Chapter 21
CSIR-NPL: Growth Driver for Effective Implementation of National Policies

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Abstract In the previous chapters, the metrological capabilities of CSIR-NPL in various parameters related to physical, chemical, engineering, biomedical, environmental, etc. along with their dissemination to various stakeholders have been explicitly deliberated upon. In this concluding chapter, we discuss how CSIR-NPL has been contributing to the nation by supporting the government in implementing its policies. A brief discussion on the ‘Atmanirbhar Bharat’ program, which is a paradigm shift towards the indigenous development of product, is presented. The applicability of Aswal model of inclusive growth—metrology is the requisite for coordination

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amongst the government, academia, industry, and civil society—for implementing the policies of Atmanirbhar Bharat is discussed. In this perspective, an overview of the contributions made by CSIR-NPL in recent past to various stakeholders (government, industry, and academia) through its services of metrological traceability of SI units, Indian Standard Time (IST) dissemination, development of Bhartiya Nirdeshak Dravyas (BNDs), transfer of technologies, consultancy services, R&D projects and training on metrological programs are elaborated. The efforts of CSIR-NPL in publicizing the role of metrology for the national growth are discussed, which include the celebration of World Metrology Day every year on May 20, inviting students, entrepreneurs, and common citizens to CSIR-NPL for discussions on metrology and its applications, organizing the science festivals like India International Science Festival (IISF-2016), etc. The Chapter is concluded with suggestions on how CSIR-NPL should strengthen its capabilities and discharge its duties to fulfill the dreams of a self-reliant India.

Accurate and precise measurements are essential to drive the growth engines of Indian Science & Industry as it removes chaos and prompts innovations, which in turn, would save precious lives, resources and time. Let us strengthen CSIR-NPL for a better future of the country.

– D.K. Aswal

21.1 Introduction: Make in India and Atmanirbhar Bharat

The Government of India launched the ‘Make in India’ program on September 25, 2014, with an intention to encourage foreign companies to manufacture their products in the country. This policy was aimed at the growth of the manufacturing sector, the creation of additional jobs in the manufacturing sector, and to enhance the contribution of manufacturing to the GDP of the country [1]. On the other hand, Atmanirbhar Bharat Abhiyan (Self-reliant India Mission) was launched by the Government of India on May 12, 2020, which was aimed at recuperation of the economic slowdown due to COVID-19 pandemic [2]. Under Atmanirbhar Bharat Abhiyan, a stimulus economic package of Rs 20 Lakh Crore (equivalent to 10% of India’s GDP) was allotted for different sectors to overcome the damage caused by the pandemic. The approach of Atmanirbhar Bharat resembles that of “glocalization”, as discussed in Chap. 1, and focuses on a growth that originates from an internal strength of the country. This has also been well represented using the slogan: vocal for local to make it global. Atmanirbhar Bharat also represents a demand-based economy system, i.e., self-producing and self-consuming, and the surplus for export. In Fig. 21.1, the concepts of Make in India and Atmanirbhar Bharat often referred to as Make in
India 1.0 and Make in India 2.0, respectively, are highlighted along with parameters required to make them a grand success.

Both Make in India and Atmanirbhar Bharat programs are aimed at transforming the country into an international design and manufacturing hub. Both of them envisage products to be manufactured in India, attract foreign investors for production in the country, reduce imports and increase exports, creation of new job opportunities, etc. The similarities and differences between these two programs are analyzed based on the parameters required for their effective implementations, as depicted in Fig. 21.1.

### 21.1.1 Investment for Manufacturing

Investment for capital and technology is the first and foremost requirement for setting up the manufacturing facilities in the country. In Make in India, foreign companies are encouraged to invest and bring technologies to manufacture their products in the country which can even be exported. For this, the government has created a conducive environment for foreign investors. According to a recent report, Foreign Direct Investment (FDI) inflows in India increased from $35.3 bn in 2014–15 to $56.00 bn during the year 2019–20 [3]. To facilitate FDI programs and to increase such ventures, the country must provide an appropriate environment to make investments profitable.

Under the Atmanirbhar Bharat program, local companies are motivated to manufacture products of international quality with government support and/or foreign investors to fulfil the local demand as well as for export. Under the Atmanirbhar Bharat package, the government not only has changed the definition of MSMEs to their advantages but also provided a big stimulus package, enhanced the scope for private participation in various sectors, and increased FDI in the defence sector, etc.
21.1.2 Innovation

It is well-known that the environmental conditions of India are quite different from those of developed nations [4]. Hence, the technologies that are brought in the country under Make in India program from these countries, need to be adopted to Indian conditions. This necessitates innovative scientific and technological solutions. For instance, cast iron products although commercially acceptable in many countries are not practicable in Indian scenarios as they are prone to rusting in Indian climatic conditions and need to have an innovative protective coating or different composition [5].

In the case of Atmanirbhar Bharat, the indigenous technologies need to be developed from basic concepts to final products through various technology readiness levels (as discussed in Chap. 1). Therefore, MSMEs would require technologies and innovations to develop new products, especially from academia as well as science and technology organizations of the country.

21.1.3 Quality Infrastructure

For both Make in India and Atmanirbhar Bharat programs, a robust national quality infrastructure (metrology, standards, and accreditation: all of them harmonized with respective international counterparts) is essential to ensure that manufactured products are in compliance with regulatory requirements. Atmanirbhar Bharat provides a scope to MSMEs for local production—right from raw materials to the finished product, and to achieve this, they would require the national quality infrastructure at each of the steps [6].

21.1.4 Skill Development

Skilled manpower is mandatory to operate the high-technology industry. Make in India provides employment opportunities for skilled manpower in high-technology manufacturing facilities, whereas nonskilled manpower may not find enough scope for the jobs. In the case of Atmanirbhar Bharat as the products are developed indigenously from scratch, it will build employment opportunities for everyone. In fact, unskilled manpower can be trained to make them capable to operate advanced machineries. To achieve maximum output, the skilled manpower should be trained to understand and implement the requirements of the quality infrastructure.
21.2 Atmanirbhar Bharat from the Perspective of Aswal Model

Atmanirbhar Bharat is a great aspiration of the government to cater to the needs of the citizens through knowledge economy that can grow faster. The vision is to achieve economic growth in quantum jumps and not the conventional incremental increase. The government has made sufficient efforts to create world-class civil infrastructure (i.e., high-quality highways and roads, uninterrupted power supply through maximal generation using renewable sources, providing high-speed internet connectivity across the country, etc.), which are creating an identity of a new and modern India. The government is in the process of developing a new system of governance based on modern technologies to realize the dreams of the twenty-first century. The rules and rituals of the past are expected to be done away with. The vibrant demography and strong demand-and-supply cycle in the economy are the assets, which need to be utilized fully to make the nation self-reliant. Therefore, the efforts made by the government of India for enhancing the economy and making the country self-reliant, stand proved beyond doubt.

The mandate of Atmanirbhar Bharat is to empower each of its citizens (>1.3 billion) to contribute to the knowledge economy of the country. This, in principle, is achievable if Aswal Model for inclusive growth, as discussed in Chap. 1, is applied for the realization of Atmanirbhar Bharat. As depicted in Fig. 21.2, the four helices of the economy, namely the government, the universities/S&T institutions, industrial establishments, and civil society and media, are expected to work together in a cohesive manner to create social and business benefits.

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**Fig. 21.2** Social and business benefits of Atmanirbhar Bharat implemented using the Aswal Model
manner through the national quality infrastructure, in which all the measurements are metrologically traceable to SI units.

Atmanirbhar Bharat if implemented using the Aswal Model will yield enormous naturally occurring social and business benefits, as listed in Fig. 21.2. Some of the notable examples are illustrated below.

(i) Metrology is the foundation of high-quality science, technology, innovation, and trade. Therefore, providing education on metrology right from schools to graduation/postgraduate levels would create human resource, conscious of national quality infrastructure. Such a high-quality metrology education is necessary for the creation of knowledge economy with high efficiency but without harming the environment.

(ii) To manufacture high-quality, indigenous, and cost-effective goods to fulfill the national needs as well as to compete in international business, meeting the laid down international standards is mandatory. This requires a robust national quality infrastructure for ensuring the conformity assessment, i.e., proven technical and regulatory requirements through well-established calibration, testing, certification, accreditation, and inspection processes. Conformity assessment entails steps taken to evaluate whether the products, processes, systems, or personnel, observe and meet the requirements identified in the concerned and relevant specified standard. These technical and regulatory requirements are strongly associated with stipulated respective standards and provide the end-user with the necessary confidence in the products and services being offered. For this reason, conformity assessment is a critically important aspect of conducting reliable global business and acts as an interface of confidence between the supplier and the customer. The manufacturers or the suppliers need to consider the benefits accrued from observing the requirements for conformity assessment and the customer, on the other hand, needs to assure himself about the business benefits of investing in terms of profitability, ease of manufacturing, ease of marketing including international business aspects as well as quality and regulatory compliance. Without meeting technical, regulatory, and conformity requirements, many export deals fall through, and large consignments get liable to be rejected leading to considerable economic loss. A few recent examples include the failure of basmati rice and seafood exporters to comply with the mandatory testing and certification of inspection in the import-bound countries [7, 8]. Conformity assessment when complied with, ensures manufacturers that their products and services are in accordance with the desired specifications of national/international standards, ensuring quality, reliability, efficiency, safety, effectiveness, interoperability, and environmental sustainability.

