its customers, identify the problems faced by them on site, and offer services by finding substantial solutions to resolve the problems. This is how KRISS is meeting the practical needs of its customers by offering customer-oriented and customer-tailored technology services of measurement. It serves as a key value that has put KRISS on par with the advanced NMIs of the world, a fact that Koreans can take pride in and that bolsters confidence in its existence and activities.

2. Recommendations

2.1. National Development Plan with Priority on National Standards Infrastructure

2.1.1. Strengthening National Competitiveness by Advancing the National Standards System

A national standards system constitutes the core element to ensure quality of products and services provided in a nation and one of essential infrastructures to reach a status of global competitiveness. Thus, the writers of government policies and strategies for

developing nations are strongly encouraged to consider the national standards system as a key for sustainable growth when establishing national development plans. A system for national standards should be established and revised within the framework of national development plans. The plans should also include a strong and steady financial commitment to investment toward strengthening the capabilities of the national metrology institute—the nation's scientific and technological foundation. Through cost-benefit analysis of KRISS, it is clearly attested that such a long-term and stable financial input of central government to national measurement standards has proven to be of value in view of its significant impact on national growth and economy.

2.2. Strengthening National Competitiveness by Advancing the National Standards System

2.2.1. Laying the Legal and Institutional Foundations Ensuring the Autonomy and Independence of the NMI and the Key Players of a NSS

The national standards system of a nation can be structured in various settings in accordance with the country's history or its governmental structure at the time. Like many other countries, the current structure in Korea also might need some restructuring. However, the important fact is that the establishment of a national standards system is the nation's obligation for any government. Moreover, when setting up the system, in addition to the establishment of organizations (or assigning appropriate missions to existing organizations) that will be responsible for the national standards system, the legal foundation has to be securely prepared for proper and effective operation of the organization. Regarding metrology (measurement standards) in particular, in light of Korea's experience and success with KRISS, it is highly advised that a national metrology institute be established as a government-supported institute as opposed to a government-run one. This is to ensure the institute's legal independence and autonomy. These are two main aspects which are essential for uninterrupted and creative R&D activities. It is also worth noting that countries such as Japan, Australia, Italy, and France have recently restructured their national metrological structure by getting different metrology institutes into one big NMI. This was to improve its operational efficiency and to effectively meet the evolving needs of metrology. [38]

38. Japan (in 2001), Australia and Italy (in 2004), and France (in 2005) consolidated their national metrology institutes into one large organization with a view to enhancing its operational efficiency as well as promoting the performance of its ability to serve its customers.

2.2.2. Efficient Division of Responsibilities between Government and Private Sectors: based on Expertise

In some developing countries, one single organization is responsible for the maintenance and development of the national standards system as a whole. In some other countries, one function of metrology has been taken over by different organizations. In many cases, this may be due to inevitable circumstances faced in the early stages of system building in developing countries. However it is important that each of the three elements of the national standards system—measurement standards, standardization, and conformity assessment—is delegated to relevant organizations that have necessary expertise in each element. When a government agency is assigned to be responsible for any of the elements simply by legal delegation, the national standards system itself can be operated inefficiently. Any responsible body of those three elements must possess expertise. This is an inevitable requirement of qualification. Operating with deficiencies of the relevant and specialized expertise needed would only hinder the nation's competitiveness and the advancement of national standards.

Regarding standardization, the most effective way is to set a policy to swiftly adopt to the International Standards as developed by international standardization bodies such as the ISO (International Organization for Standardization) and IEC (International Electrotechnical Commission) as the national standards. A qualified expert should be commissioned to attend wide-ranging ISO/IEC technical committee activities of those international standardization bodies to collect and communicate the relevant information for the particular industrial sector or to prepare a strategic plan. In the early stage of industrial development, a government is advised to set up and support expert committees for standardization financially to be organized into specialized fields. Also, when national strategies on industrial development have already been set up in accordance with a national economic development plan, it is effective to operate a policy of standard developers such as the Cooperation Organizations of Standard Development (COSD) in Korea in which expert agencies of various fields join efforts to facilitate the standards development in interested areas. When expert institutes cooperate with each other, they will be able to respond more efficiently and effectively to meet the expectations and needs of the global arena.

It is critical to ensure impartiality in conformity assessment. Thus entrusting the conformity assessment activities to the private sector is perhaps the best strategy in the spirit of conformity assessment and with the prospective of strengthening capabilities. Another important factor that should be kept in mind is to establish a central role for the coordination of national conformity assessment programs. Many government ministries and agencies may set up and operate their own systems of conformity assessment. However, a central coordinator is absolutely necessary for the efficient coordination of conformity

assessment activities in a nation. To designate an agency that will be responsible for legal metrology (weights and measures), the key criteria of the decisions should be professional expertise in science and technology required for carrying out the responsibility, rather than by legal authority secured by the law. Such a structure will nourish the competitiveness of a nation which is based on knowledge and expertise with backgrounds in science and technology. National metrology institutes are responsible for the legal metrology (weights and measures) in many developed countries due to the very same reasons of scientific and technical expertise.

