



# 75th Foundation Day of CSIR-National Physical Laboratory: Celebration of Achievements in Metrology for National Growth

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**Abstract:** The CSIR-National Physical Laboratory (CSIR-NPL), the National Metrology Institute (NMI) of India, is a premier laboratory, founded on January 04, 1947, under the umbrella of Council of Scientific and Industrial Research (CSIR), New Delhi, Government of India, by an Act of Parliament. It has now completed 74 glorious years after inception and entered into its 75th year, i.e. Platinum Jubilee Year. To commemorate its 75th Foundation Day, the CSIR-NPL organized a National Metrology Conclave (NMC) on January 04, 2021. On this auspicious occasion, the Honourable Prime Minister of India, Mr. Narendra Modi dedicated the National Atomic Timescale and Bhartiya Nirdeshak Dravya (BND<sup>®</sup>)—CRMs to the nation. He also laid the foundation stone of National Environmental Standard Laboratory. He addressed the august gathering in the gracious presence of Honourable Union Minister of Science and Technology, Dr. Harsh Vardhan. Honourable Prime Minister inspired, motivated and appreciated the strides made by Indian Scientists for nation building, especially the role of CSIR-NPL and impact of metrology for self-reliant India. Honourable Minister, Dr. Harsh Vardhan, inaugurated the exclusively designed poster gallery, displaying accomplishments and importance of metrology in the CSIR-NPL campus and released a book entitled, “Metrology for Inclusive Growth of India”. Several of the world metrology leaders also presented their visions, in the NMC, on the role of metrology in societal and industrial growth through online virtual platform. The main emphasis was placed on the importance and impact of the metrology in the success of several initiatives of Government of India, namely ‘AtmaNirbhar Bharat’ (Self-Reliant India), ‘Make in India’, ‘Digital India’, ‘Skill India’, ‘Vocal for Local’, etc. During all these years, the journey of the CSIR-NPL has been wonderful, splendid and magnificent on several aspects of celebrations, pride, recognition, global visibility and its services for the national cause. It has achieved many milestones, developed technologies of national eminence, organised many memorable events, successfully participated in various national missions’ time to time and published considerable amount of literature for knowledge generation in the form of research papers, patents, copyrights, books, monographs, technical peers, Calibration and Measurement Capabilities (CMCs) and study reports, etc. The successful journey of these glorious years though looks easy, simple, normal and customary but in actual sense, lot of pain staking efforts, huge work, vicissitudes are behind all these accomplishments. The glimpses of the journey of CSIR-NPL from its inception to recently held NMC and the excerpts of addresses made by the dignitaries are also summarized in detail in this article.

**Keywords:** Metrology; Platinum jubilee of CSIR-NPL; National metrology conclave; National atomic timescale; Bhartiya nirdeshak dravya (BND<sup>®</sup>)—CRM; National environmental standard laboratory

## 1. Introduction

For the scientific and metrological infrastructure of any country, metrological standards and related activities are essentially required. Metrology plays a central role as an engine of industrial revolution and inclusive growth. It

plays a vital role in support of the sustainable development because metrology is essential to protect the planet, ensure the dignified and quality lives for all people, and attain wide-ranging economic growth and opulence. It is a primary pillar for trade, scientific research, novelty and promising technologies, technical collaboration, or even simple exchange of information [1–3]. For the scientific and industrial advancement of any nation, the NMs play significant and unique role in the progression of metrological fields and associated technologies. Each nation

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requires a strong metrology scheme in place to provide the metrological traceability to stakeholders in each of segment of the economy. This exercise is obvious for maintaining the parity in all the measurements to attain sustainable developments at various front like science, engineering, technology, industry, commerce, business trade, etc., which eventually enables to accomplish the goal of self-reliance. It is also requisite for the NMIs world over to constantly upgrade and maintain their measurement systems at par with the other NMIs and as per the new technological advancement and challenges arising in the international scenario.

The CSIR-NPL, being NMI of India, is also playing exceptional role since its inception on January 04, 1947, taking the metrology field to masses through its invaluable metrological services to stakeholders; educational, awareness, training and academic activities and campaign for students, industry, academicians, policy makers, regulators, etc., and providing time to time need-based solutions, services, technologies and advises to all the stakeholders and government agencies etc. Recently, CSIR-NPL has celebrated its 75th Foundation Day, which was attended and graced by a galaxy of political and science leaders. In order to commemorate its glorious journey of 74 years, it was considered appropriate to make a concise go over of the events which eventually resulted in the formation of this wonderful leading laboratory of the country; its major accomplishments of national and international relevance; excerpts of inspiring and motivating speeches/messages of some of the eminent political and science leaders, specially the most stirring peroration of Honourable Prime Minister of India Mr. Narendra Modi; and the summary of various activities held during National Metrology Conclave (NMC-2021) organised on the Platinum Jubilee Foundation Day, i.e. January 04, 2021. The CSIR-NPL has not only been playing its primary role of establishing and disseminating the national measurement standards in the country, but also formulates and advises the India specific policies, guidelines and gives recommendations on evolving advanced metrology programmes for the government organizations, institutions, regulators, industries and other stakeholders. It is also helping Bureau of Indian Standards (BIS) and Department of Legal Metrology in the formulation of written standards and assisting National Accreditation for Calibration and Testing Laboratories (NABL) in many ways in accreditation of calibration and testing laboratories. We hope that the brief reassess thus published as a feature article would be useful for the readers involved/interested in metrological activities as a historical and up to date source of information.

## 2. Historical Aspects

Historically, metrology is not a new concept in India and it dates back to ancient times. However, with times, era, civilization, culture and geographical areas, the uses, types and names of the standards, units, measurement techniques, etc., continued to change [4–8]. The *Harappa* civilization, which is considered one of the highly developed civilizations (about 5000 years old), had witnessed several admirable examples of developed dwellings and township having planning and architecture, which would have not been possible without metrology [4, 5]. The identical size of the bricks used in the structure is one of the beautiful examples. Around 2400 years ago, there existed a distinct system of weights and measures in the *Maurya* era [4–7]. Later on in the *Mughal* era, the emperor Akbar had introduced a unit of length ‘guz’, which was widely used [4, 8]. It is still in use in countryside even after the introduction of the metric system in India in 1956. Illustrations of the equal arm balances found in the art of *Ajanta* cave and beams of steelyard balances are other beautiful examples, which were discovered during eighth century. Some of these examples evident that the measurement system is an integral part of each civilization/era.

### 2.1. Creation and Establishment of Scientific Institutions Responsible for Metrological Activities

The Railway Board established the National Test House (NTH), formerly known as the Government Test House (GTH) in the Kolkata (then Calcutta) in 1912 to fulfil the requirements of the Indian Railways as import substitution. The Indian Industrial Commission (IIC) recommended for the formation of an Indian Stores Department (ISD) during the year 1916–1918. Later on, the NTH was merged with ISD for doing regular testing of the general stores of the Government Departments including defense for a long time. During the year 1934, Government of India formed the Industrial Intelligence and Research Bureau (IIRB), which later on renamed as Industrial Research Bureau (IRB), which is the origin of the present CSIR. The IRB formed and nurtured in NTH for conducting the Research and Development (R&D) for the indigenous development of raw materials [9].

During British era before independence, the Institution of Engineers (India) (ISEI), situated in Calcutta was given the mammoth task giving recommendations for building up the industrial infrastructure in the country and the ISEI had prepared the first draft of the constitution of an institution which could take up the task of formulation of *National Standards*. This leads to the establishment of Indian Standards Institution (ISI) through a memorandum issued on

September 03, 1946, by the Department of Industries and Supplies. The ISI finally came into existence on the January 06, 1947. The ISI became Bureau of Indian standards (BIS) on April 01, 1987 through an act of parliament dated November 26, 1986. Through this change over, the Government aimed to building a quality infrastructure, awareness and more participation of stakeholders in the formulation and implementation of the national standards [9].

In order to initiate, a laboratory accreditation program in India and provide the accreditation services to the testing and the calibration laboratories, the Department of Science & Technology (DST), Government of India, in the year 1982 set up the National Coordination of Testing & Calibration Facilities (NCTCF). The NCTCF started providing accreditation to testing and calibration laboratories with the cooperation of CSIR-NPL (NMI of India) as well as having its office in CSIR-NPL. Subsequently in 1993, the NCTCF was renamed as National Accreditation Board for Testing and Calibration Laboratories (NABL). The NABL was registered under society Act on August 12, 1998, with the objective of maintenance, implementation, promotion, guidance, coordination, etc., of an accreditation system for laboratories. In the year 2017, NABL merged with Quality Council of India (QCI) [10, 11].

## 2.2. Establishment of CSIR-NPL

The Government of India through Legislative Assembly recommended the objectives of CSIR, New Delhi, on November 14, 1941, for the purpose of fostering industrial development in the country. The CSIR was established on September 26, 1942, under the leadership of Sir Shanti Swarup Bhatnagar. In the year 1943, the governing body of CSIR decided to establish 5 national laboratories—National Physical Laboratory (NPL), National Chemical Laboratory (NCL), National Metallurgical Laboratory (NML), Central Fuel Research Institute (CFRI; now CIMFR) and Central Glass & Silicate Research Institute (CGSRI; now CGCRI) [9, 12–14]. One of the objectives in the *CSIR-Bye Laws—2018, Para 2, (b)-vii clearly stipulates the need of* “maintenance of national physical standards and a library of standard reference materials” [14]. Keeping in view the importance of NMI in the socio-economic and industrial growth of the country, our former visionary leaders worked hard for establishing the CSIR-NPL to work for the establishment, custody, maintenance, upgradation of national standards of measurements, primary standards linking them to SI units and other standards in terms of derived units. Historically, the foundation of CSIR-NPL was laid down exactly 74 years ago on January 04, 1947, before India became independent by Pandit Jawaharlal Nehru, then Vice President of Interim

Government of India. The former Deputy Prime Minister Sardar Vallabhbhai Patel formally opened it on January 21, 1950. During this period, India didn't have the statutory acceptance from the International Bureau of Weights and Measures (BIPM) as well as well-equipped laboratory to take-up the measurement standards activities [15, 16].

## 2.3. Legal Identity, Framework and International Linkages

The Government of India enacted the “Standards of Weights and Measures Act” for the first time in 1956 to ensure that every citizen has an access to uniform standards of weights and measures those are traceable to the SI units [17]. During the year 1957, India became member of the General Conference of Weight and Measures (CGPM), BIPM, an International Intergovernmental organisation constituted by diplomatic treaty, i.e. ‘The Metre Convention’. Being NMI of India and to fulfil the mandate, Dr. K. S. Krishnan, the then Director, CSIR-NPL signed the ‘Metre Convention’ on behalf of Government of India in the year 1957 (Fig. 1) [18]. Subsequently in the year 1957, BIPM provided CSIR-NPL the Copies No. 57 and No. 4 of International Prototypes of the Kilogram (IPK) and the platinum-iridium (Pt–Ir) Metre bar, respectively, to realize the SI base units ‘kilogram’ and ‘metre’ [9]. This was the milestone in the foundation of quality infrastructure in independent India.

The *Standards of Weights and Measures Act* was subsequently amended in years 1976 and 1987. *The current version of The Legal Metrology Act, 2009 was issued on January 14, 2010, and subsequently The Legal Metrology (National Standards) Rules, 2011 was issued on January 7, 2011 (The Gazette of India: Extraordinary, Part II-Sec3(i) [17].* The use of the national prototype of the metre, was discontinued after the establishment of laser-based primary length standard as national standard of length. However, the national prototype of the kilogram is still in use as national standard of mass. Recently, the Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India, has designated CSIR-NPL as a national agency responsible for carrying out the certification for the instruments and the equipments for monitoring emissions and ambient air through a gazette notification issued on August 22, 2019, under Section 3 of the Environment Protection Act, giving CSIR-NPL the authority to certify instruments [19].

In the year 1977, the Commonwealth Science Council (CSC) and the CSIR-NPL along with 9 Commonwealth countries formed a cooperation whose main objective was to form a Regional Metrology Programme of joint projects to link each National Measurement System into a collaborative network, which later on became Asia Pacific

**Fig. 1** Republic of India became member of the CGPM in 1957 and currently represents in 3 Consultative Committees (CCEM, CCM and CCTF) of CIPM. India also signed the CIPM MRA in 1999 and was authorised to use CIPM MRA logo on calibration certificates in 2007

The screenshot displays the CIPM MRA website for the Republic of India. It features a navigation menu with tabs for 'General info.', 'CIPM MRA', 'BIPM services', 'CBKT', 'Senior engagement', and 'Quality infrastructure'. The main content area includes a header 'The Republic of India' and a sub-header 'General info.'. A key message states: 'The Republic of India became a Member State in 1957.' Below this, it lists 'Representatives of the NMIs or designated institutes of the Republic of India (see CIPM MRA) participate in the following Consultative Committees:'. A table shows participation in various committees: CCAUV, CCEM, CCL, CCM, CCPR, CCQM, CCRI, CCT, CCTF, and CCU. The CCEM, CCM, and CCTF committees have checkmarks, indicating active participation. The CCTF committee also has a checkmark. The CCT committee has '[obs.]' in its cell. Below the table, there is another section titled 'The Republic of India' with a sub-header 'General info.'. This section provides contact information for NPLI, including the address (110012 New Delhi), telephone (+91 11 2584 6296), fax (+91 11 575 2678/11 576 4189), and website (http://www.nplindia.org/). It also mentions that India has been participating in the CIPM MRA since 14 October 1999 and lists the signatory as Arup Kumar RAYCHAUDHURI (then Director, NPLI). The 'Signatory/NMI' is listed as CSIR National Physical Laboratory of India (NPLI), New Delhi. The 'Designated institute(s)' are listed as Bhabha Atomic Research Centre (BARC), Mumbai (from 28 July 2003). At the bottom, the KCDB logo is shown, and it states that NPLI is authorized to use the CIPM MRA logo for the fields of measurement supported by CMCs published in the KCDB from 2 March 2007. A link to 'See the full list of participants' is provided.

Metrology Program (APMP) [20]. The APMP presently comprises of 45 full members. India signed the International Committee on Weights and Measures Mutual Recognition Arrangement (CIPM MRA) in 1999 and CSIR-NPL initiated the implementation of Quality Management System (QMS) based on the international standard ISO/IEC 17025 to establish the international measurement equivalences for barrier-free trade [18]. The CIPM MRA responds to the growing need for an open, transparent and comprehensive system to give users reliable and quantitative information on the compatibility of national metrology services and to provide technical basis for the wider agreement for the international trade, commerce and regulatory affairs. CSIR-NPL has been maintaining the quality system based on ISO/IEC 17025 for the various parameters under Physico-Mechanical, Electrical and Electronic standards since 2003. The BIPM has authorised CSIR-NPL to use CIPM MRA logo on the calibration certificates issued by it within the currently approved 236 CMCs registered in KCDB of BIPM (Fig. 1). The calibration activities in these areas have been peer-reviewed during 2003–06, 2009–11 and further under the peer review process during 2020–2022 to fulfil the requirements of the CIPM MRA.

#### 2.4. Adoption of Redefined SI Units

Recently, in a landmark and historic decision, the groundbreaking R&Ds by the world's scientific and technical

community, resulted into *acceptance and adoption of redefined SI units by CGPM at BIPM on November 16, 2018 by 60 member states* [21]. Dr. D. K. Aswal, Director of CSIR-NPL, also voted for this landmark revision of the SI units. The new definition of SI units successfully replaced the artefact-based units and aptly opened up the new era for quantum world by linking all the seven base units, i.e. the kilogram (kg), metre (m), second (s), ampere (A), kelvin (K), mole (mol) and candela (cd) to constants of nature, which are invariants of time and space. Worldwide, the redefined SI units have been implemented on May 20, 2019, i.e. the 'World Metrology Day (WMD-2019)' in terms of physical constants. Since fundamental constants are inherently stable, these are chosen so that the redefined SI need not be modified again in near future to accommodate the possible improvements in the realization of base units [1, 21–23].