(iii) Exceptionally reliable data obtained by ensuring the metrological traceability, enable formulation of regulation and policies that benefit the country both nationally and internationally. The formulation of regulations and policies is aimed at improving the quality of life of the citizens, which keep on evolving with time, and therefore, depend upon trustworthy data obtained through national quality infrastructure.
In view of the above, the role of CSIR-NPL, as NMI of the country, undoubtedly becomes pivotal. In the next section, we analyze how CSIR-NPL has been contributing to the growth of the nation as well as those of neighboring nations.

### 21.3 CSIR-NPL’s Metrology Services Towards National Growth

As shown in Fig. 21.3, the CSIR-NPL through its wide-ranging metrological services, namely primary/national measurement standards, accurate and precise Indian Standard Time (IST), the certified reference materials under the trademark of Bhartiya Nirdeshak Dravyas (BND®), transfer of technologies, consultancy services, sponsored R&D projects, skill development on metrology, etc. have been contributing towards knowledge creation for the overall growth of the nation. The beneficiaries of these metrological services include government ministries, regulatory bodies, public sector undertakings, private industries, MSMEs, strategic sectors, S&T organizations, etc. In addition, CSIR-NPL has been supporting the NMIs of neighboring countries, especially those who belong to the South Asian Association for Regional Cooperation (SAARC) nations.

In the preceding chapters of this book, the contemporary and world-class, accurate, and neoteric services for various measurement parameters have been elaborated. In this section, an attempt is made on the critical analyses of metrological services provided by CSIR-NPL to various sectors, as summarized in Fig. 21.3. The trust and
confidence inherent in the dissemination of metrologically traceable measurements by CSIR-NPL are demonstrated as a significant component of the scientific, industrial, economic development of the nation and its role in elevating the status of the civil society.

CSIR-NPL provides various metrological services through its four organs namely, Centre for Calibration and Testing (CFCT), the Industrial Liaison Group (ILG), Planning, Monitoring and Evaluation (PME), and Human Resource Development (HRD). CFCT acts as an interface between CSIR-NPL and patrons requiring the metrological traceability. Currently, CFCT is supporting >3970 patrons from industries, national laboratories, and government organizations from all over the country and abroad. CFCT provides services in a professional manner and most of the desired information is available at its website. PME undertakes the sponsored, grant-in-aid, or collaborative R&D projects from external agencies. ILG acts as an interface for taking up several technical services. These include technology development and transfer, consultancy services in various research areas, joint development of the products, optimization of industrial processes, impact assessment studies, upgradation of technologies, feasibility studies, fabrication of specialized products, modeling and machining, development of specialized device/component/product, design of calibration facilities, development of software for automation, characterization of devices/parts, interference studies, improvements in the design/accuracy, structural studies, specialized calibration and testing, operation, performance checking, troubleshooting, effect assessment studies, instrumentation and automation, development of methodologies, the establishment of the calibration laboratories, performance optimization, etc. Finally, the HRD group deals with the training programs related to metrology and research scholars/students.

21.4 Analyses of Calibration and Testing Services of CSIR-NPL

21.4.1 Metrological Traceability to Government, Industries and SAARC Nations

As mentioned, a total of 3970 agencies have registered at CFCT to avail the calibration and testing services of CSIR-NPL on a regular basis. Figure 21.4 shows the distribution of various agencies belonging to government sectors, central PSUs, state PSUs, private industries, and SAARC nations which benefit from CSIR-NPLs metrological services. As accurate and precise measurements are key to the manufacturing, it is not a surprise that >82% of the CSIR-NPL metrological services are availed by private industries, which include small scale industries and NABL accredited testing and calibration laboratories across the country. The government/PSUs contribute to 17.4%, while SAARC nations to 0.3%. A partial list of the beneficiaries belonging to the different categories mentioned above is given in Table 21.1. The small contribution of SAARC nations as depicted in Fig. 21.4, is quite expected as only the NMIs
of these countries approach CSIR-NPL for calibration and traceability. Fairly strong
connects of CSIR-NPL with both industries and government is a testimony to the
applicability of the Aswal model, that metrology acts as a binding force, which is
elaborated further in subsequent sections.

It is worth mentioning here that the validity period for calibration and testing
certificates issued by CSIR-NPL is fixed, which depends upon the nature of the
parameter and can vary between 1 and 3 years. Therefore, the registered agencies
approach CFCT only when the validity of calibration and testing certificates issued
to them approach their expiry dates. For financial years 2015–16 to 2019–20, the
CFCT data showing (a) number agencies registered for metrological services and
(b) number of calibration and testing certificates issued by CSIR-NPL are plotted
in Fig. 21.5. It is seen that on an average ~ 1000 agencies register every year for
calibration and testing services and correspondingly, the issued average number of
certificates is ~2500 per year. This implies that most agencies avail calibration/testing
facilities for more than one parameter.

21.4.2 Sector Wise Analyses of Metrological Traceability

Data

As discussed in Chap. 1, CSIR-NPL has 236 CMCs at the BIPM for a wide range
of parameters, which were elaborated in subsequent Chapters. Here we present
Table 21.1 A partial list of users availing the primary/national calibration facilities of CSIR-NPL

1. Government/semi-government organizations

- Air Force; Air India; Bharat Electronics; BHEL; Bhilai Steel Plant; Bureau of Indian Standards; Bharat Dynamics; Central Pollution Control Board; State pollution control boards; Central Power Research Institute; Central Public Works Department; Railway Information System; Central Institute of Mining and Fuel Research; Defense Research and Development Organization; Defense Electronics Applications Laboratory; Delhi Jal Board; Directorate of Border Security Force; Hindustan Aeronautics Limited; Indian Oil; HPCL; ISRO Inertial Systems Unit; Maharashtra State Electricity; Micro, Small and Medium Enterprise Testing Center; NTPC; Nuclear Fuel Complex (DAE); Ordnance Factory; Rail Coach Factory; Steel Authority of India, etc.

2. Private industries

- Adani Electricity; Tata Steel; CK Birla Group; GE power systems; ABB India; ACC; AIMIL Ltd.; Alstom India; Ambuja Cement; Binani Cement; Bangur Cement, Birla Tyres; Blue Star; Bureau Veritas; Casio India; Crompton Greaves Limited; Diesel Locomotive Works; Essar Oil Ltd.; Godrej and Boyce Mfg. Co. Ltd; Havells India; Honda Cars; International Zinc Association; J. K. White Cement; JK Lakshmi Cement; Kirloskar Brothers; Larsen and Toubro; Maruti Suzuki; Mysore Paints and Varnish; Philips India; Piramal Healthcare; Ranbaxy; Rapid Metro Rail Gurgaon; Samsung India; Honda Siel; Surya Roshni, Wipro consumer care and lighting; Orient Electric; ITC, Halonix Technologies, Astra lighting; Bharat Forge; Tetronix India; Fluke Technologies; Verka Dairy; etc.

3. SAARC nations

- Nepal Bureau of Standards and Metrology (MBSM), Nepal; Bangladesh Standards and Testing Institution (BSTI), Bangladesh; Measurement Units, Standards and Services Department (MUSSD), Sri Lanka; National Physical and Standards Laboratory (NPSL), Pakistan; Bhutan Standards Bureau (BSB), Bhutan; Afghanistan National Standards Authority (ANSA), Afghanistan; Maldives Standards and Metrology Unit (MSMU), Maldives

the CFCT data in terms of metrological services provided to vital sectors, which contribute to the knowledge economy and knowledge society. These are categorized into following twenty sectors: automobile, aviation, biomedical and pharmaceutical, diary, food and beverages, defense, electrical/electronics, energy/power, environment metrology, home appliances, housing/infrastructure, irrigation and agriculture, IT consultancy, and banking, laboratory equipment, petrochemicals and chemicals, railways, S&T and academic, space, testing laboratories, textile, and others. The “other” category includes SAARC nations and those that could not fit into the above-mentioned specialized categories.

Figure 21.6 shows the sector-wise distribution of metrological services of CSIR-NPL for 2015–16 to 2019–20. The testing labs and laboratory equipment are the top
sectors. This is quite expected because the NABL accredited laboratories across the country, need to obtain the mandatory metrological traceability to SI units through CSIR-NPL. As discussed in the next section, most of the government ministries have their own secondary testing and calibration laboratories to ensure the conformity assessments for their regulations as well as for products manufactured in India or imported. Since these secondary laboratories are spread across the country, the state regulators approach these local laboratories for calibration and testing. This also explains why the number of state PSUs that approach CSIR-NPL is relatively lower in number, as observed in Fig. 21.4. These secondary laboratories have their traceability to the SI units through CSIR-NPL.

The other major sectors which obtain measurement traceability to SI units through CSIR-NPL are automobiles, biomedical and pharmaceutical, defense, home appliances, housing/infrastructure electrical and electronics, energy/power, S&T and academic, aviation, railways, and space. The measurement traceability to sectors
like diary, food and beverages, environment/ metrology, IT consultancy and banking, textile, etc. are although not significant at present in availing the facilities of CSIR-NPL, but possibilities exist that they may be using secondary calibration and testing laboratories. However, it must be ensured that all sectors utilize measurement values traceable to SI units for quality assurance. As discussed in earlier Chapters, CSIR-NPL is strengthening its capabilities in environmental and biomedical metrology, which will immensely benefit these sectors.