2.3. Cultivating Human Resources

2.3.1. Qualified Staff

It is highly advised to employ well qualified human resources with specialties in a wide area of science and technology related to metrology. It is necessary to set up a clear policy on some of the practical aspects to recruit qualified staff such as salary, incentives, job title, and fringe benefits. To support domestic industries, metrology on the physical sciences was necessary at the industrial development stage of Korea, but have now broadened to include many other areas of science and technology. Physics has been regarded as the science for metrology traditionally. But many other academic areas are contributing to metrology related to food safety, health, medical services, safety issues, etc. It is clearly indicating the growing importance of metrology in modern society. The increasing demand of services by metrology institutes can also be observed in developing nations. It is recommended, based on a survey of demands of metrology services, to recruit well qualified staffs in an aggressive manner who will contribute to the advancement of measurement capabilities related to chemistry, bioscience, food science, forensics, etc.

2.3.2. Training at Advanced NMIs

The first generation of KRISS scientists stayed in foreign countries for their advanced degrees, were recruited and sent to the National Bureau of Standards (NBS), the world's leader in national measurement standards (currently the National Institute of Standards and Technology, US). It was designed to give them opportunities to have on-site experience of doing metrology based on their major areas for six months to a year. This could be perhaps the single most critical factor among factors that contributed to rapid growth and success of KRISS to become one of the world-leading metrology institutes today in such a short amount of time. The lessons learned by KRISS are invaluable information for those NMIs setting up strategies of similar rapid growth within a relatively short period of time.

To orient well-qualified scientists into good metrologists, KRISS looked for resources and opportunities of long-term training in advanced NMIs besides NIST, and developed a cooperation program with Germany and Japan, who participated actively in ODA (Official Development Assistance) programs at that time. In the development of a strategic plan, many factors for successful training have to be taken into account including securing necessary resources, financial support, capability build-up of institute, personal achievements, etc. For the training NMI staff, the program offered by the University of Science and Technology (UST) in Korea can be considered as one of candidates. This national research graduate school is an excellent place for promising young scientists to pursue their Masters and doctoral degrees in metrology. More information is available on their website at www.ust.ac.kr.

2.4. Building Capacity to Meet the Requirements of the CIPM-MRA

2.4.1. Signing the CIPM-MRA

The Meter Convention is an international treaty; applying for full membership is the job of a central government. As an NMI, therefore, it can be a strategy to apply for an associate membership status as an initial step to join the framework of the CIPM-MRA and to participate in related activities. Joining a regional metrology organization (RMO) is also another way to look for the possibility of establishing traceability by participating in RMO activities. Thus, it is important to join the RMO and take full advantage of the activities it entails. It will also be more efficient to participate in the CIPM-MRA later. Another additional option can be joining other RMOs as an associate or an observing member, and then participate in comparisons.

2.4.2. Enhancing Capacity on Conformity Assessment: Strengthening Capabilities of Calibration Laboratories

Together with the national metrology institutes (NMIs), conformity assessment bodies (CABs) take a significant part in the national standards system. They offer conformity assessment services in forms of calibration, test, inspection, certification, etc. Accreditation bodies are responsible to ensure confidence that the quality management system operated by CABs is fulfilling the requirements of the relevant international standards, so that certificates issued by CABs could also be accepted by their customers at home and abroad. Accreditation bodies play such an important role in operating the national standards system. However, the crucial factor is to ensure its effectiveness and efficiency. It is recommended that there be a central authority in place on a national level with the capacity to perform comprehensive coordination of various conformity assessment activities.

For example, DAkkS, the national accreditation committee of Germany, is entrusted by the federal government to coordinate the nationwide conformity assessment programs operated in various sectors. In the case where different conformity assessment activities are already taking place in diverse areas, it will prove quite difficult to artificially integrate such programs. Rather, it might be wise to devise a strategy costing less yet producing more efficiency, and, thereby to establish a mechanism of central coordination that does not involve much conflict or cause waste of resources.

One of the main functions of NMIs is to provide national measurement standards of international equivalence to its customers including conformity assessment bodies. Therefore, it is recommended that NMIs make efforts to enhance the capability of calibration laboratories, the primary customers of NMIs, by means of training and technical advice in addition to the calibration services for them. It will help strengthen the technical capability of the conformity assessment bodies, which will lead to enhancing the reliability of conformity assessment activities.