Further during WMD-2019, CSIR-NPL introduced redefined SI Units to the nation through a series of events and released 11 posters, policy document, recommendations and souvenirs. The posters released were based on BIPM theme poster (The International System of Units—Fundamentally Better); 2 NPL's designed posters introducing redefined SI to nation in terms of constant of nature and highlighting impact of metrology on every moment of human life; released poster on Bhartiya Nirdeshak Dravya (BND®) and released 16 new CSIR-NPL certified BNDs; posters on special projects of socio-economic and



industrial relevance being implemented at CSIR-NPL for creation of testing and calibrations facilities for LED lightings and testing of ballistic materials; posters on technologies transferred, commercialised, patents granted, number of users served through metrological services by CSIR-NPL during 2018–2019. In order to create awareness and promoting redefined SI units, CSIR-NPL designed and released special souvenirs, one key ring on SI units and another Metrology Wheels on SI Units, depicting the all the seven SI units and their links to corresponding fundamental constants. Further, for the commemoration of the event, CSIR-NPL also designed and painted a huge Wall of Metrology Graffiti in CSIR-NPL's beautiful campus as a token of continuation of celebrations over the time. Director, CSIR-NPL declared open the Wall of Metrology Graffiti for the stakeholders.

As a national responsibility and keeping in view of the importance and recognition of new revision of SI, the CSIR-NPL prepared and released documents on (i) NPL Policy on Metrological Traceability [24], (ii) recommendations on the proposed changes to be incorporated in the National Council of Educational Research and Training (NCERT), New Delhi, textbooks and implement the new changes to impart cotemporary education to its students [25] and (iii) recommendations on the proposed changes to be incorporated in syllabi of metrology courses in graduate engineering and academic courses being taught in All India Council for Technical Education (AICTE), Indian Institutes of Technology (IITs), National Institutes of Technology (NITs), and other academic institutes [26].

On this special occasion, CSIR-NPL published and released a book titled as “Redefined SI Units and Glimpses of NPL Metrological Activities” to disseminate the information accommodating details on new changes, posters and documents mentioned above and the role of CSIR-NPL in strengthening the Indian metrological infrastructure for the Government representatives, certification bodies, regulators, policy makers, academic institutions, industries and public as a whole [27]. CSIR-NPL put efforts to highlight the new and advancement in metrological activities to masses.

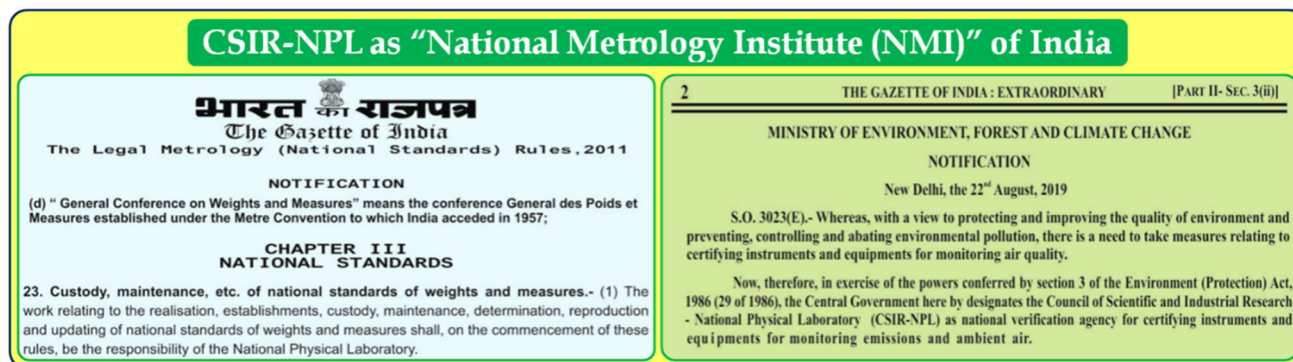
### 3. Commemoration of 75th Foundation Day of CSIR-NPL

During the year 2019, CSIR-NPL started celebrating the CSIR-NPL Foundation Day by organising theme-based National Metrology Conclave (NMC) wherein the stakeholders are invited to share their experiences and issues for

the possible solution by the NMI of India. As mentioned earlier, in order to commemorate the 75th foundation day of CSIR-NPL India, and as a mark of the Platinum Jubilee year, this year, i.e. January 04, 2021, was celebrated as special foundation day. On this occasion, CSIR-NPL organised a National Metrology Conclave 2021 (NMC-2021) under the theme ‘Metrology for the Inclusive Growth of the Nation’. During the NMC-2021, a series of events were organised and the key achievements of CSIR-NPL were dedicated to the nation. A galaxy of political and science leaders attended the events. These key accomplishments include releasing of a book, laying down of foundation stone of a national environment standard laboratory by Honourable Prime Minister and President CSIR through virtual platform and Honourable Union Minister, Science and Technology; Health and Family Welfare, and Earth Sciences and also Vice President, CSIR, Dr. Harsh Vardhan in the august presence of Dr. Shekhar C. Made, Director General, CSIR. The conclave included the technical talks delivered and messages from the eminent metrologists of leading NMIs of the world, namely Director, BIPM; Director, NMI South Africa and President, CIPM; President, PTB Germany and Vice President, CIPM; Director General, NMI Japan and Secretary, CIPM; CEO, NPL UK; CEO, NMI Australia, and the Director, NPL India.

One of the authors, as Director, CSIR-NPL delivered the welcome address. In his talk, he highlighted the chronology of events which lead to the foundation of CSIR-NPL and informed the august gathering about the overwhelming welcome received from the international community on the formation of CSIR-NPL, which was also published in *Nature* in 1947 and 1951 (Fig. 2) [15, 16]. He revisited the need of uniform measurement system worldwide through first metre convention, held in year 1875 to the formation of CGPM, CIPM and BIPM France. To harmonize the measurements in India efforts resulted in formation of NTH (National Test House) which was established way back in India in 1910 and then came BSIR (Board of Scientific and Industrial Research), which later become CSIR (Council of Scientific and Industrial Research), in 1942. He also cited Dr. Charles Volet, the then Director, BIPM, for his words to CIPM about the proposal of creation of NPL India, sent by the then Government of India to BIPM in 1953 for making NPL as NMI of India.

He further reiterated the main aim of the laboratory and providing measurement traceability, consultancy, technology transfer and know-how and training man power in metrology. Being one of the founding members in establishment of APMP, NPL India has fulfilled the expectations



**Fig. 2** The creation of CSIR-NPL in 1947 and the coverage of the event published in Nature. Also depicted are the Gazette notifications of Legal Metrology Rules 2011 about keeper of the measurement

and hopes of its founding fathers and international communities since last seven decades and in the process registered 236 CMCs and 196 international inter-comparisons. He mentioned that NPLI very recently undergone its peer review on the quality system based on ISO/IEC 17025 : 2017 and ISO 17034 : 2016 through APMP to fulfil the requirements of CIPM MRA.

In his address, he further mentioned that CSIR-NPL has expanded its research areas, which are important to India and its industrialization to meet the challenges. Today CSIR-NPL provides the measurement traceability to more than 4000 customers in India as well as in SAARC nations. He also recalled that during the 26th CGPM in 2018, held in France, India along with 60 other member states played its role and voted for the landmark revision of SI units on the basis of fundamental constants, which was implemented worldwide from May 20, 2019, highlighting the importance of metrology as one of the key pillars in ensuring the quality of life interconnecting government, academia, industries and civil society together under various initiatives and programs. Therefore, metrology has its direct impact from trade, economy, and health to society as a whole.

The audiences were briefed about the current role and recent focus of CSIR-NPL on the accurate and precise time keeping using atomic clocks, environmental monitoring, biomedical devices, photovoltaic metrology, material metrology and certified reference materials (registered trade marked as Bhartiya Nirdeshak Dravyas, BNDs), realization of quantum standards for industry 4.0 in the spirit of AtmaNirbhar Bharat. The CSIR-NPL ensured the measurement traceability especially to PPE kits, medical devices and pharmaceutical industries during the pandemic time. He then briefed about the technical programme in the next session on role of metrology for inclusive growth of society, one of the goals of UN. He further thanked all the audience and dignitaries present and connected online.

standards and Ministry of Environment, Forest and Climate Change notifying CSIR-NPL as National verification agency for emission and ambient air monitoring instruments

### 3.1. Inaugurations/Releases by Honourable Minister of Science and Technology and Vice President, CSIR

#### 3.1.1. Inauguration of Poster Gallery

To commemorate the occasion and highlight the foundation, glorious past, important milestones achieved in seven and half decades of continuous research and services and present activities of CSIR-NPL, one of the main galleries of CSIR-NPL was chosen to display all these glorious achievements in the form of self-explanatory, wall-sized posters to offer the general information about CSIR-NPL and its activities to all the dignitaries and visitors. The Poster gallery was inaugurated and thrown open to all the visitors to CSIR-NPL by the Honourable Union Minister of Science and Technology and Vice President, CSIR, Dr. Harsh Vardhan on this auspicious occasion as shown in Fig. 3. The gallery not only throws light on the CSIR-NPL metrological achievements but also casts the importance of metrology, unbroken chain of measurement traceability, the redefinition of SI base units in terms of natural constants, various derived units and their inter linkages to the base SI units, CSIR-NPL as NMI of India, various services of CSIR-NPL to the nation.

#### 3.1.2. Screening of Short Animated Film on CSIR-NPL

A short animated film on CSIR-NPL foundation, progress and activities towards the nation's development was screened on the occasion. The film depicted that in the year 1999, NPL, India signed the treaty on CIPM MRA and implemented its quality management system based on ISO/IEC 17025 to establish the international measurement equivalences for barrier free trade. Currently NPLI holds 236 CMCs and participated in 130 international inter-comparisons organised by BIPM and APMP to enhance its



**Fig. 3** **a** Inauguration of the Poster Gallery by Honourable Minister of Science and Technology and Vice President, CSIR, Dr. Harsh Vardhan; Other dignitaries present were Dr. Shekhar C. Mande, DG,

CSIR; Dr. D. K. Aswal, Director, CSIR-NPL and Dr. K. Lal, Former Director, CSIR-NPL **b** The dignitaries showing keen interest in poster to enlighten the mandate of CSIR-NPL since its inception

measurement capability and global visibility. These CMCs support more than 4000 test and calibration services annually to various industries of different sectors directly and more than 4 hundred thousand users in India and SAARC nations through secondary and regional laboratories. It also included that NPL India along with 60 member states also voted and witnessed the landmark decision on revision of SI base units based upon fundamental constants of nature on November 16, 2018, in CGPM general meeting at BIPM, France. After which as an NMI of India, CSIR-NPL implemented the revised definition of SI base units and releases the metrology policy and suggestions for revised definition in NCERT text books, syllabus in metrology courses in academia and legal metrology rules. To name a few mile stone achievements and unique duties, the film also depicted scientific endeavours of CSIR-NPL for the development of indelible ink used in electoral process, safe preservation and continuous maintenance and safeguarding the original copy of constitution of India. The vast role of CSIR-NPL was listed in terms of creation of key institutions of country, namely NABL, CEL, etc. The other scientific key achievements and services with which CSIR-NPL is playing its nation building role were also shown briefly such as National Atomic Timescale, generating and disseminating 2.8 ns accurate IST and its dissemination to ISRO towards AtmaNirbhar Bharat and safe digital India mission programs. The CSIR-NPL along with other reference material producers, is also producing cost effective certified reference materials (CRMs), trade marked as Bhartiya Nirdeshak Dravyas (BND<sup>®</sup>), for accurate and precise testing by 4 hundred thousand laboratories in India and supporting self-reliant India mission. The NPLI is also notified vide national gazette as national verification agency for certifying air-monitoring equipment in Indian ambient conditions under NPLI certification scheme (NPLICS).

### 3.1.3. Release of Book titled, “Metrology for Inclusive Growth of India”

To mark the historic occasion, a book published by Springer Nature [1] titled, ‘Metrology for Inclusive Growth of India’, describing the metrological activities, mandate and glorious past of NPL, was released by the Honourable Union Minister of Science and Technology and Vice President, CSIR, Dr. Harsh Vardhan (Fig. 4). The book edited by Dr. D. K. Aswal and contributed by most of the CSIR-NPL Scientists, elucidates the implication of metrology in details for the wide ranging growth of India and its applications in physico-mechanical metrology, electrical and electronics metrology, measurements and dissemination of Indian standard time, Bhartiya Nirdeshak Dravyas (BND<sup>®</sup>) and various other parameters related to microwave metrology, environment, biomedical, materials. It also introduces the ‘Aswal Model’, which connects metrology, unison with accreditation and standards, science and technology, government and regulatory frameworks, civil society, media and industries. The book exclusively enlists and presents critical analyses of contributions made by CSIR-NPL through its scientific contributions and apex measurement facilities of international equivalence in the areas of industrial growth, strategic sector growth, environmental protection, cyber security, sustainable energy, affordable health, international trade, policy-making, etc. The book is very useful and expected to serve the purpose of a reference guide for science and engineering students, researchers, metrologists, policy-makers and entrepreneurs. The book was appropriately appreciated by the Honourable Prime Minister through a citation letter.





**Fig. 4** Release of Book titled, “Metrology for Inclusive Growth of India” (Left to Right: Dr. D. K. Aswal, Dr. Harsh Vardhan and Dr. Shekhar C. Mande)

### 3.1.4. Release of Thesaurus for Metrology (M-Map)

On the occasion, the Honourable Union Minister also dedicated the online ‘Thesaurus of Metrology’, developed by CSIR-NPL with the support of different subject experts of CSIR-NPL. The thesaurus would be helpful for students in building their comprehensive of introducing with core concepts of the subject in semantic manner, while for subject experts it would serve as an aid and provide additional vocabulary for literature search and quality academics. For the semantic representation of metrology concepts, CSIR-NPL has also developed an online platform ‘m-Map’ for the structured trade work of domain concepts. The ‘m-Map’ platform created for Thesaurus of Metrology would be helpful for understanding of metrology for all the people.

### 3.1.5. Excerpts from the Speech of Honourable Minister

In his address, honourable Dr. Harsh Vardhan congratulated the NPL as well as CSIR on the occasion and said, ‘*The expertise found within the many science laboratories of India is driving the ground-breaking research and development and is a key force in helping our country become a leading science superpower*’. He further stated that the ‘*scientific community has been the most prominent in the last one year. The Herculean efforts made by our scientists have finally paid off.*’ The Minister said, ‘*Today, we have several vaccines that have been developed across the world, two of which have been developed at a record-breaking speed and granted authorization in India*’. He pointed out, ‘*It has all been possible due to the exemplary and collaborative efforts of scientists across the world, it has been an extraordinary level of sharing of science and its knowledge*’.

The Minister expressed his belief, “*Our scientists can give us game-changing ideas and the opportunities that can be harnessed to boost our industry, create new jobs, and make a real difference in everyday life. Science can be the biggest equalizer. It can ensure that the poorest man leads a comfortable life with just simple ideas and innovations. That’s what I want you all to do*”.