India is a big country and to ensure inclusive growth, it is essential that every part of it grows industrially and economically. As measurement traceability is linked to economic growth, organizations in the various states of India, availing the CSIR-NPL facilities are plotted in Fig. 21.7. New Delhi is the frontrunner, which is expected as most of the government bodies and industries approach CSIR-NPL due to its proximity. Similar is the case with Haryana, being an adjoining state. Otherwise, the ranking in measurement traceability to SI units through CSIR-NPL and the industrial growth appears to be correlated well. According to RBI’s recent report, states like Maharashtra, Tamil Nadu, Gujarat, Uttar Pradesh, and Karnataka have a high rate of industrial growth while north-eastern states have the lowest industrial growth. Therefore, to improve the economy of the country, among many other parameters, the respective state governments should be encouraging industries and MSMEs to ensure the measurement traceability for industrial growth through the manufacturing of products of international quality.

![Fig. 21.7](image)

**Fig. 21.7** State-wise distribution of metrological services of CSIR-NPL, in percentage, for the period 2015–16 to 2019–20
21.5 Collaboration Between CSIR-NPL and Government Organizations

A critical analysis of the past 5 year’s data of CFCT, ILG, PME, and HRD shows that the metrological services of CSIR-NPL have reached the majority of the existing government ministries, as schematically depicted in Fig. 21.8, through regulatory bodies, R&D organizations, and/or public sector undertakings (PSUs) working under them. Major sectors that regularly pursue CSIR-NPL's metrological traceability services include defense, civil aviation, heavy industries, power, steel, oil and natural gas, space, atomic energy, railways, science, and technology, etc. Other sectors seeking the metrological traceability services include dairy, water, railway, health, petrochemicals, environment monitoring, etc. There are many sectors looking for new and contemporary measurement and/or materials metrology services, which have either been initiated or are under the process of the establishment by CSIR-NPL. These sectors include AYUSH, cybersecurity, finance, textiles, etc.

![Fig. 21.8](image.png) A schematic showing the metrological services provided by CSIR-NPL reaching majority of government ministries through regulatory bodies, R&D organizations, and/or central public sector enterprises (CPSEs)
It is worth mentioning that the Department of Public Enterprises (DPE) formulates policies for Central Public Sector Enterprises (CPSEs), which are mainly related to performance evaluation and improvement, financial delegation and autonomy, and personnel management. DPE, based on the performance and annual profits has listed 10 Maharatna Companies in India namely, Bharat Heavy Electricals Limited (BHEL), Bharat Petroleum Corporation Limited (BPCL), Coal India Limited, GAIL (India) Limited, Hindustan Petroleum Corporation Limited (HPCL), Indian Oil Corporation Limited (IOCL), NTPC Limited, Oil and Natural Gas Corporation Limited (ONGC), Power Grid Corporation of India Limited (PGCIL) and Steel Authority of India Limited (SAIL) \[9, 10\]. Most of these Maharatna companies and other Navratna companies are beneficiaries of the metrological traceability services offered by CSIR-NPL.

The following sections describe the specific areas where crucial metrological services of CSIR-NPL are being disseminated. Gap analysis of the areas where the expertise and facilities have further potential to grow and/or added is also made and an attempt is made to envisage the future directions.

### 21.5.1 Defense and Civil Aviation

CSIR-NPL provides regular metrological services to Defense and Civil Aviation sectors. Defense is one of the most important areas as it protects the sovereignty of our borders and very existence as a Nation. To ensure synergy, interoperability, and efficient utilization of resources for defense equipment and applications, maximizing standardization is one of the basic demands. Therefore, all measuring equipment needs to be calibrated to national/primary standards traceable to SI units. Table 21.2 lists the organizations under the defense ministry which are supported by CSIR-NPL for metrological traceability services along with the calibration/testing parameters. It is evident that all three wings of the Defense Ministry, i.e., military, navy, and air force as well as their associated research and scientific organizations are beneficiaries of the national/primary standards of CSIR-NPL. One of the major constituents of defense is the Defense Research and Development Organization (DRDO) which is the R&D wing of Defense Ministry with a vision to empower India with cutting-edge defense technologies and a mission to achieve self-reliance in strategic defense technologies and systems while equipping our armed forces with state-of-the-art weapon systems and equipment in accordance with requirements laid down by the three services. It has several laboratories, under different clusters such as Naval Systems and Materials (NS&M), Aeronautical Systems (Aero), Armament and Combat Engineering Systems (ACE), Missiles and Strategic Systems (MSS), Electronics and Communication Systems (ECS), Life Sciences (LS), and Micro Electronic Devices, Computational Systems and Cyber Systems (MED and CoS) \[11\]. CSIR-NPL provides crucial metrological services for the standardized measurements in these areas as listed in Table 21.2. Bharat Electronics Limited, the electronics wing of DRDO, supplies advanced electronic components to the Indian Armed forces. These include
Table 21.2 List showing the CSIR-NPL’s metrological services provided to defence and civil aviation sectors

| Ministry                  | Organization/PSU/Joint Venture                                                                 | Traceability/calibration/MoU area                                                                 |
|---------------------------|-----------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------|
| Defense                   | • Defense Electronics Application Laboratory (DEAL)                                               | Pressure, vacuum, and ultrasonic metrology                                                      |
|                           | • Defense Research and Development Laboratory, (DRDL),                                        |                                                                                                  |
|                           | • Opto Electronics Factory, Dehradun, Uttarakhand                                                |                                                                                                  |
|                           | • Mishra Dhatu Nigam Limited (MIDHANI), Hyderabad                                                |                                                                                                  |
|                           | • Bharat Earth Movers Limited (BEMIL), Bengaluru                                                  |                                                                                                  |
|                           | • Gas Turbine Research Establishment (GTRE), Bengaluru                                            |                                                                                                  |
|                           | • Naval Sci. and Tech. Lab, Vishakhapatnam                                                       |                                                                                                  |
|                           | • Military Engineer Services, New Delhi                                                         |                                                                                                  |
|                           | • Directorate of Standardization, New Delhi                                                      |                                                                                                  |
|                           | • Directorate of Border Security Force (Air Wing)                                                |                                                                                                  |
|                           | • Indian Air Force                                                                                |                                                                                                  |
|                           | • Bharat Dynamics Ltd.                                                                          |                                                                                                  |
|                           | • Gun Carriage Factory (GCF), Jabalpur, M.P                                                     |                                                                                                  |
|                           | • Indian Ordnance Factories at Ghaziabad, Kanpur, Nagpur                                         |                                                                                                  |
|                           | • Heavy Alloy Penetrator Project (HAPP), Kolkata, W Bengal                                       | Mass metrology, optical radiation, time and frequency                                           |
|                           | • AIR Force Station, Palam, Delhi                                                               |                                                                                                  |
|                           | • High Explosives Factory, Pune, Maharashtra                                                     | Mass, volume, viscosity, temperature, and humidity                                              |
|                           | • Bharat Dynamics Ltd, Hyderabad, Telangana                                                      | Luminance and fluid flow                                                                       |
|                           | • Defense Bioengineering and Electromedical Laboratory (DEBEL), Bengaluru                       |                                                                                                  |
|                           | • Department of Defense Research and Development (DRDO)                                         |                                                                                                  |
|                           | • Defense Research and Development Organization (DRDO)                                          |                                                                                                  |
|                           | • DRDO, Ammunition Factories                                                                     |                                                                                                  |
|                           | • DRDO Proof and Experiment Establishment Bharat Electronics Ltd. (BEL), Bengaluru              |                                                                                                  |
|                           | • Bharat Electronics Ltd. (BEL), Ghaziabad                                                      |                                                                                                  |
|                           | • Bharat Electronics Limited, Panchkula                                                         |                                                                                                  |
|                           | • Office of Commanding officer, Airforce Station, New Delhi/Goa                                |                                                                                                  |
|                           | • Hindustan Aeronautics limited, U.P                                                            |                                                                                                  |
|                           | • Indian Air Force, Department of Defense Production: Ordnance Factory Board                     | Electrical and electronics, precise timing systems                                             |
|                           | • Hindustan Aeronautics Limited (HAL)                                                           | Pressure, vacuum, and ultrasonic length and dimension, acoustic, and vibrations, optical, magnetic |
### Table 21.2 (continued)

| Organization | Test Parameters |
|--------------|-----------------|
| Directorate General of Quality Assurance, New Delhi | Force and hardness, LF and HF, voltage, current and microwaves |
| Opto Electronics Factory, Dehradun Ordnance Equipment Factory, Kanpur | Acoustics and vibration, optical radiation |
| Ordnance Factories | AC power and energy, fluid flow, length and dimension, pressure |
| Command Met Officer, HQ Training Command Air force, Bengaluru. Western Air Command, New Delhi-10 | Information on earth’s ionized media for frequency management; Geophysical and solar activity |
| DRDO | Spark Plasma synthesis of Bi2Te3 alloy-based nano-composites |
| **Civil aviation** | |
| Air India Limited | Pressure, fluid flow, optical radiation, magnetics, mass |
| Air India Engineering Services | |
| Office of Commanding Officer, Airport Authority of India (AAI), New Delhi | Luminance meters, photometric and radiometric scales |
| Manager-SO&I, IATA, New Delhi Air India Flight Dispatch, IGI Airport, New Delhi Air India Flight Dispatch JFK Airport, New York Sr. Manager - Flight Dispatch Air India | Geophysical and solar activity, HF propagation for daily message |

Radars, naval systems, C4I systems, defense communication weapon systems, homeland security, electronic warfare, tank electronics, telecom and broadcast systems, electro-optics, professional electronic components, solar photovoltaic systems, etc. The quality control and quality assurance of these depend upon the calibration of all the electronic and electrical parameters from CSIR-NPL.