Each accredited laboratory or applicants for accreditation should be reviewed on site by an evaluation team. Usually, the evaluation team is composed of qaulity system reviewer and technical capability reviewer. Based on our experience, we found the consistency in evaluation is very important to provide reliability on conformity assessment scheme. To achieve this goal, it is recommended to invite the senior evaluator having technical capability from NMIs who has specialties in that field.

2.5. Seeking Opportunities of ODA in Metrology

2.5.1. Taking Full Advantage of ODA Loans and Grants

ODA can be either in the form of loans or grants. It should be actively pursued and one should take full advantage of it. KRISS's success history fully attests to this point clearly. The ODA in loan is long-term in nature with low interest rates, so the government of developing countries is strongly encouraged to utilize such resources. It can be learned from the experience of KRISS to appropriately allocate such a loan into large-scale projects such as the construction of R&D building or purchase of measuring equipment. ODA as grants are also available. These grants, while available in smaller amounts compared to the loans, take much less time to process and thus are ideal for immediate launching of the project or addressing issues requiring immediate attention.

2.5.2. Seeking Resources Available from Foreign Partners and International Donor Organizations

Countries such as Germany, Japan, the Republic of Korea, China, Thailand, and several Northern European nations are constantly strengthening their ODA activities for developing nations as part of their national strategies for future growth. It is recommended to develop suitable ODA projects on metrology in close cooperation with advanced NMIs in donor countries.

Meanwhile, diverse U.N. organizations including UNDP, UNIDO, and UNESCO have developed and supported a variety of projects/programs to address the issues facing developing countries. It is encouraged to keep close communications with those international organizations exchanging ideas and information about how and what to do to develop ODA projects in metrology. International organizations serve as good resources for financing and finding potential partners for implementing the ODA project in metrology as well making the best of their global networks.

BAHNG, Gun-Woong (2012), "National Standards System in Korea," KRISS

BAHNG, Gun-Woong (2012), "Economic Impact of Metrology and NMIs," KRISS

CHOI, Dong Geun (2013), "A Primer on Korea's Standards System: Standardization, Conformity Assessment, and Metrology," National Institute of Standards and Technology (NIST), USA

Jun, Seung-Woon, et al, (2006), "Mid- and Long-term Policy and Strategies on Donation of Korea," Korea International Cooperation Agency (KOICA)

KATS (2011), "White Paper on Technology Standards 2010," Ministry of Knowledge Economy

KIM, Myungsoo (2009), "How NMIs Benefit Global Enterprises – Success stories of CIPM-MRA in Korea," Korea Research Institute of Standards and Science (KRISS)

Kim, Zae Quan (2000), "Establishment of National Standards System in Korea," The Korean Academy of Science and Technology

Korea Research Institute of Technology Management (2007), "A Study on the Effects of '70's ~ '90's Major Science Policies on S&T and Industrial Development," Ministry of Science and Technology

KRISS (1997), "20 Years of Korea Research Institute of Standards and Science," KRISS

KRISS (2002), "Analysis on the Economic Impact of National Measurement Standards," KRISS

KRISS (2005), "30 Years of Korea Research Institute of Standards and Science," KRISS"

KRISS (2009), "Mid- and Long-term Development Plan of Korea Research Institute of Standards and Science," KRISS

KRISS (2011), "The Third Five-Year Basic Plan on National Standards and its Relevant Laws and Regulations," KRISS

KSA (2007), "Future Society & Standards," Korean Standards Association

Lee, Myung Jin (2011), "Operation of S&T Cooperation Network for Promoting ODA Activities," Ministry of Education, Science & Technology

Park, Seung Duk (1998), "Winning the Future with Science and Technology,"(*The Myung Hyun*)

SEO, Sangwook (2012), "CIPM-MRA, Prerequisite for Trade Capacity Building," KRISS

STEPI (2008), "Economic Impact Analysis on Major R&D Programs of KRISS"

http://kosis.kr/

http://www/scopus.com

www.bipm.org

www.nist.gov

http://kcdb.bipm.org/default.asp

www.kats.go.kr

www.ksa.or.kr

www.ksp.go.kr

Ministry of Strategy and Finance, Republic of Korea

339-012, Sejong Government Complex, 477, Galmae-ro, Sejong Special Self-Governing City, Korea Tel. 82-44-215-2114 www.mosf.go.kr

KDI School of Public Policy and Management

130-722, 85 Hoegiro Dongdaemun Gu, Seoul, Korea Tel. 82-2-3299-1114 www.kdischool.ac.kr

9 791155 450642 94320

ISBN 979-11-5545-064-2

Knowledge Sharing Program
Development Research and Learning Network

- 130-722, 85 Hoegiro Dongdaemun Gu, Seoul, Korea
- Tel. 82-2-3299-1071
- www.kdischool.ac.kr