He further said that CSIR-NPL which is the NMI of India; Member of the CGPM, BIPM, an International Intergovernmental organisation constituted by diplomatic treaty, i.e. ‘*The Metre Convention*’; and Founder Member of the Global Regional Metrology Organisation, i.e. APMP, has the mandate to realize, establish, upgrade, maintain and disseminate the measurement standards by Act of Parliament. On the occasion of CSIR-NPL entering its platinum jubilee celebrations, a series of events have been organised with world science leaders. More than 50 thousand participants have joined through online including several metrologists, industrialists, regulators, policy makers, academicians and students. Several other dignitaries from all over the world have also participated in the event to commemorate the 75th Foundation day of this premier laboratory. A technical session on the theme ‘*Metrology for Inclusive Growth of India*’, is chaired by Prof A. K. Grover, Chairman, Research Council, CSIR-NPL. Talks and technical deliberations by Directors of BIPM and Directors/Science Leaders of various other NMIs (Germany, UK, Japan, South Africa, Australia and India) are some of the other highlights of the Conclave.

### 3.2. Unveiling/Dedication/Laying Foundation of the Following by Honourable Prime Minister and President CSIR

One of the highlights of the events was the online presence of Honourable Prime Minister, Government of India and President, CSIR, New Delhi, Mr. Narendra Modi and sparing his valuable time to unveil/Dedicate/Lay down Foundation Stone of several scientific facilities for national Importance and global relevance, which are described later on in this section. Director General, CSIR, Dr. Shekhar C. Mande greeted and welcomed the honourable Prime Minister and President, CSIR, Mr. Narendra Modi for his gracious online presence, Union Minister present on the dais and also other online dignitaries of sixty nations worldwide. He also extended his heartily felicitations on behalf of the CSIR family to all the NPL members for entering into the glorious 75th year.



### 3.2.1. Unveiling of '75th Commemorative Plaque' Depicting the IST and BND Network

For the historic celebrations of 75th Foundation Day, CSIR-NPL has innovatively conceptualized the '75th Commemorative Plaque' depicting the IST and BND Network across the country to percolate the spirit of AtmaNirbhar Bharat in every sector. The plaque indicates the locations of users of National Atomic Clock generating IST<sup>TM</sup> and its Pan-India dissemination. The plaque also shows the locations of Bharatiya Nirdeshak Dravya (BND<sup>®</sup>) and links with reference material producers across the India. The Honourable Prime Minister unveiled the '75th Commemorative Plaque' to the nation as shown in Fig. 5 (Top left).

### 3.2.2. Dedication of 'National Atomic Timescale'

CSIR-NPL is the timekeeper of the nation using atomic clocks. On this auspicious occasion, Honourable Prime Minister, Mr. Narendra Modi, dedicated the *National Atomic Timescale* to the nation as shown in Fig. 5 (Top right). CSIR-NPL realizes and maintains the Indian Standard Time (IST<sup>TM</sup>) traceable to Coordinated Universal Time (UTC) with an uncertainty of  $\pm 2.8$  ns. A bank of ultra-stable atomic clocks are used to realize the National Primary Timescale, IST<sup>TM</sup>, and its dissemination across the Indian subcontinent is done through the network time service and satellite links. CSIR-NPL is on the mission of

"One Nation One Time" to synchronize all the clocks in the country to IST<sup>TM</sup> for digital transformation and cyber security. The IST<sup>TM</sup> traceability to ISRO's timing centres located at Bengaluru and Lucknow is already established for their space programme. The CSIR-NPL is establishing five traceable secondary timing centres at RRLs across India at five centres, namely Faridabad, Bengaluru, Bhubaneshwar, Ahmedabad and Guwahati for Department of Legal Metrology, as regional timing centres for providing IST dissemination services to the various sectors and stakeholders in realizing the mission of safe digital India. Sectors like telecommunication, cyber security, cyber-physical systems, ISRO for the crucial NavIC program, air traffic control, secure banking and stock transactions, geodesy, deep space navigation, radio telescopes, power grids, etc., increasingly require precise time synchronization. An estimate shows that an economic impact of IST synchronization in these sectors is more than 10% of GDP.

Various technologies, such as time dissemination through telephones, NTP, PTP, CV/AVGNSS & TWSTFT, are available for the time and the frequency synchronization. Along with time realization and dissemination services, CSIR-NPL also pursues R&D on primary standards. India's first Caesium fountain (NPLI-CsF1), approved by BIPM as a primary frequency standard, was indigenously designed and developed at CSIR-NPL. The focussed and concentrated efforts are being placed on the design and

**Fig. 5** Honourable Prime Minister Shri Narendra Modi dedicated, top left: 75th Commemorative Plaque; Top right: National Atomic Timescale; Bottom left: Bharatiya Nirdeshak Dravya (BND<sup>®</sup>); and Bottom right: laid down the foundation stone of the National Environmental Standard Laboratory



development of a single trapped Ytterbium ion-based optical frequency standard, which would possibly be used for redefinition of SI second. CSIR-NPL will become ready for adopting and implementing the redefinition of SI second, which is expected in 2026. At present, IST is disseminated across the country through calibration, network time services, and satellite links [28–30].

### 3.2.3. *Dedication of 'Bhartiya Nirdeshak Dravya (BND®)' for self-reliance*

Honourable Prime Minister. Mr. Narendra Modi also dedicated the “*Bharatiya Nirdeshak Dravya (BND®)*” for the nation for self-reliance and to support the testing and calibration laboratories across the country for quality assurance at par with International Standards as shown in Fig. 5 (bottom left). Reliability of the laboratory results depends upon the traceable calibration through certified reference materials (CRMs). These CRMs are used to calibrate the testing equipment with utmost accuracy. These CRMs traceable to SI units are produced under the stringent conditions following the international standards for quality assurance and the data as per international acceptance. These CRMs are also used for calibration, testing, quality control, method validation purpose, assigning the values to other tested materials and finally to maintain or establish traceability to conventional scales. The Indian CRMs are registered as Trademark name *Bhartiya Nirdeshak Dravya (BND®)*. These BNDs are used by industries, government sectors and academia to ensure the best accuracies with minimum uncertainties in measurement through calibration of instruments, validity of measurements and method validation for quality assurance. As on today, India imports CRMs worth several hundreds of crores. Being the NMI, it is the responsibility of CSIR-NPL to overcome this flow of foreign exchange and produce as many CRMs and become self-reliant. In order to cater the demands of Indian Industries and huge potential of CRMs production, CSIR-NPL has started a massive mission mode programme in association with Ministry of Commerce and Industry (MoC) for indigenous production of CRMs/BNDs. Many MoUs have been signed with several Reference Material Producers (RMPs). Such coordinated and sustained initiatives taken by CSIR-NPL would surely entail a significant change in the socio-economic structure of the nation through an effective and reliable quality control and assurance programme. This would help enhancing barrier-free export and import of goods, services and CRMs as well as saving foreign exchange. Production of BNDs would also help in employment generation; enhance global trade and international visibility of India [31, 32].

### 3.2.4. *Laying of the Foundation Stone of 'National Environmental Standard Laboratory'*

On this historic occasion, Honourable Prime Minister Shri Narendra Modi virtually laid down the foundation stone of the National Environmental Standard Laboratory, as shown in Fig. 5 (bottom right) for the self-reliance in certification of ambient air and industrial emission monitoring equipment through CSIR-NPL Indian Certificate Scheme. The quality of data in air pollution monitoring instruments is vital in concluding the correct and reliable results. Role of measuring instruments and their calibrations are the major issues that also need to be addressed. At present, most of the used instruments are imported having product certifications from international agencies, namely United States Environmental Protection Agency (US EPA), Technischer Überwachungsverein (TUV), Germany, Monitoring Certification Scheme for Equipment, personnel and organizations (MCERTS), UK, etc. The calibration certificates issued with such instruments are as per the environmental conditions of the certification/manufacturing nation. However, the prevalent environmental conditions in India are normally different. This affects the quality and reliability of measurements taken with these equipments operating for a long time in the Indian conditions and warrants a revisit of the certification process at regular intervals.

The value of global market for the air pollution monitoring system is estimated to be about US\$ 3997.8 million, and by the year 2025 it is expected to reach US\$ 7118.7 million. Majority of such equipments along with their compliance with the concerned regulatory requirements will be installed worldwide. India along with other third world countries are the major target economies, which will offer a great market opportunity. CSIR-NPL is designated, by the ministry of Environment, Forest and Climate Change (MoEF & CC), as verification and certification agency for emission and ambient air pollution monitoring equipments in India through the notification in the Gazette of India (shown in Fig. 3). Therefore, “CSIR-NPL India Certificate Scheme (NPLI CS)” is developed by CSIR-NPL to provide certification of performance evaluation for air pollution monitoring equipments. With financial support from MoEF & CC, the CSIR-NPL is establishing a state-of-the-art ‘National Environmental Standard Laboratory’ for the performance checking of ambient air and emission pollution monitoring instruments and devices. These instruments include Continuous Ambient Air Quality Monitoring System (CAAQMS), Online Continuous Emission Monitoring Equipment (OCEMS), etc. This will provide the required testing and calibration facility for air pollution monitoring equipments. This initiative will also support the goals of ‘AtmaNirbhar Bharat’ set by the Honourable Prime Minister of India in the area of air

pollution monitoring [19, 33]. All imported as well as indigenously developed environmental monitoring equipment's will be certified using this facility. NPLI CS will be equivalent to those of the international certification schemes like MCERTS, US EPA, TUV, etc., and save over several thousands of crore Rupees worth of foreign exchange that are annually spent on calibration and certification of such equipment from abroad. NPLI CS will facilitate indigenous development and manufacturing of Air Quality and Industrial Emission monitoring equipment, making India self-reliance as well as capable of exporting.

### 3.2.5. Address by Honourable Prime Minister and President, CSIR, Mr. Narendra Modi

The honourable Prime Minister thereafter addressed the whole scientific fraternity attending the National Metrology Conclave from all over the globe through online platforms as well as physically in some of the institutions. Figure 6 depicts a small glimpse of more than two hundred thousand participants hearing one of the most inspiring speeches delivered by political or science leaders. The entire address, as published in Press Information Bureau (PIB) of India, is reproduced and included in Table 1 in Hindi as well as in English versions [34–37].

## 4. Technical Session of National Metrology Conclave [37]

The second half day of the National Metrology Conclave was exclusively devoted on the technical talks, discussions and deliberations on the theme *Metrology for Inclusive Growth of India*. Prof. Kehar Singh, Ex-Member, NPL Research Council and Chairman of the Session, welcomed all the speakers, the NMIs Directors and Executives, other



**Fig. 6** Address by Honourable Prime Minister and President, CSIR, Mr. Narendra Modi

online participants across the globe and the audience physically present in the technical session. He cited the evolution of metrology from primitive metrology mainly focused about human activities and trade or commerce in India, China, Egypt and Mesopotamia, the ancient civilizations, to its present form in modern era, viz. micro- and nanometrology. He emphasized on the plethora of books, review articles and popular journal (*Metrologia*) featuring metrology which is useful practically to all spheres of human importance, namely semiconductor industry, forensic, material science, clinical practices, automotive industries, environment, chemical industries. He, at the juncture, also highlighted the dire need of M. Tech level courses to be conducted on the metrology subject in India.

### 4.1. Comparable Measurements for a Digital World

The first talk was delivered by none other than the Director, BIPM, Dr. Martin Milton, on a most contemporary and relevant topic, i.e. *Comparable Measurements for a Digital World*. First of all, he congratulated the Director NPLI and its scientists highlighting the historic letter wherein the then BIPM Director briefed the CIPM about NPL India and the Metre Convention in October 1953, just after the establishment of the NPL in 1950 and finally India acceded to the metre convention on January 11, 1957. Having mentioned that six outstanding Indian scientists (all Directors of the NPL) were members of CIPM. He also briefed about the Task group formation on the digital SI framework towards CIPM's latest initiative (via New Digital Transformation Project) to provide a Digital SI framework for the documents and data that are fair and trustworthy. He further added about the CIPM efforts for NMIs to do Metrology in the fighting against Covid-19, and BIPM and OIML have decided that the theme for World Metrology Day-2021 would be Measurement for Health.

### 4.2. Metrology for Renewable Energies: Challenges for the Twenty-First Century

Prof. Joachim Ullrich, President, Physikalisch-Technische Bundesanstalt (PTB), Germany and Vice President, CIPM, explained the role of German NMI, i.e. PTB, towards renewable energies and underlying challenges. In context of India, he highlighted that how PTB is committed in renewable energy projects worldwide, especially developing QI and Primary Reference Solar Cell Measurement System, Climate Protection & Biodiversity and in Green Economy (Water Monitoring of the Ganga River). India centric long history of partnership, especially, SAARC project to strengthen regional cooperation in metrology, were also highlighted. As the talk progressed, Dr. Ullrich

**Table 1** The Hindi and English versions of Honourable Prime Minister's address delivered during National Metrology Conclave held on January 04, 2021 at CSIR-NPL, New Delhi to commemorate the Platinum Jubilee Foundation Day of the Laboratory [34–37]

केन्द्रीय मंत्रिमंडल में मेरे साथी डॉक्टर हर्षवर्धन जी, Principal Scientific Advisor डॉक्टर विजय राघवन जी, CSIR के मुखिया डॉक्टर शेखर सी. मांडे जी, विज्ञान जगत के अन्य सभी महानुभाव, देवियों और सज्जनों!

National Physical Laboratory की प्लेटिनम जुबली समारोह की आप सभी को बहुत-बहुत बधाई। आज हमारे वैज्ञानिक National Atomic Time-scale और 'भारतीय निर्देशक द्रव्य प्रणाली' राष्ट्र को समर्पित कर रहे हैं, और साथ ही देश की पहली National Environmental Standards Laboratory का शिलान्यास भी हुआ है। नए दशक में ये शुभारंभ, देश का गौरव बढ़ाने वाले हैं।

साथियों,

नया साल अपने साथ एक और बड़ी उपलब्धि लेकर आया है। भारत के वैज्ञानिकों ने एक नहीं दो-दो Made in India कोविड वैक्सीन विकसित करने में सफलता पाई है। भारत में दुनिया का सबसे बड़ा Covid Vaccine प्रोग्राम भी शुरू होने जा रहा है। इसके लिए देश को अपने वैज्ञानिकों के योगदान पर बहुत गर्व है, हर देशवासी आप सभी वैज्ञानिकों का, टेक्नीशियनों का, सबका कृतज्ञ है।

साथियों,

आज उस समय को भी याद करने का दिन है जब हमारे वैज्ञानिक संस्थानों ने, आप सबने कोरोना से मुकाबले के लिए, वैक्सीन को विकसित करने के लिए दिन रात एक कर दिया। CSIR समेत अन्य संस्थानों ने एक साथ आकर हर चुनौती का सामना किया, नई नई परिस्थितियों के समाधान तलाशे। आपके इसी समर्पण से आज देश में अपने इन science institutions के प्रति जागरूकता और सम्मान का एक नया भाव पैदा हुआ है। हमारे युवा आज CSIR जैसे संस्थानों के बारे में और ज्यादा जानना समझना चाह रहे हैं। इसलिए मैं चाहूँगा कि CSIR के वैज्ञानिक, देश के ज्यादा से ज्यादा स्कूलों के साथ, छात्र-छात्राओं के साथ संवाद करें। कोरोना काल के अपने अनुभवों को और इस शोध क्षेत्र में किए गए कामों को नई पीढ़ी से साझा करें। इससे आने वाले कल में आपको युवा वैज्ञानिकों की नई पीढ़ी तैयार करने में, उन्हें प्रेरित करने में बड़ी मदद मिलेगी।

साथियों,

थोड़ी देर पहले साढ़े 7 दशक की आपकी उपलब्धियों का यहाँ जिक्र हुआ है। इन वर्षों में इस संस्थान की अनेक महान विभूतियों ने देश की उत्तम से उत्तम सेवा की है। यहाँ से निकले समाधानों ने देश का पथ प्रशस्त किया है। CSIR NPL ने देश के विकास के scientific evolution और evaluation, दोनों में अपना अहम रोल निभाया है। बीते सालों की उपलब्धियों और भविष्य की चुनौतियों पर चर्चा के लिए आज यहाँ Conclave भी हो रहा है।

साथियों,

आप जब पीछे देखते हैं तो, आपकी शुरुआत गुलामी से बाहर निकले भारत के नवनिर्माण के लिए की गई थी। समय के साथ आपकी भूमिका में और विस्तार हुआ है, अब देश के सामने नए लक्ष्य हैं, नई मंजिलें भी हैं। देश वर्ष 2022 में अपनी स्वतंत्रता के 75 वर्ष पूरे कर रहा है, वर्ष 2047 में

My Cabinet colleague Dr. Harsh Vardhan; Principal Scientific Advisor Doctor Vijay Raghavan; Head of CSIR Dr. Shekhar C. Mande; other stalwarts from the scientific community; Ladies and gentlemen!