To ensure the safe flight conditions, both Air Force and Civil Aviation require accurate information on various parameters related to geophysical activities. These include geomagnetic field, solar wind conditions (in last 24 h on any given day and its forecast), solar activity (i.e. sunspot number and value of solar 10.7 cm (2.8 GHz) radio flux and its forecast), and high frequency (HF) propagation conditions and their forecast (normal, fair or bad) at different latitudes, turbulence, thunderstorm, icing, ceiling, visibility, etc. [12]. Information on these crucial parameters is provided by CSIR-NPL to both the Air force and Civil Aviation.

The Ministry of Civil Aviation has three statutory bodies, i.e., Directorate General of Civil Aviation, Airports Authority of India, Bureau of Civil Aviation Security, and Commission of Railway safety. Air India, the national carrier is one of the significant clients to which calibration is provided in the areas of pressure measurement, fluid flow, optical radiation, magnetics, mass metrology, etc. Pressure is a crucial parameter both for maintaining cabin pressures in aircraft as well as for estimation of the height using Altimeters. Also, calibration of luminance meters, photometric and radiometric scales are being given to the Office of Commanding Officer, Airport Authority of India (AAI), New Delhi. In addition, CSIR-NPL also provides radiation dose data to Regional warning centers under the Ministry of Civil Aviation.
21.5.2 Ministry of Consumer Affairs, Food, and Public Distribution

As amply discussed in Chap. 1, the Legal Metrology has a responsibility to ensure that the benefits of metrological traceability of weight and measures to SI units are transferred to all the citizens of the country. Therefore, Legal Metrology has the statutory power to establish and enforce the standards of weights and measures, regulate trade in commerce, and all goods which are either sold or distributed by weight. The legal metrology, therefore, guarantees fair trade in the market by assuring citizens through correct measurements. Legal Metrology has to comply with the requirements of agreement on technical barriers to trade (TBT agreement) of the World Trade Organization (WTO). The Legal Metrology discharges its duty through five regional reference standard laboratories (RRSLs) across the country for weights and measures. These RRSLs obtain metrological traceability from CSIR-NPL, as summarized in Table 21.3, for the parameters of mass, length and dimension, and the temperature. CSIR-NPL provides traceability on mass and length metrology for, respectively, weights (a set of 1 mg to 5 kg weights) and length (meter bar—1 m and Gauge blocks M-112) to each RRSL for maintaining the weights and measures systems in the country. The weights need to be recalibrated every three years, whereas lengths need to be recalibrated every five years. The temperature standards in ranges 44–300 °C are provided using liquid-in-glass thermometers (LIGTs) and in ranges 90–400 °C using platinum resistance thermometers (PRT). Legal Metrology further disseminates the measurement traceability down to state and district level weights and measurement laboratories. Recently Legal Metrology has also started a nationwide program on dissemination of Indian Standard Time, traceable to CSIR-NPL, through its RRSLs, which is expected to help the country in the field of cybersecurity, power sector, telecom sector, digital, aviation, etc.

Table 21.3 The mass, dimension, and temperature reference standards at regional reference standard laboratories (RRSLs) are calibrated at CSIR-NPL

| RRSL              | Dimension Artefact       | Mass         | Temperature                                      |
|-------------------|--------------------------|--------------|--------------------------------------------------|
| RRSL Ahmedabad    | Gauge Block Set M-122    | 1 mg–5 kg    | LIGT 275–300 °C/least count 0.05 °C              |
|                   |                          |              | LIGT 44–56 °C/least count 0.02 °C                |
| RRSL, Faridabad   | Meter Bar (1 m)          | 1 mg–5 kg    |                                                  |
| RRSL Bhubaneshwar | Meter Bar (1 m)          | 1 mg–5 kg    | LIGT 44–56 °C/least count 0.02 °C                |
| RRSL Guwahati     | Gauge Block Set M-122    | 1 mg–5 kg    |                                                  |
| RRSL Bengaluru    | Gauge Block Set M-122    | 1 mg–5 kg    | PRT PT-100 with temperature indicator—90–400 °C/Resolution 0.01 °C |
The working links between CSIR-NPL and Legal Metrology are strong. CSIR-NPL also provides measurement traceability to RRSLs for many other derived parameters, including pressure, vacuum, fluid flow, force, etc. CSIR-NPL also supports the Indian Institute of Legal Metrology, Ranchi, by providing measurement traceability to its secondary and reference standard weights. CSIR-NPL is also collaborating with Legal Metrology for setting up of following facilities at different RRSLs.

(i) Design, development, fabrication, and establishment of customized indigenous working standards for verification of blood pressure measuring instruments for RRSL, Faridabad
(ii) Establishment of a reference standard for length using laser interferometry for RRSL, Bengaluru.
(iii) Establishment of clinical thermometer testing kit for RRSL, Guwahati.
(iv) Setting up of secondary atomic time scales at all the 5 RRSLs and a disaster recovery primary atomic time scale at Bengaluru.

In addition, CSIR-NPL provides regular training programs for the officers of Legal Metrology in areas of mass, length, temperature, and pressure metrology.

CSIR-NPL also provides traceability to the National Test House (NTH), which is one of the oldest multi-disciplinary industrial testing laboratories in the country. NTH has six regional laboratories located at Kolkata, Mumbai, Chennai, Ghaziabad, Jaipur, and Guwahati. These NTH labs cater to the testing needs of local industries, institutions, and trades. In all these labs, testing and evaluation facilities for raw materials as well as finished products are available for all the branches of engineering disciplines. These NTH labs obtain measurement traceability from CSIR-NPL for various parameters viz. pressure, vacuum, ultrasonic, photometric, radiometric, length and dimension, force and hardness standards, etc.

21.5.3 Departments of Space and Atomic Energy

Department of Space (DoS) and Department of Atomic Energy (DAE) are very important and strategic departments of India. Both the departments have made enormous contributions to international recognition in their respective areas of space technologies and nuclear technologies, which in turn, has contributed to the scientific, strategic, and economic development of India.

DAE is a leader in the development of nuclear power technology and applications of radiation technologies in the fields of agriculture, medicine, industry, and basic research. DAE comprises of five research centers, three industrial organizations, five public sector undertakings, and three service organizations. Bhabha Atomic Research Center (BARC) is the Designated Institute for the ionization radiation, and as per CIPM-MRA, the quality management of BARC is looked after by CSIR-NPL. Table 21.4 shows the services provided to DAE institutions by CSIR-NPL.

DOS has the primary objective of promoting the development and application of space science and technology, to assist in the all-round development of the
Table 21.4  Services provided to DAE institutions by CSIR-NPL

| Organization                                                                 | Traceability/calibration/consultancy area/projects                                                                 |
|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------|
| Nuclear Power Corporation of India Limited (NPCIL)                         | Mass, temperature, electrical and electronics and related parameters                                              |
| Electronics Corporation of India Limited (ECIL)                           | Electrical and electronics and related parameters                                                                  |
| Bhabha Atomic Research Center (BARC), Mumbai                               | • Support as designated institute in ionization radiation  
• Mass and fluid flow  
• Development of high-temperature resistant C/C composite tube, development of nuclear grade high-density graphite  
• Calibration of magnetic fields and magnetic materials for INO project  
• Development of high density isotropic nuclear grade  
• Synthesis of high figure-of-merit thermoelectric materials  
• Development of thermally stable novel nanophosphors for improving color rendering index (CRI) in white-LEDs |
| Nuclear Fuel Complex, Hyderabad                                           | Force and hardness                                                                                               |

Table 21.5  Services provided to DoS institutions by CSIR-NPL

| Organization                                                                 | Traceability/calibration area/MOU                                                                 |
|----------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| ISRO Telemetry, Tracking and Command Network (ISTRAC), Bengaluru and Lucknow | • Precise timing systems  
• Mass, pressure, vacuum, and ultrasonic  
• LF and HF voltage, current, and microwaves |
| Vikram Sarabhai Space Center, Thiruvananthapuram                           | • Force and hardness  
• LF and HF impedance and DC standards |
| Satish Dhawan Space Centre (SDSC), Sriharikota                           | • Temperature and humidity, precise timing systems  
• LF and HF impedance and DC standards  
• LF and HF voltage, current, and microwaves |
| ISRO Master Control Facility, Karnataka ISRO-Space Applications Center, Ahmedabad | • Geophysical and solar activity, HF propagation daily message  
• Indian regional navigation satellite system (IRNSS) |
ISRO obtains the strategic time synchronization with nanosecond accuracy, which is traceable to UTC through Indian Standard Time (IST) generated by the national Primary Atomic Clock Ensemble at CSIR-NPL. Atomic clocks in Global Navigation Satellite Systems (GNSS) keep time to within few nanoseconds. All GNSS satellites need to transmit their data signals exactly at the same time, which demands clock synchronization of all satellites to primary reference time, i.e., IST. GNSS signals are monitored constantly and adjusted as needed. In addition, metrological traceability of physicomechanical and electrical parameters is provided to various ISRO centers located at Sriharikota, Ahmedabad, Thiruvanthapuram, and SAS Nagar, Panjab.

### 21.5.4 Uplifting Science and Technology in the Country

Ministry of Science and Technology has several departments, including DSIR, DST, DBT, and MoES. Various laboratories under these departments work on context-driven research for industrial applications. Several research laboratories under CSIR work in diverse areas including electronics, instrumentation, metallurgy, petroleum, mining, leather, environment, glass, and ceramics, etc. These labs utilize the national measurement standards of CSIR-NPL for the calibration of several equipment required for critical and strategic projects, as summarized in Tables 21.6 and 21.7.