Many congratulations to you all on the Platinum Jubilee Celebration of the National Physical Laboratory. Today, our scientists are dedicating the National Atomic Time-scale and the Bhartiya Nirdeshak Dravya Pranali to the nation and the foundation stone of the country's first National Environmental Standards Laboratory is also being laid. These launches in the new decade are going to raise the profile of the country.

Friends,

The new year has brought another major achievement. Scientists of India have been successful in developing not one but TWO 'Made in India' COVID-19 vaccines. World's largest Covid vaccination Program is also going to begin in India. For this, the country is proud of its technicians and scientists' contribution; every countryman is grateful to you.

Friends,

Today is the day to remember that time too, when our scientific institutions and all of you had toiled day in and day out to challenge the coronavirus by starting to develop the vaccine. All the institutions including CSIR had come together to face every challenge and seek solutions for the new circumstances. With this dedication of yours, A new sense of awareness and respect has arisen towards these scientific Institutions in the country today. Our youth today wish to know and understand more about these institutions like CSIR. So, I would like CSIR to communicate with more and more students and schools of the country and to share your experiences in the Corona era with the new generation. This will help you in developing a new generation of young scientists for the coming tomorrow and to motivate them.

Friends,

A short while ago; your achievements over the seven and a half decades were being enumerated here. Over these years, many great personalities from this institute have served the nation. The solutions emanating from here have paved the way for the country. CSIR NPL has played a major role both in Scientific evolution & evaluation of the development of the country. Today a Conclave has been organized here today to discuss the achievements of the past years and future challenges of the country.

Friends,

When we look back, this was started for the rebuilding India that had come out of the colonial



Table 1 continued

<p>हमारी आजादी के 100 वर्ष होंगे। इस Time Period में हमें आत्मनिर्भर भारत के नए संकल्पों को ध्यान में रखते हुए नए मानकों, नए पैमानों - New Standards, New Benchmarks, को गढ़ने की दिशा में आगे बढ़ना ही है।</p>	<p>rule. Your role has expanded over time; now there are new goals and new destination in front of the country. The nation will complete 75 years of independence by 2022 and in the year 2047 it will complete 100 years of freedom. In this time period, we should set new standards, new bench-marks keeping in mind the new resolutions of a self-reliant India</p>
<p>साथियों, CSIR-NPL तो भारत का एक प्रकार से time keeper है। यानी, भारत के समय की देखरेख, व्यवस्था आपके ही जिम्मे है। जब समय की जिम्मेदारी आपकी है तो समय का बदलाव भी आपसे ही शुरू होगा। नए समय का, नए भविष्य का निर्माण भी आपसे ही दिशा जाएगा।</p>	<p>Friends, CSIR-NPL is India's time keeper i.e, it monitors India's system of time. As the responsibility of time is yours, the time must start changing from you. The beginning of a new time and a new future will also start from you.</p>
<p>साथियों, हमारा देश, दशकों से quality और मेज़रमेंट के लिए विदेशी standards पर निर्भर रहा है। लेकिन इस दशक में भारत को अपने standards को नई ऊंचाई देनी होगी। इस दशक में भारत की गति, भारत की प्रगति, भारत का उत्थान, भारत की छवि, भारत का सामर्थ्य, हमारी Capacity बिल्डिंग, हमारे standards से ही तय होंगे। हमारे देश में services की quality हो, सरकारी सेक्टर या फिर प्राइवेट सेक्टर में, हमारे देश में products की क्वालिटी हो, चाहे सरकार बनाए या प्राइवेट सेक्टर, हमारे quality standards ही ये तय करेंगे कि दुनिया में भारत और भारत के products की ताकत कितनी ज्यादा बढ़े।</p>	<p>Friends, Our country has been dependent on foreign standards in terms of quality and measurement over the decades. But in this decade, India must strive to achieve its own standards. In this decade, the India's momentum, India's progress, the rise of India, the image of India, the Strength of India and Our Capacity Building will be decided by our own standards. The quality of services and products both in the government and private sector in our country should be known by our quality standard. Only this will decide how powerful India and the Indian products are in the world.</p>
<p>साथियों, ये Metrology, साधारण भाषा में कहें तो मापने-नापने की साइंस, ये किसी भी वैज्ञानिक उपलब्धि के लिए भी बुनियाद की तरह काम करती है। कोई भी रिसर्च माप और नाप के बिना आगे नहीं बढ़ सकती। यहाँ तक कि हमें अपनी उपलब्धि भी किसी न किसी पैमाने पर मापनी ही पड़ती है। इसीलिए, मेट्रोलोजी, modernity की आधारशिला है। जितनी बेहतर आपकी मेट्रोडोलोजी होगी, उतनी ही बेहतर मेट्रोडोलोजी होगी और जितनी विश्वसनीय मेट्रोडोलोजी जिस देश की होगी, उस देश की विश्वसनीयता दुनिया में उतनी ही ज्यादा होगी। मेट्रोडोलोजी हमारे लिए मिरर की तरह होती है। दुनिया में हमारे products कहाँ stand कर रहे हैं, हमें क्या सुधार की जरूरत है, ये पहचान, ये self-introspection मेट्रोडोलोजी से ही तो संभव होता है। इसलिए, आज जब देश आत्मनिर्भर भारत अभियान, इसका संकल्प लेकर आगे बढ़ रहा है, तो हमें याद रखना है कि इसका लक्ष्य quantity भी है, लेकिन साथ-साथ quality भी उतनी ही महत्वपूर्ण है। यानी, scale भी बढ़े, और साथ-साथ Standard भी बढ़े। हमें दुनिया को केवल भारतीय उत्पादों से भरना नहीं है, ढेर नहीं खड़े करने हैं। हमें भारतीय उत्पादों को खरीदने वाले हर एक कस्टमर का दिल भी जीतना है और दुनिया के हर कोने में दिल जीतना है। Made In India की न केवल ग्लोबल डिमांड हो बल्कि ग्लोबल acceptance भी हो, हमें ये सुनिश्चित करना है। हमें Brand India को Quality, Credibility के मजबूत स्तंभों पर और मजबूत बनाना है।</p>	<p>Friends, Metrology, in a layman's language is the Science of measurement. It also acts as a foundation for any scientific achievement. No research can proceed without measurement. Even we have to measure our achievement on some scale. Therefore, metrology is the cornerstone of modernity. The better your Methodology, the better will be Metrology. And the more reliable a country's metrology is, the higher will be the credibility of that country in the world. Metrology is like a mirror for us. Metrology makes it possible for us to know where our products stand in the world or what improvements are needed. This self-introspection is possible only with metrology. Hence, today, when the country is moving forward with the resolve of Atma Nirbhar Bharat Abhiyan, we have to remember that its goal includes both quantity and quality i.e, both the scale and the standard should increase simultaneously. We just don't have to fill the world with Indian products, but also have to win the hearts of every customer who purchases Indian products. We have to ensure that the Made in India products not only have a global demand but also a global acceptance. We need to strengthen Brand India in terms of Quality and Credibility</p>
<p>साथियों, मुझे खुशी है कि भारत अब इस दिशा में तेजी से आगे बढ़ रहा है। आज भारत दुनिया के उन देशों में है जिनके पास</p>	<p>Friends, I am glad that India is now moving rapidly in this direction. Today, India is among the countries</p>

Table 1 continued

अपना नैविगेशन सिस्टम है। नाविक से भारत ने ये उपलब्धि हासिल करके दिखाई है। आज इसी ओर एक और बड़ा कदम बढ़ा है। आज जिस भारतीय निर्देशक द्रव्य का लोकार्पण किया गया है, ये हमारे उद्योग जगत को Quality Products बनाने के लिए प्रोत्साहित करेगा। अब food, edible, oils, minerals, heavy metals, pesticides, pharma और textiles जैसे अनेक क्षेत्रों में अपने 'सर्टिफाइड रेफरेंस मेटिरियल सिस्टम' को मज़बूत करने की तरफ हम तेज़ी से आगे बढ़ रहे हैं। अब हम उस स्थिति की तरफ बढ़ रहे हैं जहां इंडस्ट्री Regulation Centric Approach के बजाय Consumer Oriented अप्रोच की तरफ बढ़े। इन नए मानकों से देशभर के जिलों में वहां के लोकल प्रोडक्ट को ग्लोबल पहचान दिलाने का अभियान है, उसको बहुत लाभ मिलेगा। इससे हमारे MSMEs सेक्टर को विशेष लाभ होगा। क्योंकि बाहर की जो बड़ी मैन्युफैक्चरिंग कंपनियां भारत आ रही हैं, उनको यहीं पर International Standard की लोकल सप्लाय चैन मिलेगी। सबसे बड़ी बात, नए मानकों से Export और Import, दोनों की क्वालिटी सुनिश्चित होगी। इससे भारत के सामान्य उपभोक्ता को भी अच्छा सामान मिलेगा, Exporter की परेशानी भी कम होगी। यानी, हमारा production, हमारे products, क्वालिटी में जितना बेहतर होंगे, उतनी ही ताकत देश की अर्थव्यवस्था को मिलेगी।

साथियों,

अतीत से लेकर वर्तमान तक आप कभी भी देखें, जिस देश ने साइन्स को जितना आगे बढ़ाया है, वो देश उतना ही आगे बढ़ा है। ये Science, Technology और Industry का 'Value creation cycle' है। साइन्स से कोई आविष्कार होता है, तो उसी के प्रकाश में technology विकसित होती है और Technology से इंडस्ट्री खड़ी होती है, नए उत्पाद तैयार होते हैं, नए आईटम निकलते थे, नए प्रोडक्ट निकलते हैं। इंडस्ट्री फिर नए रिसर्च के लिए साइन्स में इन्वेस्ट करती है। और ये cycle नई संभावनाओं की दिशा में आगे बढ़ती जाती है। CSIR-NPL ने भारत के इस वैल्यू साइकिल को आगे बढ़ाने में अहम भूमिका निभाई है। आज जब देश आत्मनिर्भर भारत के लक्ष्य को लेकर आगे बढ़ रहा है, तब साइन्स से मास मैन्युफैक्चरिंग की इस वैल्यू क्रिएशन सायकिल का महत्व और बढ़ जाता है। इसलिए CSIR को इसमें बढ़ा रोल निभाना होगा।

साथियों,

CSIR NPL ने आज जिस National Atomic Timescale को देश को सौंपा है, उससे भारत Nano Second यानि एक सेकेंड के 1 अरब हिस्से तक समय को मापने में भी आत्मनिर्भर बन गया है। 2.8 Nano-second का ये एकयूरेसी लेवल हासिल करना, अपने आप में बहुत बड़ा सामर्थ्य है। अब International Standard Time को हमारा Indian Standard Time 3 नैनोसेकंड से भी कम की एकयूरेसी लेवल से match कर रहा है। इससे ISRO सहित हमारे जितने भी संस्थान Cutting edge technology में काम कर रहे हैं, उनको बहुत मदद मिलने वाली है। इससे बैंकिंग, रेलवे, डिफेंस, हेल्थ, टेलिकॉम, Weather Fore-cast, Disaster management, अनगिनत सेक्टर से जुड़ी आधुनिक टेक्नॉलॉजी में बहुत मदद मिलेगी।

which have their own navigation system. India has shown this feat with NAVIC. Today, another major step has been taken in this direction. The Bharatiya Nirdeshak Dravya (National Atomic Timescale) released today will encourage our industries to manufacture Quality Products. Various sectors like food, edible oils, minerals, heavy metals, pesticides, pharma and textiles are moving rapidly towards strengthening their 'Certified Reference Material System'. Now we are moving towards the situation where the industry will move towards a Consumer Oriented approach instead of a Regulation Centric -approach. With these new standards, the campaign to enhance the global identity of the local products in districts across the country will get a fresh boost. This will particularly be of great advantage to our MSMEs sector. The big manufacturing companies coming to India from abroad will receive a local supply chain of International Standards within India. Moreover, with the new standards the quality of both Export and Import will be ensured. It will also provide good quality products to the general consumer of India and the Exporters will also not face any problem. This means the better our production and products are, the stronger will the country's economy.

Friends,

If you look at a country's journey from the past to the present, the country which has advanced the science & technology has progressed at a faster rate. This is the 'Value creation cycle' of science, Technology and Industry. Science leads to an invention, which in turn develops a technology. Technology creates an industry. The industry then invests in science for new research and this cycle moves in the direction of new possibilities. CSIR NPL has played an important role in extending this value cycle of India. Today, when the country is moving forward towards the goal of a self-reliant India, the importance of this value creation cycle of from science to mass manufacturing increases. Therefore, CSIR will have to play a greater role in it.