**Table 21.6** Metrological traceability services to various research organization under the Ministry of Science and Technology

| Organization                                             | Traceability/calibration area/projects                                      |
|----------------------------------------------------------|---------------------------------------------------------------------------|
| Central Electronics Limited                              | • Optical radiation parameters                                             |
| Fie Research Institute                                   | • Force, hardness, torque<br>• Length and dimensional, pressure and<br>• Thermal parameters |
| CSIR-Central Electrical and Electronics Research Institute | • Acoustics and vibration                                                |
| CSIR- Central Scientific Instruments Organization        | • Mass, volume, viscosity<br>• Fluid flow<br>• LF and HF voltage, current, and microwaves |
| CSIR-Central Institute of Mining and Fuel Research       | • Force and hardness<br>• Acoustics and vibration                         |
| CSIR-Central Leather Research Institute                  | • Fluid flow                                                              |
| CSIR-Indian Institute of Petroleum                       | • Fluid flow<br>• LF and HF voltage, current, and microwaves               |
| CSIR-Central Mechanical Engineering Research Institute   | • Length and dimension<br>• Precise timing systems                        |
| CSIR-National Metallurgical Laboratory                   | • Temperature and humidity<br>• Force and hardness<br>• Acoustics and vibration |
| Organization | Projects |
|--------------|----------|
| Department of Science and Technology (DST) | • Investigation of the molecular dynamics at the interface of liquid crystal and immiscible structures  
• Electronic and magnetic properties of some single-layered cobaltite based compounds  
• Conversion of waste magnetic energy into useful electricity with Magnetoelectric Composite for wireless sensor nodes  
• Studies of stabilization of ferromagnetism in MnX(X = Al, Ga) binary alloy thin films by ion beam irradiation  
• Development of innovative cathode materials and flexible lithium-ion conducting ionic liquid-based gel polymer electrolytes for rechargeable Li-batteries  
• Advanced single-photon detector and establishment of single-photon detection based quantum standard for QuEST  
• Development of new interfacial layers for efficient and stable excitonic solar cells  
• Growth and study of highly conducting delafossite single crystal: device application in metrology  
• Buried contacts high-efficiency crystalline radial p-n junction Si nano cord solar cell  
• Advancing the efficiency and production potential of excitonic solar cells  
• Chemical composition and source apportionment of aerosols using receptor Models at urban sites of the Himalayan Region of India  
• Designing, development, and calibration of PM2.5 and PM10 high volume sampler  
• Structure/microstructure magneto-transport correlations in sputtered magnetically doped Bi$_2$Se$_3$ topological insulator thin films  
• Development of interface layer of perovskite solar cells in view of silicon-perovskite tandem solar cell fabrication  
• Fabrication of efficiency enhanced nanostructured InGaN/GaN  
• Process development for the deposition of Poly-Si-films on bi-axially textured substrate for solar cell application  
• Development of efficient, stable, and environmentally friendly metal-halide perovskite photovoltaic cells  
• Separation, Purification, and Standardization of Glucose for Glucose meter and other clinical applications  
• Study of atmospheric brown clouds over the Indo-Gangetic Plain and their impact on monsoon and agro-ecosystem  
• First principles investigation of electronic, thermal, magnetic properties of solids  
• Design and fabrication of perovskite-Si tandem solar cells and flexible perovskite solar cells  
• MEMS sensor array for environmental monitoring  
• Fabrication of cadmium-free large area kesterite (Cu$_2$ZnSnS$_4$) solar cells  
• Exploring the role of weak interactions in biomimetic host-guest complexes for efficient solar energy conversion |

(continued)
| Organization | Projects |
|--------------|----------|
|              | • Fabrication and characterization of perovskite-based electronics devices: different types of low voltage field-effect transistors and resistive switching memory  
|              | • Investigation of the effect of misoriented/ patterned substrate on the properties of Nitrides structures grown by PAMBE technique  
|              | • Semiconducting Thiophene based electronic materials for organic solar cells  
|              | • Development of Carbon-based force sensors for artificial intelligence and biomedical applications  
|              | • Novel graphene supported metal anode catalysts and PWA based electrolyte for direct ethylene glycol fuel cells  
|              | • Design of Rare-earth substitution at a metal-organic framework to highly efficient luminescent security feature for anti-counterfeiting application  
|              | • Search for quasi-two-dimensional electron gas in new oxide hetero-interfaces: Theory and Experiments  
|              | • Development of stable and luminescent hybrid organic-inorganic nanocomposites of Pb-free/Pb-based perovskite quantum dots for LED applications  
|              | • Organic molecular tracers and isotopic compositions of atmospheric aerosols at varying altitudes of Himalayan Region  
|              | • Designing of graphene quantum dots for photocatalytic organic transformations  
|              | • Design and fabrication of high-efficiency silicon solar cells: Passivated Emitter and Rear Cell (PERC)  
|              | • A novel strategy of AlGaN/GaN heterostructure based pollution monitoring system: Nitrogen dioxide gas sensing under UV illumination  
|              | • Design and development of novel autonomous self-healing graphene-carbon nanotubes hybrid-based polymer nanocomposites  
|              | • Investigation of Sub-auroral ionosphere region for different space weather conditions and its global impact for effective communication and navigation application  
|              | • Organic intercalated 2D Layered transition metal sulfide dichalcogenides (TMSDCs) hybrid nanostructures for thermoelectric application  
|              | • Investigation on the unclonable security functions generated from plasmonic nanostructures for anti-counterfeiting application  
|              | • Indigenous Development of PEDOT: PSS type materials employing novel methods for cost-effective and flexible excitonic solar cell applications (clean energy)  
|              | • Introducing magnetoelectric coupling in rare-earth orthoferrite and barium thin films and in multi-layers through magnetic anisotropy  
|              | • Development of cost-effective water purification set up on carbon-based nanocomposite for rural areas of India  
|              | • Force spectroscopy study of modified polydimethyl siloxane surface using atomic force microscope  
|              | • Synthesis of cost-effective environmentally friendly luminescent materials for solid-state lighting devices  
|              | • Simple and efficient frequency offset locking scheme for lasers in atomic physics experiments  

(continued)
### Table 21.7 (continued)

| Organization                                      | Projects                                                                                                                                 |
|---------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------|
| Central Electronics Limited, originated from CSIR-NPL, is a Govt. of India Enterprise under Department of Scientific and Industrial Research (DSIR), Ministry of Science and Technology. It works with an objective to commercially exploit the indigenous technologies developed by national laboratories and R&D institutions in the country. The lux meter and other optical radiation measurements for CEL are carried out by CSIR-NPL. Fie Research Institute is also a NABL accredited calibration and testing laboratory for parameters like force, hardness, dimension, torque, pressure, thermal, etc. The metrological traceability for these parameters is obtained from CSIR-NPL. |
| **21.5.5 Power, Steel, and Heavy Industries**     |                                                                                                                                              |

The Power, Steel, and Heavy Industries form the backbone of any growing economy for technical advancement and especially for self-reliant services and products. Modern industrialization relies heavily on a strong steel base as well as the power to drive the plants to produce heavy machinery for the industrialization and progress. India is the world’s sixth-largest energy consumer, accounting for 3.4% of global energy consumption. India is also the sixth-largest in terms of power generation. CSIR-NPL plays a significant role with a myriad of parameters providing metrological traceability through calibration to various state and center owned organizations related to power, steel, and heavy industries as briefly summarized in Table 21.8.

In the heavy industry sector, BHEL is involved in the design, engineering, manufacturing, construction, testing, commissioning, and servicing of a wide range of products, systems, and services for the core sectors of the economy, viz. power,
Table 21.8  Traceability services rendered to power, steel and heavy industries

| Ministry                                    | Organization                                                                 | Traceability/calibration area                                                                                                                                 |
|---------------------------------------------|-------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Steel                                       | National Mineral Development Corporation Limited (NMDC)                       | Pressure, vacuum                                                                                                                                              |
|                                             | Steel Authority of India Limited (SAIL)                                       | • Acoustic and vibration  
• Pressure, vacuum                                                                                                                                          |
| Power                                       | Damodar Valley Corporation (DVC)                                              | • AC high voltage and AC high current  
• Magnetics, magnetic parameters                                                                                                                                     |
|                                             | Central Power Research Institute (CPRI), Bangalore, Karnataka; National Hydroelectric Power Corporation Limited (NHPC); Power Grid Corporation of India Limited (POWERGRID); Rural Electrification Corporation Limited | • Pressure, vacuum, and ultrasonic  
• AC Power and energy  
• Fluid flow  
• Magnetics, magnetic parameters  
• Acoustics and vibrations  
• AC high voltage and AC high current  
• LF and HF voltage, current, and microwaves                                                                                                    |
|                                             | National Thermal Power Corporation NTPC                                       | • AC high voltage and AC high current  
• Acoustics and vibrations                                                                                                                                          |
|                                             | State Electricity Boards                                                    | • Magnetic parameters  
• Electrical and related parameters                                                                                                                                 |
|                                             | • Ajmer Vidyut Vitran Nigam Ltd                                             |                                                                                                                                                             |
|                                             | • Gujarat Electricity Board                                                 |                                                                                                                                                             |
|                                             | • Kerala State Electricity Board Ltd                                         |                                                                                                                                                             |
|                                             | • Maharashtra State Electricity Board                                        |                                                                                                                                                             |
|                                             | BEE (Bureau of Energy Efficiency)                                           | • Creation of testing and calibration facility for LED and LED-based lighting at NPL India as per national/international standards                        |
| Heavy Industries and Public Enterprises     | Bharat Heavy Electricals Limited (BHEL)                                      | • Electrical and electronics and related parameters  
• Pressure, vacuum and ultrasonic, optical radiation  
• Acoustics and vibration  
• LF and HF impedance and DC standards                                                                                                                               |

(continued)
transmission, renewable energy, water, oil and gas, aerospace and defense. CSIR-NPL provides significant calibration services to BHEL for parameters like electrical, pressure, acoustic parameters, etc.