Friends,

CSIR NPL today has dedicated the National Atomic Timescale to the country by which India will be able to measure 1 Nano second i.e. India has become self reliant in calculating 1 billionth part of a second. This achievement of 2.8 Nano-second accuracy level is great potential in itself. Now our Indian Standard Time is able to measure the International Standard Time at an accuracy level of less than 3 nanoseconds. With this, all our institutions including ISRO, working on cutting edge technology will be benefitted immensely. Modern technology of the various sectors like banking, railway, Defense, Health, Telecom, Weather Fore-

Table 1 continued

<p>इतना ही नहीं हम जो industry Four Point Zero की बात करते हैं। उस industry Four Point Zero के लिए भी भारत की भूमिका को सशक्त करेगा।</p> <p>साथियों, आज का भारत पर्यावरण की दिशा में दुनिया का नेतृत्व करने की तरफ बढ़ रहा है। लेकिन Air quality और Emission को मापने की Technology से लेकर Tools तक में हम दूसरों पर निर्भर रहे हैं। आज इसमें भी आत्मनिर्भरता के लिए हमने एक बड़ा कदम उठाया है। इससे भारत में प्रदूषण से निपटने के लिए ज्यादा सस्ते और प्रभावी सिस्टम तो विकसित ही होंगे, साथ में air quality और एमीशन से जुड़ी Technology के Global Market में भी भारत की हिस्सेदारी बढ़ जाएगी। हमारे वैज्ञानिकों के ही सतत प्रयासों से भारत आज ये उपलब्धि हासिल कर रहा है।</p>	<p>cast, and Disaster management will be benefitted with this. Moreover, it will strengthen India's role for Industry 4.0.</p> <p>Friends, Today's India is moving towards leading the world towards environment. But we have been dependent on others for technology to measure Air quality and Emission as well as tools. Today, we have taken a major step towards self-sufficiency in this regard too. With this, cheaper and more effective systems will be developed to deal with pollution in India. AT the same time, it will help in growing India's share in the global market in terms of technologies to measure air quality And emission. With the relentless efforts of our scientists, India is achieving this feat today.</p>
<p>साथियों, किसी भी प्रगतिशील समाज में रिसर्च जीवन का एक सहज स्वभाव भी होता है, और सहज प्रक्रिया भी होती है। रिसर्च के प्रभाव commercial भी होते हैं, सोशल भी होते हैं और रिसर्च हमारे ज्ञान को, हमारी समझ को विस्तार देने के लिए भी काम आती है। कई बार रिसर्च करते समय ये अंदाजा नहीं होता है। कि Final Goal के अलावा भी वो और किस दिशा में जाएगी, भविष्य में वो और किस काम आएगी। लेकिन इतना तय है कि रिसर्च, ज्ञान का नया अध्याय कभी भी व्यर्थ नहीं जाता है। हमारे यहां शास्त्रों में जैसे कहा है न आत्मा कभी मरती नहीं है। मैं मानता हूँ रिसर्च भी कभी मरती नहीं है। इतिहास में ऐसे कितने ही उदाहरण हैं, Father of genetics मेंडल के काम को पहचान कब मिली? उनके जाने के बाद मिली। निकोला टेस्ला के काम का potential भी काफी बाद में दुनिया पूरी तरह समझी। कई रिसर्च हम जिस दिशा में, जिस उद्देश्य के लिए कर रहे होते हैं, वो पूरा नहीं होता। लेकिन वही रिसर्च किसी दूसरे sector में path-breaking हो जाती है। उदाहरण के तौर पर देखिए, जगदीश चंद्र बोस जी ने कोलकाता के प्रेसीडेंसी कॉलेज में माइक्रोवेव के सिद्धान्त को प्रस्तुत किया, सर बोस उसके commercial इस्तेमाल की दिशा में नहीं बढ़े, लेकिन आज radio communication system उसी सिद्धान्त पर खड़ा है। विश्व युद्ध के समय जो research युद्ध के लिए था या सैनिकों को बचाने के लिए हुई, बाद में उन्होंने ही अलग-अलग sectors को revolutionize कर दिया। ड्रॉन्स भी पहले युद्ध के लिए ही बनाए गए थे। लेकिन आज ड्रॉन्स से फोटोशूट भी हो रहा है, और सामान की delivery भी हो रही है। इसलिए, आज ये जरूरी है कि हमारे वैज्ञानिक, और खासकर युवा वैज्ञानिक, research के cross utilization की हर संभावना को Explore करें। उनके sector से बाहर उनकी रिसर्च का कैसे प्रयोग हो सकता है, ये सोच हमेशा रहनी चाहिए।</p>	<p>Friends, Research life has a simple form and a smooth process in any progressive society, The impact of Research also has Commercial and social implications. Research is also useful to expand our knowledge and understanding. Often while conducting a research, it is not known that besides the final goal in which direction will it go or what more will be its use in the future. But it is certain that research and any new chapter of knowledge never goes in vain. There are many such examples in history, the work of Father of genetics Mendel received recognition posthumously. The world came to understand the potential of Nikola Tesla's work later. A lot of research work doesn't get completed with the objective or in the direction in which we move. But the same research can turn into a path-breaking invention or discovery in some other sector. For example, Jagdish Chandra Bose Ji had presented the theory of microwave at the Presidency College, Kolkata. Sir Bose didn't move in the direction of its commercial use but today the radio communication system is based on the same principle. The research conducted at the time of the world war for war-efforts or to save soldiers, later revolutionized different sectors. Drones were manufactured for the wars only. But today drones are also being used for photo-shoots, and photography. Hence, today it is important that our scientists, especially the young scientists, explore every possibility of cross utilization of research. They should always think about how their research can be used outside their sectors too.</p>
<p>साथियों, आपकी छोटी सी रिसर्च कैसे दुनिया का भविष्य बदल सकती है, कई उदाहरण हैं दुनिया में अगर बिजली का ही उदाहरण लें। आज जीवन का कोई ऐसा हिस्सा नहीं है, कोई पहलु नहीं है। जहां बिजली के बिना गुजारा हो सके।</p>	<p>Friends, Electricity is a direct example of this how a small research can change the future of the world. Today, everything from transportation, communication, industry, Or everyday life, is dependent upon electricity. The world has changed so much with the invention of a semi-conductor. A digital revolution has enriched our lives. So many possibilities are</p>

Table 1 continued

transportation हो, communication हो, industry हो, या फिर रोजमर्रा का जीवन, सब कुछ बिजली से जुड़ा हुआ है। एक सेमी कंडक्टर के आविष्कार से दुनिया इतनी बदल गई है। एक डिजिटल क्रांति ने हमारे जीवन को कितना एनरिच कर दिया है। ऐसी कितनी ही संभावनाएं इस नए भविष्य में हमारे युवा researchers के सामने पड़ी हैं। आने वाला भविष्य आज से बिलकुल अलग होगा। और इस दिशा में वो एक research, वो एक आविष्कार आपको ही करना है। पिछले छह सालों में देश ने इसके लिए नए सिरे से future ready eco-system बनाने की दिशा में काम किया है। आज भारत ग्लोबल इनोवेशन रैंकिंग में दुनिया के टॉप 50 देशों में पहुँच गया है। देश में आज बेसिक रिसर्च पर भी जोर दिया जा रहा है और पीयर-*reviewed* science and engineering publications की संख्या में भारत दुनिया के टॉप 3 देशों में है। आज भारत में industry और institutions के बीच collaboration भी मजबूत किया जा रहा है। दुनिया की बड़ी बड़ी कंपनियाँ भी भारत में अपने रिसर्च सेंटर और facilities स्थापित कर रही हैं। बीते वर्षों में इन facilities की संख्या भी बहुत ज्यादा बढ़ी है।

इसलिए साथियों, आज भारत के युवाओं के पास रिसर्च और इनोवेशन में असीम संभावनाएं हैं। लेकिन आज हमारे लिए जितना इनोवेशन क्रिटिकल है, उतना ही महत्वपूर्ण है innovation को institutionalize करना। ये कैसे हो, intellectual property की सुरक्षा कैसे हो, ये भी आज हमारे युवाओं को सीखना है। हमें ये याद रखना है कि हमारे जितने patents होंगे, उतनी utility हमारे इन patents (पेटेंट्स) की होंगी, हमारी research जितने sectors में lead करेगी, उतनी ही आपकी पहचान मजबूत होगी। उतना ही ब्रांड इंडिया मजबूत होगा। हम सबको 'कर्मण्ये-वाधिकारस्ते मा फलेषु कदाचन' के मंत्र से ऊर्जा लेकर कर्म में जुटे रहना है। और शायद इस मंत्र को जीवन में अगर किसी ने उतारा है। तो मुझे हमेशा लगता है साइंटिस्टों ने उतारा हुआ है। उनका यही मन रहता है वो Laboratory में एक ऋषि की तरह तपस्या करते रहते हैं। 'कर्मण्ये-वाधिकारस्ते मा फलेषु कदाचन' कर्म करते रहें फल मिले या न मिलो वो लगा रहता है। आप सिर्फ भारत की साइंस और टेक्नॉलॉजी के ही कर्मयोगी नहीं हैं, बल्कि आप 130 करोड़ से ज्यादा भारतीयों की आशाओं और अपेक्षाओं की पूर्ति के भी साधक हैं। आप सफल होते रहें, इसी कामना के साथ आपको नए साल की फिर से बहुत – बहुत शुभकामनाएं देता हूँ।

बहुत-बहुत धन्यवाद!

lying in front of our youth researchers in this new future. The future will be completely different from today. And in this direction, you have to conduct that one research, or invention. In the last six years, the country has worked towards developing a future-ready eco-system for the same. Today, India is among the top 50 countries of the world in the global innovation ranking. Basic research is also being emphasized in the country today and India is among the top 3 countries in the world in terms of number of Peer-reviewed science and engineering publications. Today in India, the collaboration between industry and institutions is also being strengthened. Major companies of the world are also setting up their research centers and facilities in India. In the past years, the number of these facilities has also increased a lot.

Friends,

Today, the youth of India have immense possibilities in research and innovation but is equally important to institutionalize the innovation today. Our youth has to learn about the ways it can be accomplished and the ways to protect the intellectual property too. We have to remember that the greater our patents are, the greater is the utility of the patents, the greater is the spread of our research in various sectors, the stronger will be your identity; and equally strong will be Brand India. Seeking inspiration and energy from the mantra of 'कर्मण्ये-वाधिकारस्ते मा फलेषु कदाचन', we must continue to engage with our Karma or duties. And I believe that scientists have followed this mantra religiously in their lives. They focus in their work in a meditative state in laboratories. Just like the mantra of 'कर्मण्ये-वाधिकारस्ते मा फलेषु कदाचन', they continue to do their task without focusing on the results. You are not only a practitioner of science and technology in India but also seekers who are aimed at fulfilling the hopes and aspirations of over 130 crore Indians.

I hope you succeed!

With this expectation, I wish you a very happy new year again!

Thank You!



discussed sources for climate change, their challenges and mitigation schemes in detail categorizing as renewable energy harvesting, handling and storage of harvested renewable energy and efficient use of energy, placing metrology playing its central role everywhere. His talk ended with congratulating NPL on the anniversary of its foundation. He further informed that as a token of appreciation of long association PTB and CSIR-NPL, the PTB will present CSIR-NPL a silicon sphere. Since a personal handover is not possible at the moment, the gift was presented symbolically as a photograph for the time being. The real silicon sphere is on its way to India [38].

#### 4.3. Impact from Metrology

Dr. Peter Thompson, CEO, NPL, UK, talked about the importance of metrology by quoting famous quotation of Lord Kelvin, that “To measure is to know. If you cannot measure it, you cannot improve it”. In the era of current pandemic situation, he highlighted the work of NPL UK citing its new services for pandemic Covid-19 management in response, measurement for economic recovery, technology and measurement foresighting. He emphasised on the importance of sustainability in the context of Climate, Energy and Environment. His talk ended with the remarks that NPL, UK, is looking forward to the future of metrology dealing in digital SI, complex systems and more importantly the confidence in data.

#### 4.4. Metrology for Building a Sustainable Society

The next talk was delivered by Dr. Takashi Usuda, Director General NMIJ, Japan, and Secretary, CIPM, on the recent activity carried out at NMIJ in metrology for building a sustainable society. He briefed about the organizational structure of National Institute of Advanced Industrial Science and Technology (AIST), the largest scientific institute of Japan which coordinate to enable sustainable society. His talk progressed with the highlights of current inspection technologies and cost conscious technologies of research laboratories for sustainable infrastructure, large but crucial involvement of IT and automation for inspection visualization of strain, defect and displacement measurement by imaging. He also underlined the importance of collaborations by highlighting some of NPL India and NMIJ collaborations in past, starting from 1998 along with members from NMIJ in the editorial board of MAPAN. He ended his talk with looking forward to NPL’s participation in International Measurement Confederation (IMEKO) in 2021 and APMP-2022 to be organized by Japan at Yokohama and Tokyo.

#### 4.5. The Contribution of Metrology to the Intra-Trade and Growth in Africa

Dr. Wynand Louw, Director of Research and Technology Development, NMISA, South Africa; Head of AFRIMETS Secretariat and President, CIPM talked on behalf of Mr. Mukahufhi, CEO, NMISA, South Africa. Highlighting the importance of metrology to the intra-trade and growth of Africa, he outlined the 10 flagship projects in 7 inclusive agendas of African union by year 2063, which mainly include a high standard of living, quality of life, well educated citizens and skills revolution underpinned by Science, Technology and innovation, healthy and well-nourished citizens, transformed economies and job creation, modern agriculture for increased production & productivity, blue ocean economy for the accelerated economic growth, environmentally sustainable and climate resilient economies and communities. Further, he talked about the challenges and the opportunities to strengthen the role of measurement science within the society, while actively developing new measurements that are fit-for-purpose for uniquely African problems to enable product safety, quality and compliance. Mentioning the African challenge of feeding approximately 2 million people by 2050, he highlighted the role of QI for the AfCFTA in meeting them and pan African QI. He also briefed that expected growth of the intra-AfCFTA exports to AfCFTA partners would rise in many aspects which he sees resulting a rising growth in exports by 46% from Africa to the rest of the world. The talk also outlined the African fight against Covid-19 with printing of 3D medical masks and plans towards development of CRMs.

#### 4.6. Metrology for Sustainable and Inclusive Development

Dr. B. Warrington, CEO, NMIA, Australia, warmly congratulated CSIR-NPL on its Platinum Jubilee celebrations. He quoted that enhancing science, technology and research collaborations is an important pillar and informed that a Joint Statement on a Comprehensive Strategic Partnership was held recently between the Australian and Indian Governments during June 2020. He further pointed the underlying importance of metrology for attaining 17 essential goals for sustainable and inclusive development of a nation, which were adopted by UN member states at the UN Sustainable Development Summit, held in 2015 at New York. The underlying metrology requires to meet the challenges in the development of technical capabilities of measurements in various key disciplines primarily including, chemical, physical, biological, legal measurements along with their shared capabilities but also affects major sectors, namely health, energy, environment and food. The

five APMP focus groups, important for international metrology framework and directly related to sustainable and inclusive growth, therefore justify their relevance and need attention. He further quoted Director of UNIDO's Department of Trade, Investment and Innovation, "Metrology is essential to protect the planet, ensure dignified lives for all people, and achieve inclusive economic growth and prosperity", said at the 26th CGPM in Versailles in 2018. He further explained few goals and current challenges involved therein including legal metrology, energy, preparation of reference material, proficiency testing and healthcare during Covid-19 crisis keeping NMIA in centre citing examples of different case studies. He finally mentioned future areas of metrology as transport, advanced manufacturing, defence and aerospace, digital and cyber and global partnership and cooperation for sustainable development.

#### 4.7. Metrology for Inclusive Growth of India

After these luminary talks and messages from eminent metrologists, Dr. D. K. Aswal, Director, CSIR-NPL, presented his views with quotation, "the economic growth that is distributed fairly across societies and creates opportunity for all", of the Organization for Economic Co-operation and Development (OECD). He mentioned that one of the main challenges of India is serving its huge population. He explained the existing models of growth and their bottlenecks/shortcomings together with the newly developed *Aswal model*, which is based upon metrology-driven quality infrastructure (QI) [1]. In this model, metrology-driven QI synergizes Government, industry, academia and society in much better way following the same measurement standard and as a result, the knowledge can be transferred into the wealth, leading to the high-quality life of citizens as well as high economy. While discussing the models, he further added his experience on effect of having non-uniform standards followed by different sectors of economy, namely Government, Academia, R&D, Industries, Society, Environment, etc. He further pointed out the inevitability of uniformity of standards, traceable to SI units and use of BNDs, i.e. the need of a strong QI in the country to be followed by each sector. He explained the *Aswal model* giving glimpses of the analysis of different domains including a few such as, technology development and industrialization, cyber-physical systems and cybersecurity, affordable healthcare, clean environment to level playing field in society for inclusive growth of the country.