The Light Emitting Diodes (LED) industry in India is also a major sector that requires calibration/testing of a large variety of products for consumer utilization. To cater to this contemporary need of lighting industries, CSIR-NPL in association with the Bureau of Energy Efficiency (Ministry of Power) is establishing a national testing and calibration facility for LEDs as per national/international standards. CSIR-NPL has also provided consultancy to Tata Steel, Jamshedpur for the development of value-added products from coal tar, as well as for characterization of different kinds of coal tar.

### 21.5.6 Certifying/Testing of Environmental Monitoring Equipment

Under the Ministry of Environment, Forest and Climate Change (MoEF&CC), the Central Pollution Control Board (CBCB) is a statutory body with the primary responsibility of advising the Central Government on any matter concerning prevention and control of water and air pollution and improvement of the quality of air. The state pollution control boards carry out similar tasks in their home states. The pollution can be of air, water, or even noise. Currently, India has no scheme for the certification of ambient air as well as industrial emission monitoring equipment. Consequently, such monitoring equipment is sent abroad for calibration, which is not only very expensive but also may not get calibrated as per the Indian environmental conditions, which are significantly different from the certifying countries. Therefore, such monitoring equipment is susceptible to erroneous readings. To circumvent this

| Ministry                        | Organization                                      | Traceability/calibration area                      |
|---------------------------------|---------------------------------------------------|---------------------------------------------------|
| Cement Corporation of India     | Cement Corporation of India Limited (CCI)         | • LF and HF impedance and DC standards<br>• Mass, temperature, and humidity<br>• Acoustic and Vibration |
| Automotive Research Association of India (ARAI) | Automotive Research Association of India (ARAI) | • Mass, temperature, and humidity<br>• Optical radiation |
| Fluid Control Research Institute (FCRI) | Fluid Control Research Institute (FCRI) | • Mass, temperature and humidity<br>• Optical radiation<br>• Pressure, vacuum and ultrasonic |
Table 21.9 Services provided by CSIR-NPL in the field of air pollution monitoring

| Statutory body                                      | Traceability/calibration/testing area                                                                 |
|----------------------------------------------------|------------------------------------------------------------------------------------------------------|
| Central Pollution Control Board (CPCB)             | • CSIR-NPL designated as national verification agency for certifying instruments and equipment for monitoring emissions and ambient air  
  • Acoustics and vibration  
  • Fluid flow  
  • BND related to aerosol, water, and gas mixtures  
  • Delineation of airshed for air quality management in Delhi-NCR |
| Delhi Pollution Control Board                      | • Acoustics and vibration  
  • Fluid flow  
  • Environment metrology |
| Chhattisgarh State Pollution Control Board         | • Improvement of quality of air pollution monitoring equipment  
  • Quality checks of the data and instruments working at air quality monitoring stations in Raipur city |
| Ministry of Environment, Forest and Climate Change (MoEF) | • Establishment of type testing calibration and certification facility for online continuous emission monitoring system (OCEMS) and continuous ambient air quality monitoring system (CAAQMS)  
  • Carbonaceous aerosols emissions, source apportionment, and climate effects |

situation, MoEF&CC and CBCB have entrusted CSIR-NPL to setup the national environment standard laboratory and the Indian certification scheme for air quality monitoring instruments. This is in anticipation of rising demand by States—against the backdrop of the National Clean Air Campaign—for low-cost air quality monitoring instruments that can monitor levels of nitrous oxides, ozone, and particulate matter. CSIR-NPL is also producing standard gas mixtures for measurement reference. Various services provided by CSIR-NPL in the field of air pollution monitoring are summarized in Table 21.9. Apart from air pollution, noise is another pollution of major concern, especially in metros and big cities. To tackle the noise pollution, CSIR-NPL provides acoustics and vibration measurements to CPCB and SPCB, e.g., Delhi, etc. The traceability in fluid flow is also being rendered by CSIR-NPL to SPCB for calibration of gas and water flowmeters.

21.5.7 Ministry of Petroleum and Natural Gas

The Petroleum and Natural Gas Regulatory Board Act, 2006, states that “it aims to protect the interest of consumers by fostering fair trade and competition amongst the entities; register entities, lay down the technical standards and specifications including safety standards in activities relating to petroleum, petroleum products, and natural gas, including the construction and operation of pipeline and infrastructure projects related to downstream petroleum and natural gas sector, etc.”. The implementation of these regulatory requirements goes a long way in ensuring the safe
### Table 21.10 Services provided by CSIR-NPL to the petroleum and natural gas industries

| Organization                                      | Traceability/calibration/BND Area                                      |
|---------------------------------------------------|------------------------------------------------------------------------|
| Engineers India Limited (EIL)                     | • Optical radiation  
|                                                  | • Mass, density                                                       |
| GAIL (India) Limited                              | • Pressure, vacuum and ultrasonic  
|                                                  | • Temperature and humidity                                             |
| Hindustan Petroleum Corporation Limited (HPCL)   | • Mass, volume, density  
| Indian Oil Corporation Limited (IOCL)            | • Temperature and humidity                                             |
| Oil and Natural Gas Corporation Limited (ONGC)    | • Pressure, vacuum, and ultrasonic                                    |
| Bharat Petroleum Corporation Limited (BPCL)      | BND related to petroleum, petroleum products, and natural gas are being produced at HPCL/BPCL in association with CSIR-NPL |

functioning, minimization of loss, and efficient execution of product distribution and standardization.

In this context, CSIR-NPL not only provides metrological traceability to a myriad of equipment in use at the many PSUs across India, but it has also embarked on an ambitious plan aiming towards self-reliant India, in the area of production of Standard Reference Materials, trademarked as “Bhartiya Nirdeshak Dravyas” as described in Chaps. 18 and 19. CSIR-NPL is producing BNDs related to petroleum, petroleum products, and natural gas in association with HPCL/BPCL [13, 14]. This will help in the quality assurance of the products. The BNDs relate to quantization of sulfur impurities in diesel, gasoline, and petrol as well as for density and viscosity evaluation in petrol samples. As summarized in Table 21.10, the major oil and gas giants, i.e., ONGC, IOCL, GAIL, HPCL, and BPCL obtain measurement traceability from CSIR-NPL in the areas of pressure, mass, density, viscosity, temperature, humidity, optical radiation, etc.

#### 21.5.8 Ministry of Electronics and Information Technology

Various organizations under the Ministry of Electronics and Information Technology (MEITY), namely Standardization, Testing and Quality Certification (STQC), Electronics Regional Testing Laboratories (ERTL), and Electronic Test and Development Centers (ETDC) require traceability for various physico-mechanical and electrical parameters from CSIR-NPL, which are listed in Table 21.11. The STQC, ERTL, and ETDC are engaged in supporting industry and trade as well as in protecting consumer interest in the electronic and information technology sector by providing customer-centric, accredited quality assurance services as per international standards for global acceptance. There are a number of regional testing and development centers working
Table 21.11  Services provided by CSIR-NPL to various research organization of the Ministry of Electronics and Information Technology

| Organizations/departments                                                                 | Traceability/calibration/consultancy area                                                                 |
|------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------------------|
| Standardization, Testing, and Quality Certification (STQC), Electronics Regional Testing Laboratories (ERTLs) at Delhi, Kolkata, Mumbai, and Thiruvananthapuram Electronic Test and Development Centers (ETDCs) at 10 locations across India | • Mass, volume, density, and viscosity  
• Pressure, vacuum  
• Temperature and humidity  
• LF and HF impedance and DC standards  
• LF and HF voltage, current, and microwaves  
• Optical radiation  
• Force and hardness,  
• Acoustics and vibration,  
• AC high voltage and AC high current  
• AC power and energy standards  
• Magnetic parameters |
| National Informatics Centre Services Inc. (NICSI)                                           | • Implementation of IST service using NPL controlled remote oscillator system for national knowledge Network at National Informatics Centre |

under the aegis of STQC, ERTL and ETDC, spread across the length and breadth of the country. These regional centers in turn further disseminate these testing and calibration services to the local industries and organizations and contribute significantly to the GDP of the nation. CSIR-NPL India, in collaboration with MEITY, has established the state-of-the-art nano-metrology facilities, which are aimed at supporting nano-technology development through very low level electrical current measurements, nanoscale dimension measurements, etc.