#### 4.8. APMP Award for Developing Economies and Citation Presentation

APMP Award for Developing Economies for the year 2020 was presented to Dr. Sanjay Yadav, Senior Principal Scientist by the Director, CSIR-NPL, and Prof. Kehar Singh on the historic occasion for his outstanding contributions in his career in metrology. To name a few, he contributed significantly in registering several Calibration and Measurement Capabilities (CMCs) in KCDB, successful participation and contribution in various international key comparisons for compatibility, equivalence and global visibility of the standards, development of several primary and secondary pressure standards, publication of many research papers in SCI journals, various copyrights, patents, technologies and know-how's. The award was conferred to him by APMP Secretariat, Japan, in the recently held APMP General Assembly and Related Meetings online during November, 2020 [34]. He is the recipient of several awards and scholarships in his meritorious career from number of reputed agencies and organizations including JICA Fellowship of JAPAN (1998) and Commendation Certificates from SASO, Saudi Arabia (2003). Apart from his present key role as Editor-in-Chief of MAPAN-The Journal of Metrology Society of India (MSI) since year 2016, he is also heading the Physico-Mechanical Metrology Division of CSIR-NPL, which is responsible for realization and maintenance of four important SI base units, namely kg (kilogram), m (metre), K (kelvin) and cd (candela) along with other derived units, viz. Pa (pressure, vacuum), Hz (ultrasonics), N (force), N/mm<sup>2</sup> (hardness), W/m<sup>2</sup> (acoustics), Hz (vibration) and m<sup>3</sup>/s (fluid flow).

#### 4.9. Commemorative Messages Received from Leaders of BIPM and Various NMIs on the 75th Foundation Day

A number of messages received from the world metrology leaders from BIPM and various NMIs on this auspicious occasion of NPL Foundation Day are summarized in Table 2.

#### 4.10. Closing Remarks for NMC

The important historic event was also graced online by Prof. A. K. Grover, Chairman, Research Council, CSIR-NPL. Interestingly, in his closing remarks, Prof. Grover drawn an amusing analogy between events organised during 1950 and 2021 by quoting the fact that the NPL building was also inaugurated remotely on May 20, 1950, by the Deputy Prime Minister of India, Sardar Vallabh Bhai Patel, like the occasion is being celebrated today, i.e.

**Table 2** Messages of Leaders of BIPM and various NMI

Sl. #	Message
1.	<p>In 1953, Dr Charles Volet, the Director of the BIPM wrote to the CIPM about the future accession of India to the Metre convention. In his letter he wrote –</p> <p>“I have here a note dedicated to the description of this splendid National Physical Laboratory recently created in New Delhi. It is clear that this fine institution will deliver essential services in the grand modernisation of India. But its role will take it beyond the national frontiers. This new laboratory must become soon the equivalent of what we call the grand national laboratories”.</p> <p>Today on the 75<sup>th</sup> Foundation Day it is a pleasure for me to confirm that Dr. Volet was absolutely correct.</p> <p>Congratulations to the Directors of the CSIR-NPL and to all the staff whose work has made it into one of the grand national metrology institutes.</p> <p>I am sure it will have every success as it explores the future opportunities to support the growth of India.</p> <p style="text-align: right;"><b>- Dr. Martin J. T. Milton, Director, BIPM, France</b></p>
2.	<p>Thank you very much for the kind invitation with regard to the celebration of CSIR-National Physical laboratory’s 75th Foundation Day. Due to previously scheduled commitments, unfortunately INMETRO will not be able to attend that important online celebration.</p> <p>I would like to express my sincere happiness to see the CSIR-NPL’s long-lasting accomplishments in the field of metrology. As a National Metrology Institute of a developing country, INMETRO strongly recognizes the high value that CSIR-NPL attaches to inclusive growth.</p> <p>I present my sincere congratulations to CSIR-NPL on such important date and hope that our two institutions may find new cooperation opportunities in 2021.</p> <p style="text-align: right;"><b>- Dr. Marcos Heleno Guerson de Oliveira Junior, President, INMETRO, Brazil</b></p>
3.	<p>On behalf of the National Metrology Institute of Japan, I wish to extend my warmest congratulations for the 75th anniversary of the CSIR-NPL. This milestone is a true testament of your success and hard work, and we look forward to seeing what the next 75<sup>th</sup> years brings to our community.</p> <p>Our relationship has been making progress through some programs and I heartily wish the friendship between CSIR-NPL and NMIJ will continue and make progressively more advance in the future.</p> <p>Even during these difficult times arising out of the pandemic, I understand that it is very meaningful and valuable to organize the events online. I am delighted to give a talk entitled “Metrology for Building a Sustainable Society” at the session, and sincerely hope that the events will be successfully completed.</p> <p>It is hard to have in-person meetings recently, however, I strongly believe that the bright future will surely come very soon and look forward to seeing you in the IMEKO World Congress in Yokohama next year and the APMP GA 2022 in Tokyo.</p> <p style="text-align: right;"><b>- Dr. Takashi Usuda, Director General, NMIJ, Japan</b></p>
4.	<p>Please find below, Peter Thompson’s/NPL’s commemorative message for the compendium of the above event:</p> <p>“The National Physical Laboratory of the United Kingdom sends our warmest congratulations to the National Physical Laboratory of India on the occasion of the 75<sup>th</sup> anniversary of its foundation. Metrology is the basis on which trade, science and most strands of human activity depend and with advanced technological development the need for this to be well founded is all the more important. Our two institutes have worked together on challenges in the past and we look forward to working with friends and colleagues in CSIR-NPL on the challenges of the future.”</p> <p style="text-align: right;"><b>- Dr. Peter Thompson, Director, NPL, UK</b></p>
5.	<p>Thank you very much for the kind invitation to the National Metrology Conclave and CSIR-NPL’s 75<sup>th</sup> Foundation Day Celebration.</p> <p>On behalf of the Norwegian Metrology Service I wish to congratulate you all on this special occasion. I am convinced that CSIR-NPL will continue to play an important part regarding inclusive growth of India.</p> <p style="text-align: right;"><b>- Dr. Geir Samuelsen, Director General, JV, Norway</b></p>
6.	<p>I congratulate you and the CSIR-NPL on this especial 75<sup>th</sup> anniversary and I want to express my acknowledgement for all the achievements in the recent years. I found very fortunate the title of your event “Metrology for the inclusive growth of the country” and the release of your book. I am sure it will be an example for many National Metrology Institutes in their national and international strategies.</p> <p style="text-align: right;"><b>- Dr. José Salvador Echeverría Villagómez, General Director of Physical Metrology, CENAM, Mexico</b></p>

on January 04, 2021, and many dignitaries are connected to NPL via online mode. He also highlighted the challenges before India in present context for its inclusive growth and among the other issues; the population is a major one. The concluding remarks was finally made by Prof. Kehar Singh. In his brief concluding remarks, he outlined the messages from Honourable Prime Minister, Minister and Director General, CSIR, the usefulness of technical session and scientific excerpts from the luminaries, who graced the occasion from other leading NMIs. He mentioned the book, released on the occasion, titled, 'Metrology for Inclusive Growth of India', edited by D. K. Aswal about the importance of metrology. He also suggested the need of compendium of literature to mark the work done by CSIR-NPL Scientists on regular interval of time. He appreciated the conduct and very well management of the programme throughout and wished all the best for future endeavours in metrology on the occasion of entering the 75th Platinum jubilee. As a follow-up, the present feature article is prepared as a compendium of information for the future references.

## 5. Collaborative Programmes

The CSIR-NPL has been always endeavouring to have collaborative programmes with various NMIs and other esteemed institutions to acquire metrological expertise and gain knowledge to enhance the skills of its scientists. Such national and international programmes are utilized to impart and train the experts and technical staff from various countries at CSIR-NPL. Though the list of such co-operations is big, few of the noticeable and running programmes are summarised in this section.

### 5.1. International Collaborations

Time to time, CSIR-NPL has been implementing several international cooperation programmes to achieve the mandate of the laboratory. One of the significant technical cooperation signed in 1971 was with PTB, Germany, to enhance its standards facilities. Several new standards facilities were established under this programme apart from the upgradation of the existing standards and calibrations facilities. In Phase-1, this programme was continued till 1984. In continuation of this programme (Phase-2), during 1989–1998, few new facilities of standards and calibration services were established at CSIR-NPL along with upgradation of Central Workshop.

During 1981–1987, CSIR-NPL worked on a project sponsored by United Nations Development Programme (UNDP) and many of the primary standards of vacuum and pressure were established which are still in service even



**Fig. 7** A preparatory workshop on inter-laboratory comparison and scientific interaction program was conducted under PTB-SAARC project during November 19–December 05, 2019

today with international compatibility. In another Indo-US collaborative project, transfer leak standards were established during 1993–1996. Various advanced surface analytical facilities (XPS, AES, SAM, etc.) were also established under Indo-US project during the period 1994–1996 [39–41].

The SAARC-PTB project has been running since 2006 for strengthening, sustainability and improvement in access to trade and demand oriented quality infrastructure in South Asia region through metrology by sharing of knowledge, experience, expertise and information among the South Asian Association of Regional Cooperation (SAARC) Member States. The project is carried out in close collaboration with the network of NMIs and National Accreditation Bodies within SAARC region. On regional level, the project's main cooperation partner is the South Asian Regional Standards Organisation (SARSO), a specialized body of SAARC. This project is funded by the PTB, Germany. The CSIR-NPL has been providing all the technical support to SAARC NMIs by providing calibration and testing services, training (including on-site), inter-comparisons, etc. in various technical parameters. This project was started in 2006 and two of its phases have successfully been completed. Currently in Phase-3 (2018–2021, extended upto 2022 due to Covid-19 pandemic), one preparatory workshop (Fig. 7) and three Scientific Interaction Programmes (SIPs) have been completed in various parameters and two inter-comparisons on length and volume are under process to establish the degree of equivalence among NMIs in SAARC region. These comparisons will provide evidence to support the calibration and measurement capabilities (CMCs) of SAARC NMIs [42].

Scientists of CSIR-NPL had visited for longer durations (6 months/12 months) in National Measurement and



Calibration Laboratory (NMCL), the NMI of Saudi Arabia, and also as Saudi Arabian Standards Organization (SASO) to establish their standards, quality documents, etc. in various technical parameters under *CSIR—SASO Bilateral Technical Cooperation Programme*. Some of the CSIR-NPL experts also extended support to SASO in the development and implementation of Quality System and accreditation mechanism. Technical Officers of NMCL and SASO have also visited different standard laboratories in CSIR-NPL time to time to acquire training and/or enhance their metrological expertise and knowledge.

## 5.2. National Collaborations

The CSIR-NPL provides traceability to Regional Reference Standard Laboratories (RRSLs), Department of Legal Metrology under Ministry of Consumer Affairs, Food & Public Distribution. The RRSLs send their reference standard weights every three years and metre bar every five years to CSIR-NPL for calibration. As per the Legal Metrology (National Standards) Rules, 2011, only CSIR-NPL can provide traceability to RRSLs to maintain weights and measures system of the country [17].

The CSIR-NPL also works in close association with BIS, the National Standard Body, in formulating the documented Indian Standards (IS) for harmonisation and improvement of quality of goods. In India, some of the standards are developed indigenously, while some of them are adopted as it is or modified from the ISO and/or IEC standards based on Indian conditions. CSIR-NPL shares technical knowledge, expertise and advices to the BIS in formulating IS standards (IS) in its technical committees as members, experts, Chairman, etc. [43].

As discussed in Sect. 2.1, NABL (Accreditation Body in India) was borne and nurtured in CSIR-NPL. Even after established as an independent entity, NABL has long association with CSIR-NPL and both have been working together for establishment and upgradation of quality infrastructure of the country. The CSIR-NPL provides traceability to the accredited laboratories to maintain quality system based on ISO/IEC 17025. Numbers of Scientists and Technical Officers have been supporting NABL in accreditation process as Lead Assessors and Technical Assessors. Some of the senior Scientists and Technical Officers are also chairs and members of the various core accreditation committees as well as acting as Chairman of NABL. CSIR-NPL supported NABL by organizing proficiency testing (PT) programmes in various parameters to monitor the performance of the accredited laboratories [11].

## 6. Dissemination of Metrology—Services, Skill Trainings and Technical Supports

### 6.1. Apex Level Calibration and Testing Services

Over the years, CSIR-NPL has developed apex level measurement and calibration capabilities for all the SI base units, i.e. the kilogram, *kg* (mass); the metre, *m* (length); the kelvin, *K* (temperature); the candela, *cd* (luminous intensity); the second, *s* (time); the ampere, *A* (electric current) and the mole, *mol* (amount of substance). Further, measurement capabilities have been developed for their derived parameters used to quantify various other important quantities, namely density, viscosity, area, volume, roundness, flatness, roughness, humidity and moisture, luminance, illuminance, luminous flux, colour temperature, colour coordinates, spectral irradiances, irradiance, pressure, vacuum, ultrasonic attenuation, ultrasonic velocity, ultrasonic power, vibration amplitude, sound pressure, sound absorption and transmission coefficient, mass and volume flowrates in fluids flow, force, torque, hardness, voltage, current, electrical power, energy, impedance, resistance, capacitance, inductance, magnetic field and flux etc. To face the new challenges of advanced technologies and demand from the stakeholders, the new measurement standards and facilities are developed/being developed time to time including those of the new as well as existing parameters. Keeping in view of such sustained demands, the new time synchronisation facilities, environmental, BNDs and biomedical measurement standards are being developed [44]. These measurement standards and measurement facilities have been playing their profound role providing traceability and expertise to stakeholders and as a result in the growth of Indian economy, together with the mission programmes of Indian Government, namely Make in India, AtmaNirbhar Bharat (self-reliant India) and other initiatives. The traceability service of CSIR-NPL through apex level calibration for various parameters has been the foundation for reproducible and trustworthy products from these Indian industries and stakeholders. Further apart from this CSIR-NPL is not only playing its important role in providing technical and consultancy services to industries and entrepreneurs, but also playing a silent role by providing technical experts for many national and international committees in the areas of metrology, standardization, accreditation or policy formulation, which form the basis of over-all inclusive growth of the country.

### 6.2. Specialised Training Programmes and HRD Activities

The CSIR-NPL regularly organises training and academic services to train participants from different industries,

Government departments, NABL accredited laboratories, legal metrology offices or other users and stakeholders to provide them technical expertise with hands-on experience related to testing and calibration of various measuring equipment for different parameters. Many of such training programmes have been organized and being organized for candidates participating from India and abroad, namely from Saudi Arabia and SAARC countries like Sri Lanka, Bangladesh, Nepal, Bhutan, Afghanistan (for example Fig. 7), etc. [45, 46].

The CSIR-NPL is also offering academic programme Doctor of Philosophy (Ph. D.) for post-graduate students. Discharging its duty as an NMI of India and apex metrology laboratory, CSIR-NPL also runs skill development programmes offering one-year Post Graduate Diploma (PGD) programme under Precision Measurement and Quality Control (PMQC) every year to train and guide young engineering graduate/diploma students by providing theoretical lectures as well as experimental demonstrations to upgrade and enhance their technical skills and understanding, related to precision measurement. Both the programmes are affiliated to Academy-CSIR (AcSIR), established in 2010 (by an Act of Parliament vide The Gazette of India as an Institution of National Importance). The PGD certificate course enables them to serve better in metrology and quality management-related industries.

### 6.3. Metrology Society of India, Organisation of Advances in Metrology (AdMet) Series of National and International Conferences and Publication of MĀPAN Journal

Metrology Society of India (MSI) was formed and registered in CSIR-NPL on January 01, 1984, under the Society Act XXI of 1860 by a group of senior scientists of CSIR-NPL and some other stakeholders to promote and disseminate metrological activities in the country. The MSI in association with CSIR-NPL annually organizes Advances in Metrology (AdMet) series of national and international conferences to highlight the importance of metrology in every discipline and to provide a forum to leading metrologists worldwide, researchers, students, academicians, and industries to share, exchange, interact, discuss, exhibits and publish the advancements and latest development in the field of metrology. Until now, the MSI has organised 10 international and 7 national conferences in AdMet series apart from several other events. The MSI has also created its four chapters in North, South, East and West regions in India. Over the time, people from various sectors including graduate students have joined the society as members. At present, total members are more than 2000 including corporate members [47].