### 21.5.9 Increasing Reliability of Dairy Products

CSIR-NPL is contributing to the milk industry by way of calibration of Butyrometers and Lactometers [15]. Butyrometer is a measuring instrument used to measure fat content in milk or milk products in general. Fat content is determined by Gerber's method and it helps in the detection of adulteration like watering and skimming of milk. Lactometer is a special type of hydrometer. It is an instrument that is used to check for the purity of milk by measuring its density. It is constructed and graduated such that lactometer reading is related to the specific gravity of milk based on the ratio of the milk to water weight of a unit volume at a specific temperature. These instruments are calibrated at CSIR-NPL for correct density measurements of milk.
Table 21.12  Services provided by CSIR-NPL to railways

| Organization                        | Traceability/calibration area                        |
|-------------------------------------|-----------------------------------------------------|
| Diesel Locomotive Works, CMT        | Ultrasonic measurements                              |
|                                     | Force and hardness                                   |
| Chief Workshop Manager’s Office, Mumbai | Acoustics and vibration                           |
| Research Designs and Standards Organization (RDSO), Manaknagar, Lucknow | Lux meter/optical radiation |
|                                     | Ultrasonic                                           |
| Rail Coach Factory                  | Electrical and electronics and related parameters   |
| Railways, N.E.                      | Ultrasonic measurements, Mass calibration            |
| RITES Ltd.                          | Acoustic and vibration                               |
| Delhi Metro Rail Corporation        |                                                      |
| Bengaluru Metro Rail Corporation Limited |                                               |

21.5.10  Safety for Railways

Indian Railways (IR) is the fourth largest railway network in the world and the largest one in Asia used for public facilities and transportation which is managed under the umbrella of the Ministry of Railways. Passenger safety is of prime importance for the rail journey. The detection of critical inherent cracks in the railhead, quite apparently, is a major challenge for the railway industry. For the defect-free production of rails, each rail is tested ultrasonically by various ultrasonic transducers connected in different orientations as per requirements. If any defect(s) are found the rail is rejected. At present, CSIR-NPL also provides metrological traceability of various parameters, e.g., acoustics, vibration, electrical, electronics, force, hardness, optical, etc. to the major rail manufacturing industries and suppliers of the Indian railway, as listed in Table 21.12. CSIR-NPL, in collaboration with CPCB is also working on the measurement of noise levels in the railway compartments for passenger safety.

21.5.11  Micro, Small and Medium Enterprises

The MSME sector has established itself as a highly vibrant and dynamic sector of the Indian economy over the last few decades. MSMEs not only play a crucial role in providing large employment opportunities at comparatively lower capital cost as compared to large industries but also help in industrialization of rural and backward areas, thereby, reducing regional imbalances, assuring more equitable distribution of national income and wealth [16]. MSMEs are complementary to large industries as
Table 21.13 Services provided by CSIR-NPL to MSMEs

| Organization                                         | Traceability/calibration/grant-in-aid project                                                                 |
|------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| MSME Kolkata                                        | • Photometric and radiometric parameters                                                                    |
| MSME Mumbai                                         |                                                                                                             |
| Institute for Design of Electrical Measuring        | • Mass, volume                                                                                            |
| Instruments, IDEMI, Mumbai                          | • Fluid flow                                                                                               |
|                                                    | • Pressure, vacuum and ultrasonic                                                                          |
|                                                    | • Temperature and humidity                                                                                    |
|                                                    | • Acoustic and vibrations                                                                                    |
|                                                    | • Multi-ferroics and magnetics                                                                             |
|                                                    | • Magnetic parameters                                                                                       |
|                                                    | • Josephson Junction                                                                                        |
|                                                    | • LF and HF voltage, current, and microwaves                                                               |
| MSME Testing Centre                                 | • Pressure, vacuum, and ultrasonic                                                                          |
| New Delhi                                           | • Mass, optical radiation                                                                                    |
|                                                    | • Length and dimension                                                                                      |
|                                                    | • Force and hardness                                                                                        |
| MSME (Ministry of Micro, Small and Medium Enterprises)| • Development of carbon fiber composite limbs for recurve bow                                               |

ancillary units and this sector contributes enormously to the socio-economic development of the country. India’s MSME base is the largest in the world after China and provides a wide range of services and manufactures >6000 products—ranging from traditional to hi-tech items. To strengthen MSMEs for the production of high-quality products of international quality, CSIR-NPL supports them by providing the metrological traceability for a large number of parameters, as listed in Table 21.13. CSIR-NPL also collaborates with MSMEs for the development of various products, e.g., indigenous development of archery recurve bow limb based on carbon fiber in association with Technology Development Centre, Meerut, ultraviolet disinfection casket for coronavirus in association with M/s Motras, production of structural tiles using waste plastics, production of PM2.5 samplers, etc.

21.5.12 Health Through Confidence in Critical Equipment/Measurements

The human happiness and wellbeing depend upon their state of health. The health of the citizens in any country also makes an important contribution to economic progress, as healthy populations live longer, are more productive, and save more. This has been amply proven in the recent Covid-19 pandemic which has stalled the world’s greatest economies. Hence, the Ministry of Health is undoubtedly an important factor, along with other government departments, organizations, civil society groups, and communities themselves.
The Central Drug Standardization and Control Organization (CDSCO) is the national regulatory body for Indian pharmaceuticals and medical devices. The various pharmaceutical companies engaged in the manufacturing of critical and life-saving drugs require an exact ratio of the constituents by weight. CSIR-NPL provides metrological traceability for mass to a number of pharma companies in India. In addition, CSIR-NPL supports the calibration of clinical thermometers, blood pressure measuring machines, Magnetic resonance imaging (MRI), etc. A detailed discussion on the contribution of CSIR-NPL in the health sector is described in Chap. 15.

21.5.13 Preservation of Original Constitution of India

In the largest democracy of the world, parliamentary affairs are extremely vital for ensuring the functioning of democratic processes and principles. These are documented in the iconic “Constitution of India” which is required to be safeguarded in its original document state. The responsibility of safeguarding the original calligraphic copies of the Constitution of India, kept at Parliament Library, is proudly, the privilege of CSIR-NPL. A discussion on this has been made in Chap. 1.

21.5.14 Sound and Noise Measurements: Housing and Urban Affairs

It is well known that noise pollution affects people’s health and quality of life. Construction and roadwork activities, cars, trains, airplanes, and other forms of transportation are some of the worst contributors to noise pollution [17]. Prolonged high levels of noise can cause hearing loss and stress-related illnesses and even cardiovascular diseases. To mitigate its ill-effects, mapping, and segregating the sources of noise are a basic requirement. CSIR-NPL plays a strategic role in creating social awareness apart from giving crucial noise mapping services to Central public works department, Delhi Development Authority, Roads organizations such as Border Roads Organization, etc. This is done by way of calibration of electro-acoustic equipment such as microphones, accelerometers, sound calibrators, sound level meters, vibration meters, testing of sound absorptive and insulating materials, as well as industrial noise and vibration measurements and control. Sound/noise insulation is provided through acoustically insulating panel designs, as well as through technical advisory consultancy in architectural acoustics, noise absorptive barriers, etc.
21.5.15 Ministry of Commerce and Industry

The QCI under the Department of Promotion of Industry and Internal Trade in the Ministry of Commerce and Industry is an important constituent of the quality infrastructure with a primary role to establish and operate the national accreditation structure for conformity assessment bodies; providing accreditation in the field of education, health, and quality promotion. The NABL is an important wing of QCI, primarily for the accreditation system accepted across the globe by providing high quality, value-driven services, fostering APAC/ILAC MRA, empanelling competent assessors, creating awareness among the stakeholders, initiating new programs supporting accreditation activities, and pursuing organizational excellence [18]. CSIR-NPL’s contribution to NABL is immense in more ways than one, and include expert assessors for almost all parameters who are routinely a part of accreditation activities for private and public laboratories across the length and breadth of the country. Innumerable calibration/testing is also regularly carried out for NABL accredited laboratories along with participation in the accreditation process, awareness programs, and formulation of policies and initiation of new programs. Ministry of Commerce has supported CSIR-NPL in the development of BNDs, as discussed in Chaps. 18 and 19. In association with National Council for Cement and Building Materials (NCCB), Ballabgarh, an Institute under Commerce Ministry, CSIR-NPL has not only produced and marketed a number of cement BNDs, but many of them have also been exported.

21.5.16 Ministry of Earth Sciences

CSIR-NPL is one of the important scientific partners of the Ministry of Earth Sciences and National Centre for Antarctic and Ocean Research Laboratory (NCAOR) and has been participating in the Indian scientific expeditions to Antarctica right from the first expedition in the year 1981 to date. CSIR-NPL also provided national leadership to four Indian scientific expeditions viz. 8th, 10th, 14th and 31st Indian scientific expeditions to Antarctica. The 8th and 31st Indian scientific expeditions to Antarctica were marked as important milestones for the Indian Antarctic mission when the two permanent Indian scientific bases, i.e., Maitri and Bharati were established by India and the country joined the elite club of countries having more than one scientific base in Antarctica. CSIR-NPL has also established a state-of-the-art Indian Polar Space Physics Laboratory (IPSPL) at Maitri for continuous and real-time monitoring of high latitude ionosphere. A detailed discussion on this is presented in Chaps. 13 and 14.
21.5.17 Polymer Engineering

Central Institute of Plastics, Engineering and Technology (CIPET) operates under the Ministry of Chemicals and Fertilizers. It is an apex Institute of International repute in the field of polymer science and technology to ensure sustainable growth in plastic engineering. It is engaged in the fields of design, tooling, plastics processing, testing, and quality assurance and inspection services to the plastics industries through a quality management system and does dedicated research on the development of new polymeric materials. The requirements of CIPET for metrological traceability in the parameters of mass and density, force and hardness, pressure, vacuum, and ultrasonic metrology, etc. are met from CSIR-NPL.

21.5.18 Contributions to Finance Sector

Among the regulatory bodies under the Ministry of Finance is the Reserve Bank of India (RBI), which regulates the issue of banknotes and keeping of reserves with a view to securing monetary stability in India and generally to operate the currency and credit system of the country to its advantage; to have a modern monetary policy framework to meet the challenge of an increasingly complex economy, to maintain price stability while keeping in mind the objective of growth. The “Security Printing and Minting Corporation of India Limited”, SPMCIL, a PSU working directly under the ministry, is engaged in the manufacture/ production of currency, security paper, non-judicial stamp papers, postal stamps, and stationery, travel documents viz. passport, security certificates, cheques, bonds, warrants, special certificates with security features, security inks, Circulation, and Commemorative Coins, Medallions, Refining of Gold and Silver, and Assay of precious metals [19]. CSIR-NPL, in coordination with SPMCIL, has launched India’s first 9999 Pure Gold BND. In addition, CSIR-NPL is also closely working with SPMCIL for indigenous development of color shift intaglio ink (CSII). Details of these are presented in Chap. 17.