The MSI in association with CSIR-NPL and CSIR also publishes a leading SCI indexed journal of metrology, i.e. *MĀPAN-Journal of Metrology Society of India (JMSI)*. It is a quarterly publication, publishing latest development and researches in the area of measurement science. The broad coverage area of publication is exclusive devoted on scientific, industrial and legal metrology. The articles published are in the form of original work, tutorial or survey papers in any metrology related area; reviews and analytical studies in metrology; case studies on reliability, uncertainty in measurements; and reports and results of inter-comparison and proficiency testing, which are original and innovative [48]. Apart from metrologists within India, the editorial board of the journal includes the spectrum of eminent metrologists from leading world NMIs [49].

## 7. Directors of CSIR-NPL

On this occasion, the authors considered it is most appropriate to include all the eminent science leaders who served as Directors of this premier institution. All these Directors of the CSIR-NPL have significantly contributed in the glorious and illustrated journey of 74 years with their tenures. The journey of CSIR-NPL as NMI was started signing Metre Convention by Dr. K. S. Krishnan in 1957 and still continued with adoption of resolution of redefinition of SI units in November, 2018 and implementation of redefined SI units in 2019 on World Metrology Day, i.e. May 20, 2019, by Dr. D. K. Aswal, the present Director. Figure 8 shows the tenures of all the Directors who have played a leading role to move forward this premium national laboratory serving the nation as NMI.

## 8. Some of the Milestones Achieved by CSIR-NPL

Over the years, CSIR-NPL has done exceedingly well and achieved several noticeable milestones of national and international eminence. It is difficult to describe all such accomplishments in a single article due to obvious reasons of limitation of space. However, some of the major achievements are described as follows;

### 8.1. Development of Indelible Ink—the Mark of Democracy

The indelible ink, the mark of Indian democracy, used during the elections, was developed by CSIR-NPL in the year 1952. The ink contains silver nitrate. When it is applied on the nails, it reacts and with further exposure to light, the dark purple colour mark appears. Once ink is applied on the fingernails its mark remains on the fingernail

**Fig. 8** Directors of CSIR-NPL with their tenures



**Fig. 9** Indian Polar Space Physics Laboratory, Maitri, Antarctica

for about two days to a month depending upon the body temperature of person and the environmental conditions. This technology was transferred to M/s Mysore Varnish and Paints Ltd. (MVPL) in the year 1962 for mass production [50]. Currently, MVPL is exporting the indelible ink to about 25 countries, such as, Thailand, South Africa, Nigeria, Ghana, Singapore, Malaysia, etc. Therefore, this indelible ink developed by CSIR-NPL is a gift to India and several other countries.

### 8.2. Contributions in Antarctica expeditions

CSIR-NPL played national leadership in the four Indian Scientific Expeditions to Antarctica (ISEA). The 8th and

31st Indian Scientific Expeditions were noticeable as important milestones for Indian Antarctic mission when the two permanent scientific bases, i.e. Bharati ( $69^{\circ} 24' S, 76^{\circ} 11'$ ) and Maitri ( $70^{\circ} 46' S, 11^{\circ} 43' E$ ), were established by India. With the establishment of these two permanent stations, India joined the elite club of nations having more than one scientific base in Antarctica. During 28th ISEA (2008–2009) CSIR-NPL had played a pivotal role in establishing an advanced Polar Space Physics Laboratory (IPSP) at Indian Permanent Research Base ‘Maitri’, Antarctica (Fig. 9) on the occasion of International Polar Year (IPY). The permanent research base station ‘Maitri’ plays its crucial role in continuous and real-time monitoring of ionosphere to address the scientific interest of high latitudinal ionospheric consequences, caused by the modulation of near-earth space environmental conditions [51].

### 8.3. Preservation of original copies of the Constitution of India

One of the other great contributions of CSIR-NPL to the country is the preservation and periodic maintenance of the “Original Copy of the Constitution of India” (both Hindi and English) which is kept and maintained at Parliament Library, New Delhi, [1, 52, 53]. For this purpose, two hermetically sealed glass cases were designed and developed by CSIR-NPL in association with Getty Conservation Institute, USA, to maintain controlled humidity, temperature and oxygen level for the safe and sustained preservation of Calligraphic copies. The “Constitution of India”, written

under the chairmanship of Dr. B. R. Ambedkar, was adopted by the Constituent Assembly on November 26, 1949, which came into force on January 26, 1950. Both the original calligraphed copies are bound in first-class Morocco leather embossed in gold. These copies have great autographic and the original signatures of the founding fathers of the Constitution give them additional historical value. Since 1994, responsibility has been given to CSIR-NPL for the preservation of these prestigious documents.

#### 8.4. Biomedical Metrology

Indian government has recently passed 'Medical Device Rule 2017' to administer the quality and conditions of the medical devices being used to support the healthcare sector [54]. It emphasises the requirements to establish the testing and calibration centres for medical devices for implementing and maintaining quality control regulations in Indian healthcare sectors. Using novel biocompatible sensing materials, CSIR-NPL is fabricating indigenous point-of-care devices for the diagnosis of chronic disease, namely heart disease and renal dysfunction to help and support their manufacturers. The calibration and testing facilities for biomedical equipment, viz. the defibrillator machine, defibrillator analyser and the electrical safety analyser, have been established, recently [55].

#### 8.5. Development of Some of the Key Technologies

##### 8.5.1. *Development of Hydroelectric Cell* [56, 57]

Recently, the development of the hydroelectric cell is a noticeable contribution of the decade. After untiring efforts of 13 years in the laboratory such water driven cell is invented. The realization of the invented cell is achieved through conversion of water into electricity. CSIR-NPL has been granted American and Indian patents for this invention. This water running hydroelectric cell can be used in the laptops, torches, mobile phones etc. and is harmless to the environment because water is being used as fuel. This cell is unique invention in field of green energy. In this cell, lithium substituted magnesium ferrite is used which is abundantly available in India. This material ionizes the water molecule at room temperature. Those ions are being collected at two different electrodes. Thus, due to flow of ions electricity generates. Hydroelectric cell would be a good alternative to the solar cell and fuel cell.

##### 8.5.2. *Technology for Converting Waste Plastic into Tiles* [58]

India generates approx. 10 million tonnes of plastic waste every year and as per Environment Ministry, nearly 40% of

which is not collected back for their safe recycling. In general, this waste plastic is dumped in open space that not only adds unwanted environmental pollution in different forms but also poses serious health hazards to living beings.

Disposal of plastic waste has been a major challenge because of its non-biodegradable nature and it consists of low-density polyethylene. Disposal through burning of these waste plastic bags causes environmental pollution. In this direction, a process technology was developed by CSIR-NPL for useful recycling of plastic waste into designing materials, paver, roof tiles and interlocks, for their rugged and waterproof applications in pathways, gardens, lanes, footpaths, false ceilings etc. This novel transformational technology not only presents a safe disposal of plastic waste but also presents an eco-friendly conversion of plastic waste into useful alternatives, at the same time, to fulfil the societal needs and mitigate environmental problems, caused due to plastic waste. This technology has been well accepted and transferred to several industries and start-ups.

##### 8.5.3. *Solar Photovoltaic (PV) System* [59]

CSIR-NPL has established the secondary standard facility for efficiency validation of solar cells. A major program is taken up for the establishment of primary standard in collaboration with PTB Germany. India has targeted the PV installations of 100 GW by the year 2022 under the National Solar Energy Mission. CSIR-NPL has a vibrant photovoltaic group in the country with a rich history in silicon based photovoltaics since last four decades. CSIR-NPL has developed silicon solar cells, for the first time in the country, in mid 70's. CSIR-NPL is the first laboratory to demonstrate the complete process 'from metallurgical grade silicon to solar grade polysilicon and fabrication of solar cells. Recently, CSIR-NPL has initiated the work on recycling of silicon solar cells/modules.

##### 8.5.4. *Methane Emissions*

After economic liberalisation of India in the year 1991, the industrial developments started growing manifold with the investment of several multinational companies, which set up manufacturing units in India. This industrial growth also brought the increment in the emission of several pollutant gases out of different sectors like sewage plants, chemical industries, sugar factories, power generation stations, etc. Indian scientists proved the actual methane emissions from the Indian paddy fields is only of the order of 3.46 Tg/year [60, 61] against the controversy over the large methane emission from paddy fields in India (which was earlier estimated as 37.4 Tg/year). This calls for the preparation of



**Table 3** Visits of Eminent Science Leaders to CSIR-NPL India

S. No.	Name of Speaker	Year	Title/ Visit to laboratory/ Event/Occasions
1.	Dr. J. D. Bernal, FRS, Professor of Physics at Birkbeck College, University of London	1950	Opening ceremony of the National Physical Laboratory
2.	Dr. Robert Robinson, NL-1947, President of Royal Society, London, FRSE	1950	Addressed the large gathering of eminent scientists from across the world and great political visionaries of India on the opening ceremony of the National Physical Laboratory
3.	Dr. Edward Condon, Director, National Bureau of Standards (Now NIST)	1950	Opening ceremony of the National Physical Laboratory
4.	Prof. O. E. H. Rydbeck, Director, Research Laboratory of Electronics, Chalmers University of Technology, Gothenburg, Sweden	1950	Opening ceremony of the National Physical Laboratory
5.	Dr. P. Auger, Director, Department of Mathematical and Natural Sciences at UNESCO	1950	Opening ceremony of the National Physical Laboratory
6.	Dr. S. S. Bhatnagar, FRS, Director General, CSIR	1950	Addressed the large gathering of eminent scientists from across the world and great political visionaries of India on the opening ceremony of the National Physical Laboratory
7.	Dr. H. J. Bhabha, FRS, Chairman, Atomic Energy Commission, Professor, Tata Institute of Fundamental Research, Bombay	1950, 1955	Opening ceremony of the National Physical Laboratory, CSIR Governing Body Meeting
8.	Dr. K. N. Mathur, Member Secretary of the Planning Committee	1950	Opening ceremony of the National Physical Laboratory
9.	Dr. M. S. Thacker, Director General, CSIR	1955, 1956, 1958	CSIR Governing Body Meeting and various other meetings
10.	Dr. S. Chandrasekhar, FRS & NL- 1989	1961 1969 1986 1989	Visited different Labs of NPL Visited different Labs of NPL Visited different Labs of NPL Speaker of Dr. K.S. Krishnan Memorial Lecture
11.	Dr. P. M. S. Blackett, NL-1948, Head of the Physics Department of the Imperial College of Science and Technology, London	1963, 1971	Report on National Physical Laboratory, New Delhi
12.	Dr. K. R. Ramanathan, Director, Physical Research Laboratory (PRL), Ahmadabad	1965	Dr. K.S. Krishnan Memorial Lecture
13.	Dr. S. Hussain Zaheer, Director General, CSIR	1967	On the occasion of NPL Open Day
14.	Mr. Triguna Sen, Honourable Minister of Science and Technology, India	1968	On the occasion of NPL Open Day
15.	Dr. D. S. Kothari, Chairman of the University Grants Commission, Chancellor, Jawaharlal Nehru University, New Delhi	1968 1969 1971 1988 1990	Dr. K.S. Krishnan Memorial Lecture and Visit to NPL with the Prime Minister of India NPL Executive Committee meeting NPL Science Exhibition On releasing of NPL Technical Bulletin On release of Special Issue on 'Pt. Nehru & NPL'
16.	Dr. S. N. Bose, FRS, General President of the Indian Science Congress, also Advisor to CSIR	1969 1971	NPL Executive Committee meeting Speaker of Dr. K.S. Krishnan Memorial Lecture
17.	Dr. C. V. Raman, NL-1930, FRS, Founder of Raman Research Institute, India	1970	Addressed the gathering of Scientists at Dr. K.S. Krishnan Memorial Lecture
18.	Dr. Atma Ram, Director General, CSIR	1969 1971	Visiting different laboratories with Dr. S. Chandrasekhar, NL A Symposium at NPL
19.	Dr. Vikram Sarabhai, Chairman, Indian National Committee for Space Research and Indian Space Research Organisation (ISRO)	1971	A symposium in NPL

**Table 3** continued

S. No.	Name of Speaker	Year	Title/ Visit to laboratory/ Event/Occasions
20.	Dr. A. Kastler, NL-1966, Professor, Ecole Normale Supérieure, Paris	1972	Speaker of Dr. K.S. Krishnan Memorial Lecture
21.	Dr. P. L. Kapitsa, NL-1978, Founder Professor of Moscow Institute of Physics and Technology	1974	Addressed the gathering of Scientists
22.	Mr. Fakhruddin Ali Ahmed, Honourable President of India	1975	Visiting different laboratories at NPL
23.	Dr. Satish Dhawan, Director, Indian Institute of Science (IISc), Bangalore Chairman, Indian Space Research Organization (ISRO), India	1976	Symposium in NPL
24.	Dr. M. G. K. Menon, Director General, CSIR	1981 2007	Visited Microwave Lab Golden Jubilee of Radio Science Division at NPL
25.	Dr. Abdus Salam, NL-1979, FRS, Founder of the International Centre for Theoretical Physics (ICTP), Trieste, Italy	1981	Visited different Laboratories of NPL
26.	Dr. G. S. Sidhu, Director General, CSIR	1981	Visited different Laboratories of NPL
27.	Dr. I. Prigogine, NL-1977, Director of the Center for Statistical Mechanics and Thermodynamics, Belgium	1983	Speaker of Dr. K.S. Krishnan Memorial Lecture
28.	Dr. P. W. Anderson, NL-1977, Professor Emeritus of Physics at Princeton University, New Jersey	1986	Speaker of Dr. K.S. Krishnan Memorial Lecture
29.	Dr. A. P. Mitra, FRS, Director General, CSIR	1986 1989 1997 2005 2007	On Dr. K.S. Krishnan Memorial Lecture On the occasion of Rajiv Gandhi S & T Lecture URSI General Assembly  Golden Jubilee of Radio Science Division at NPL & 18th AGM of MRSI
30.	Dr. A. Hewish, NL-1974, Professor of Radio Astronomy in the Cavendish Laboratory, University of Cambridge	1988	Speaker of Dr. K.S. Krishnan Memorial Lecture
31.	Dr. A. Guinier, Professor, University of Paris-Sud in Orsay, Paris	1990	Releasing special issue on ' <i>Pt. Nehru &amp; NPL</i> '
32.	Dr. S. K. Joshi, Director General, CSIR	1992	On Dr. K.S. Krishnan Memorial Lecture
33.	Dr. C. H. Townes, NL-1964, Professor of Physics, University of California at Berkeley	1991 1997	Speaker of Dr. K.S. Krishnan Memorial Lecture Speaker of Rajiv Gandhi S & T Lecture
34.	Dr. N. F. Ramsey, NL-1989, Professor of Physics at Harvard University	1993	Speaker of Dr. K.S. Krishnan Memorial Lecture
35.	Dr. P. G. De Gennes, NL-1991, Professor at the Collège de France, Paris	1996	Speaker of Dr. K.S. Krishnan Memorial Lecture
36.	Dr. R. A. Mashelkar, FRS, Director General, CSIR	1997 2001 2002 2003 2003 2004 2005 2006 2007	30 Years of Progress in Atmospheric Chemistry Launch of NPL website Dr. S S Bhatnagar award presentation On his 60th Birthday celebration On CSIR Diamond Jubilee Celebration On CSIR Foundation Day On Dr. K.S. Krishnan Memorial Lecture On Dr. K.S. Krishnan Memorial Lecture Golden Jubilee of Radio Science Division
37.	Dr. P. J. Crutzen, NL-1995, Professor Aeronomy at the Department of Physics and Astronomy, Utrecht University, The Netherlands	1997	Speaker of Dr. K.S. Krishnan Memorial Lecture
38.	Dr. R. Chidambaram, Chairman, Research Council, NPL & Secretary, Dept. of Atomic Energy of India	1998, 2008, 2019	NPL-PTB Co-operation project ceremony function, 14th APAM Conference, Inauguration function of International Metrology Day

**Table 3** continued

S. No.	Name of Speaker	Year	Title/ Visit to laboratory/ Event/Occasions
39.	Dr. R. L. Mossbauer, NL-1961, Emeritus Professor of Physics, Technical University of Munich	1998	Speaker of Dr. K.S. Krishnan Memorial Lecture
40.	Dr. Hideki Shirakawa, NL-2000, Emeritus Professor at University of Tsukuba, Ibaraki, Japan and Zhejiang University, China	2005	Speaker of Dr. K.S. Krishnan Memorial Lecture
41.	Dr. Alan J. Heeger, NL-2000, Former Professor of Physics at University of California, Santa Barbara	2005	Speaker on Plastic electronics and Optoelectronics
42.	Dr. C. N. R. Rao, Bharat Ratna, Honorary President of Jawaharlal Nehru Centre for Advanced Scientific Research, Bangalore and Chair of the Scientific Advisory Council to Prime Minister of India	1997 2006	Visit on Rajiv Gandhi S & T Lecture, Speaker of Dr. K.S. Krishnan Memorial Lecture
43.	Dr. K. Kasturirangan, Chancellor of Central University of Rajasthan, Chairman of the Indian Space Research Organisation (ISRO)	2007	Golden Jubilee of Radio Science Division at NPL
44.	Dr. Anil Kakodkar, Secretary, Department of Atomic Energy and Chairman, Board of Governors of the Indian Institute of Technology, Bombay	2007	Visited different laboratories of NPL & 18th Annual General Meeting of Material Research Society India
45.	Prof. Samir K. Brahmachari, Director General, CSIR	2007–2013	On various occasions
46.	Prof. Yash Pal, Chancellor of Jawaharlal Nehru University, New Delhi	1988, 2008	On various occasions
47.	Dr. Jose Manuel Silva Rodriguez, Director General of the European Commission	2007 2010	Laboratory visit News from quantum effects in two-dimensional systems
48.	Prof. T. V. Ramakrishnan, FRS, Emeritus Professor, Banaras Hindu University, Varanasi, India	2010	Speaker of Dr. K.S. Krishnan Memorial Lecture
49.	Prof. Ajay K. Sood, FRS, IISc Bangalore, Chairman, Research Council of CSIR-NPL	2011–2016	RC Meetings and on several other occasions
50.	Dr. Girish Sahni, Director General, CSIR	2013–2018	On various occasions
51.	Prof. Dr. Klaus von Klitzing, NL-1985, Director, Max Planck Institute for Solid State Research, Stuttgart, Germany	2010, 2016 2021	Speaker of Dr. K. S. Krishnan Memorial Lecture Plenary Talk on SI Units (AdMet -2016) Virtual Address and Lecture on National Science Day-2021
52.	Dr. Stuart S. P. Parkin, FRSE, IBM Fellow	2013	Speaker of Dr. K.S. Krishnan Memorial Lecture
53.	Prof. Richard Henry Friend, FRS, Cavendish Professor of Physics at the University of Cambridge	2006 2014	Delivered invited lecture Speaker of Dr. K.S. Krishnan Memorial Lecture
54.	Prof. G. S. Agarwal, FRS, Professor, Texas A & M University, Texas (USA), Former Director, Physical Research Laboratory (PRL), Ahmedabad	2007	Delivered invited lecture
55.	Prof. J. H. Ullrich, President, PTB, Germany	2013 2016, 2017 2021	Keynote Address (AdMet -2013) Keynote Address (AdMet -2016) Metrology in the International Quality Infrastructure Redefinition- tasks and strategies for the BIPM (APMP-2017) Virtual to deliver a Talk at National Metrology Conclave 2021
56.	Dr. Shekhar Basu, Secretary, Department of Atomic Energy and Chairman Atomic Energy Commission of India	2016	India International Science Festival (IISF)-2016 and various other occasions
57.	Prof. K. L. Chopra, Indian Material Physicist and Former faculty Indian Institute of Technology (IIT), Delhi, Former Director, IIT, Kharagpur	2016	India International Science Festival (IISF)-2016 and various other occasions
58.	Prof. Anil D. Sahasrabudhe, Chairman, All India Council for Technical Education (AICTE)	2016, 2020	India International Science Festival (IISF)-2016 and various other occasions Talk on 'Metrology in Education' on World Metrology Day-2020

**Table 3** continued

S. No.	Name of Speaker	Year	Title/ Visit to laboratory/ Event/Occasions
59.	Prof. Vijay P. Bhatkar, Chairman of Board of Governors of Indian Institute of Technology (IIT) Delhi, Founder Executive Director of C-DAC (Centre for Development of Advanced Computing, India)	2016	India International Science Festival (IISF)-2016 and various other occasions
60.	Prof. K. Vijay Raghavan, FRS, Principal Scientific Adviser to Government of India, Former Secretary, Department of Biotechnology (DBT), India	2016–2021	India International Science Festival (IISF)-2016 and various other occasions
61.	Dr. Alok Prakash Mittal, Member Secretary, AICTE	2016	India International Science Festival (IISF)-2016
62.	Prof. Yogesh Singh, Vice Chancellor of Delhi Technological University, Delhi	2016	India International Science Festival (IISF)-2016
63.	Dr. V. K. Saraswat, Director General, Defence Research and Development Organisation (DRDO), Chancellor of Jawaharlal Nehru University, New Delhi, Member, NITI Aayog (Planning Commission of India)	2017	Visited to deliver invited talk
64.	Dr. Martin Milton, Director BIPM, France	2016 2017 2021	Keynote Address and Chief Guest, AdMet 2016 Panel discussion on APMP Future Development (APMP-2017) Virtual To deliver a Talk at NMC-2021
65.	Dr. Toshiyuki Takatsuji, APMP Chair, NMIJ Japan	2017	Panel discussion on APMP Future Development (APMP-2017)
66.	Prof. A. K. Grover, Chairman, Research Council, CSIR-NPL, Former Vice-Chancellor, Panjab University, India	2017–2021	Invited to deliver talk on various occasions and celebrations
67.	Dr. Shekhar C. Mande, Director General-CSIR	2018, 2019, 2020, 2021	Visited on various occasion and celebration and dedication of achievements of NPL
68.	Dr G. Satheesh Reddy, Secretary, Department of Defence R&D and Chairman, Defence Research and Development Organisation (DRDO)	2019	Not Available
69.	Dr. Thomas Liew, Executive Director, NMC, A*STAR, Singapore	2019	Keynote Address (AdMet -2019)
70.	Dr. Walter G. Copan, Director, NIST	2019	Keynote Address (AdMet -2019)

methane standard and it was successfully developed by the CSIR-NPL at the time.

#### 8.5.5. Carbon Technologies

The advanced carbon products/materials, magnetic and thermoelectric materials developed at CSIR-NPL are catering the need of the country in the industrial, health, energy as well as strategic sectors like defense, aerospace and nuclear power. Some of the recently developed carbon technologies are, activated carbon, flexible multi wall carbon nanotubes bucky/paper for Li batteries, single layer graphene by CVD, torrefied rice straw pellets for thermal power plants, high density nuclear grade graphite, CNT yarn and CNT based body armour materials to name a few [62].

## 9. Visitors of CSIR-NPL

The CSIR-NPL has always been the centre of interest, importance, relevance and place of attraction for the visitors from various fields across the globe. During all these years, a list of the world-renowned dignitaries who have visited CSIR-NPL are summarised in Table 3 for science leaders and in Table 4 for political leaders. These visitors include Presidents, Prime Ministers, other Ministers of different countries, Nobel Laureates, Metrologists, Policy makers, etc.

## 10. Conclusion

An illustrated, glorious and magnificent journey of CSIR-NPL, the NMI of India, highlighting its accomplishments



**Table 4** Visits of elected key Representatives/ Political Leaders of India and abroad to CSIR-NPL India at various Occasions/ Events

Sl. No.	Name of Speaker, Country	Year
1	Mr. Jawahar Lal Nehru, Honourable Vice President of the Interim National Government of India	1947
2	Mr. Jawahar Lal Nehru, Honourable First Prime Minister of India	1950, 1955, 1956, 1958, 1961
3	Sir C. Rajagopalachari, Bharat Ratna, Honourable Governor General of India	1950
4	Sardar Vallabhbhai Patel, Honourable Deputy Prime Minister of India	1950
5	Dr. Shyama Prasad Mookerjee, Honourable Minister for Industry and Supply	1950
6	Dr. Rajendra Prasad, Honourable President of India	1951
7	Lord Halifax, Ex. Viceroy of India and Lady Halifax	1952
8	Mr. Clement Attlee, Honourable Prime Minister of United Kingdom	1953
9	Mohammad Ali, Honourable Prime Minister of Pakistan	1953
10	Mr. S. R. Sidky, Honourable Minister for Agriculture, Egypt	1954
11	Mr. Marshal J. B. Tito, Honourable President of Yugoslavia	1954
12	The Crown Prince of Saudi Arabia	1955
13	Mr. Sukarno, Honourable President of Indonesia	1955
14	Mr. N. A. Bulganin, Honourable Prime Minister of Soviet Union	1955
15	Mr. G. A. Nasser, Honourable President of Egypt	1955
16	The Princess of Laos	1955
17	Ms. Ratna, Queen of Nepal	1955
18	Mr. Sukarno, Honourable President of Indonesia	1955
19	Mr. N. A. Bulganin, Honourable Premier of Soviet Union	1955
20	The Dalai Lama of Tibet, Tibet	1956
21	Mr. Tanka Prasad Acharya, Honourable Prime Minister of Nepal	1956
22.	Mr. Zhou Enlai (Chou En-Lai), Honourable Premier of People's Republic of China	1956
23.	Mr. Lal Bahadur Shastri, Honourable Minister of Railways and Transport	1958
24.	Mr. Harold Macmillan, Honourable Prime Minister of United Kingdom	1958
25.	Mr. V. Siroky, Honourable Prime Minister of Czechoslovakia	1958
26.	Mr. Humayun Kabir, Honourable Minister of Science & Technology of India	1958, 1961
27.	Prince Philip, Duke of Edinburgh	1959
28.	Prince Akihito of Japan, Japan	1960
29.	Mrs. Indira Gandhi, Honourable Prime Minister of India	1966, 1968, 1975
30.	Dr. S. Radhakrishnan, Honourable Vice-President of India	1960
31.	Mr. U. Nu, Honourable Prime Minister of Burma	1961
32.	Mr. Paul King and Frederika Queen of Greece	1963
33.	King Hussein I of Jordan	1963
34.	Mr. Georges Raymond Pompidou, Honourable Prime Minister of France	1965
35.	Dr. Karan Singh, Honourable Union Minister of Tourism and Civil Aviation of India	1971
36.	Mr. Fakhruddin Ali Ahmed, Honourable President of India	1975
37.	Dr. Nurul Hassan, Honourable Minister of Science & Technology of India	1977
38.	Md. Yousif Shiromi, Honourable Minister of Bahrain	1988
39.	Sir. S. Ramphal, Commonwealth Secretary General	1989
40.	K. R. Narayanan, Honourable Minister of Science & Technology of India	1989
41.	Mr. P. V. Narasimha Rao, Honourable Prime Minister of India	1991
42.	Mr. Chandra Shekhar, Honourable Prime Minister of India	1991
43.	Dr. Y. K. Alagh, Honourable Minister for Science & Technology of India	1997
44.	Mr. Atal Behari Vajpayee, Honourable Prime Minister of India	2002
45.	Dr. M. M. Joshi, Honourable Union Minister of Human Resource Development of India	2002
46.	Mr. Bachi Singh Rawat, Honourable Union Minister of State, Department of Science and Technology, Ministry of Science and Technology	2002

**Table 4** continued

Sl. No.	Name of Speaker, Country	Year
47.	Dr. A. P. J. Abdul Kalam, Honourable President of India	2003, 2005
48.	Dr. Prithviraj Chavan, Honourable Union Minister of Science and Technology	2010
49.	Mr. Vilasrao Deshmukh, Honourable Union Minister of Science and Technology	2011
50.	Mr. S. Jaipal Reddy, Honourable Union Minister of Science and Technology	2012
51.	Dr. Farooq Abdullah, Honourable Union Minister of New and Renewable Energy, India	2012
52.	Mr. Kapil Sibal, Honourable Union Minister of Science and Technology	2004, 2007, 2008, 2009
53.	Mr. Y. S. Chaudhary, Honourable Minister of State for Science and Technology	2015, 2016
54.	Mr. Soren Pind, The Honourable Danish Minister of Science, Innovation and Higher Education	2016
55.	Mr. Anil Madhav Dave, Honourable Minister of State (Independent Charge) for Environment, Forest and Climate Change	2016
56.	Dr. Jitendra Singh, Honourable Union Minister of State for Prime Minister's Office of India and Minister of State, Department of Space and Department of Atomic Energy	2018, 2019
57.	Dr. Harsh Vardhan, Honourable Minister of State for Science and Technology	2016, 2018, 2019, 2021
58.	Mr. Rajnath Singh, Honourable Union Minister of Home Affairs	2016
59.	Dr. Suresh Prabhu, Honourable Union Minister of Railways	2016
60.	Mr. Narendra Modi, Honourable Prime Minister of India (Virtual addressing)	2021

\*The listed information presented in above Tables 3 and 4, are not exhaustive and are based on the available information and resources

^NL – Nobel Laureate

+FRS – Fellow of the Royal Society

±FRSE—Fellow of the Royal Society, Edinburgh

<sup>†</sup>Bharat Ratna – The Highest Civilian Award of India

Information regarding visits of the important dignitaries can be accessed at <https://www.nplindia.in/down-memory-lane> and <https://www.nplindia.in/npl-annual-report>

from its birth in 1947 to recently celebrated 74th Foundation Day on January 04, 2021, is described and presented in a though concise but exhaustively adequate review report. The establishment of CSIR-NPL as NMI of India and its crucial role in the inclusive growth of the country over the years is outlined, as also highlighted by the Honourable Prime Minister of India in his NPL Foundation Day Speech and Honourable President of India in his Presidential Address of Joint Parliament Session on January 29, 2021. His Excellency mentioned, “Our very own Navigation Satellite System ‘NavIC’ is also enhancing the prestige of the country. Thousands of fishermen are now benefitting from it. New standards have been set in the form of National Atomic Timescale and Bhartiya Nirdeshak Dravya Pranali, which were dedicated to the nation recently. These indigenous solutions will help in developing Indian products as per international standards”. The journey of contributions to the nation included few milestones, namely development of indelible ink, preservation of original copy of the Constitution of India, solar photovoltaic technology, methane emission, contribution to Indian Antarctica missions etc. The article also includes the pioneering achievements on National Atomic Timescale, Bhartiya Nirdeshak Dravya (BND®)—CRM, foundation

of National Environmental Standard Laboratory dedicated to the nation, by the Honourable Prime Minister of India for nation building. A list of galaxy of scientific and political leaders, visionaries who made their visit to this esteemed institution ever since its inception and witnessed its journey as grand national laboratory of India, taking its role beyond the national frontiers, is also summarized at the end. The feature article therefore, would certainly serve as a useful reference document with relevant information, for researchers, scientists, academicians, policy makers, regulators, administrators, industries, stakeholders and science historians, collected at one place.

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