21.5.19 New and Renewable Energy

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters relating to new and renewable energy including solar photovoltaic technologies and systems. MNRE is the regulatory body in policy framework and implementation of various programs and activities through central electricity authority, state nodal agencies (SNAs), academic institutions, national laboratories, public sector undertakings, and state and central government departments. To support the Ministry, there are five institutions consisting of three autonomous bodies, i.e., National Institute of Solar Energy (NISE), National
Table 21.14  Projects of CSIR-NPL with MNREs

| Organization                                | Grant-in-aid project                                                                 |
|---------------------------------------------|--------------------------------------------------------------------------------------|
| Ministry of New and Renewable Energy (MNRE) | • National primary standard facility for cell calibration                             |
|                                             | • To conduct regular workshops and hand-on-training on solar photovoltaic for bridging the gap between industry and academia |

Institute of Wind Energy (NIWE) and National Institute of Bio-Energy (NIBE) and two public sector undertakings, i.e., Indian Renewable Energy Development Agency (IREDA) and Solar Energy Corporation of India (SECI). CSIR-NPL in association with MNRE worked on R&D projects on solar photovoltaics and systems. Currently, CSIR-NPL is establishing “National primary standard facility for solar cell calibration”, which will be used for the dissemination of measurement traceability to PV industry and academic institutes in the country. Projects undertaken by CSIR-NPL with MNRE are listed in Table 21.14.

21.5.20  Jute Recycling

The Ministry of Textiles, Government of India has constituted the National Jute Board (NJB) in the exercise of the powers conferred by Sub-Sect. (1) of Sect. 3 of the National Jute Board Act, 2008 (No. 12 of 2009). CSIR-NPL in association with National Jute Board is working on development of activated carbon from waste jute stick biomass. The technological solution provided by CSIR-NPL for conversion of jute sticks biomass into activated carbon will be a game-changer in the whole chain of jute business involving industries, farmers and people of the area because they will be benefited from the additional income from waste jute sticks. It will also create an ecofriendly environment with an emphasis on the conversion of ecology into the pristine status and achieve an ever-elusive pollution-free environment.

21.5.21  Providing Confidence to the Flow of Jal Shakti

Jal or water is the basis for all life. For regulatory purposes, all water flow meters in use need to be calibrated. The fluid flow facility of CSIR-NPL is utilized by several state water boards to calibrate/test these water flow meters, including Delhi Jal Board, New Delhi Municipal Corporation, Uttar Pradesh Jal Nigam, Uttarakhand Jal Sansthan, and Tamilnadu Water Board, etc. Water meter testing is carried out up to DN50 size for threaded type domestic water meters. The bulk type water meters of sizes DN50-DN200 are tested in the primary water flow calibration facility for
accuracy. The traceability to these boards is further disseminated to the consumer through various manufacturers and NABL accredited laboratories.

### 21.5.22 Skill Development Initiatives

The Skill Development Ministry is responsible for co-ordination of all skill development efforts across the country, removal of disconnect between demand and supply of skilled manpower, building the vocational and technical training framework, skill up-gradation, building of new skills, and innovative thinking not only for existing jobs but also jobs that are to be created. CSIR-NPL along with other CSIR labs has recently emerged as a skill development center in addition to its dominion over metrology for the Nation. Diploma courses, area-specific training courses, seminars as well as workshops are regularly being organized for building skilled man-power, up-gradation of skills for industrial job requirements, etc. The details of the skill initiatives at CSIR-NPL are described in Chap. 20.

### 21.6 Collaboration Between CSIR-NPL and Industries

As shown in Fig. 21.5, private industries are major beneficiaries of the calibration and testing facilities of CSIR-NPL. Many of the small industries take the metrological traceability from the NABL accredited laboratories. However, most of the multinational companies manufacturing their products in India, as well as many large industries obtain measurement traceability to SI units from foreign NMIs. One of the reasons for this could be the limited CMCs of CSIR-NPL at BIPM, as discussed in Chap. 1. Therefore, CSIR-NPL is working on enhancing its CMCs.

Apart from the measurement traceability, during the past few years, CSIR-NPL has started supporting private industries through the transfer of technologies, consultancies, and/or collaborations. A partial list of the notable collaborations established with various private industries is listed in Table 21.15. The technology transfers are mostly for the societal applications, e.g., PM2.5 sampler, recycling of the waste plastics, utilization of jute, UVC based disinfectant casket, etc. One of the major successes of CSIR-NPL has been to rope in the private industries for the development of BNDs in the areas of water, food, hardness, petroleum, etc. Such collaborations are very important for becoming self-reliant in the area of reference materials, which are undoubtedly critical for quality control and quality assurance. CSIR-NPL also has a collaboration with M/s IFR for time signal (IST) broadcast using long-wave transmitters.

Table 21.15 gives a glimpse of the technologies propagated by CSIR-NPL for societal benefits. Many in India are still not aware of the fact that during each general election in India, nearly 40 million people wear a CSIR-NPL mark on their fingers, known as the ‘indelible Ink’ [20]. This Indelible ink is a time-tested gift of CSIR-NPL.
| Private industry                                      | Technology                                                                 |
|------------------------------------------------------|---------------------------------------------------------------------------|
| M/s Mysore paint and Varnish Limited (MPVL), Mysore, Karnataka | Development of indelible ink marker pen (IIMP)                            |
| M/s Max Super Specialty Hospital, Delhi, India        | Infrared spectroscopic study for tumor diagnosis                           |
| M/s Kataline Infra Products Pvt Ltd,                  | Long afterglow phosphors                                                 |
| M/s Tata Steel Ltd.                                   | Feasibility study on development of value-added carbon products from coal tar |
| M/s Shayna Ecounified India Pvt. Ltd., Delhi          | Recycling of waste plastic bags into tiles for structure designing        |
| M/s Cell Propulsion Pvt Ltd., Karnataka               | Development of carbon foam as a heat sink for high energy Lithium ions batteries for electrical vehicles |
| M/s Environmental Solutions, Noida                    | High-volume PM$_{2.5}$ impactor sampler                                  |
| M/s Addin Infra Private Limited, Rajkot              | Recycling of waste plastic bags into tiles for structure designing        |
| M/s ATOS Instruments Marketing Services, Bangalore    | Ferroelectric loop tracer                                                 |
| M/s IFR Information Dissemination Pvt Ltd             | Dissemination of IST by long-wave transmitters                            |
| M/s Rajasthan Electronics and Instruments Limited (REIL), Jaipur | Solid-state Peltier refrigerator                                         |
| M/s Aashvi Technology, Ahmedabad                      | Production of water Bhartiya Nirdeshak Dravyas                            |
| M/s Sreeni Labs Pvt. Ltd, Hyderabad                   | Production of Poly (3,4-ethylenedioxythiophene)-poly(styrenesulfonate) (PEDOT:PSS) |
| M/s Vyzag Bio Energy Fuel Private Limited, Madhavadhara, Visakhapatnam | Recycling of plastic waste into useful tiles                            |
| M/s Reliable Diesel Engineers (P) Ltd, Faridabad      | Noise absorptive barrier for metro/railway/highway/airport/noise abatement |
| M/s Global PT Provider (P) Limited, Okhla Industrial Area, New Delhi | Production of hardness Bhartiya Nirdeshak Dravyas |
to the spirit of democracy in India. Today the know-how for the same has been given to M/s Mysore Paints, which is the sole organization authorized to manufacture it. It is also exported to Sri Lanka, Indonesia, Turkey, and other democracies. Likewise, the technology for converting waste plastic into useful tiles for construction purposes, low-cost Peltier based refrigerator which works on solar power and has been designed for rural areas, indigenous BNDs which save precious foreign exchange, disinfectant casket to mitigate the vicious spread of Covid-19, PM2.5 samplers for monitoring pollution levels, noise mitigation barriers to decrease noise pollution, etc. are only a few of the highlights of CSIR-NPL’s recent contributions to the civil society for benefit of the masses of this country [21, 22]. A complete list of the technologies developed at CSIR-NPL for transfer to start-ups/industries is available on the CSIR-NPL website [23].

21.7 CSIR-NPL’s Connect with Society

CSIR-NPL, being the NMI of the country, has the responsibility to disseminate the knowledge created at the international level in the domain of metrology and its applications to common citizens of the country. In addition, the initiatives of the GoI also need to be communicated to the masses. The Ministry of Science and Technology (MoST) is resolute to cultivate scientific temper amongst the young minds, who in turn, would be the country’s most trustworthy assets for the implementation of the various GoI missions. Scientific temper is a way of thinking and action that uses scientific methods and involves the application of logic for problem-solving. Scientific temper includes questioning, hypothesizing, observing physical reality, testing, analyzing, and communicating, and fairness, equality, and democracy are an integral part of it. CSIR-NPL executes this mandate of MoST, as described in the following sections, as it also allows CSIR-NPL to have direct interactions with masses to disseminate the basics and benefits of metrology to them.

21.7.1 Communicating the World Metrology to Masses

Each year BIPM celebrates World Metrology Day on May 20 to inform the world about the contributions the measurements make to our daily life [24]. Each year, BIPM releases a poster on this day with a particular theme, as summarized in Table 21.16 for the last five years. CSIR-NPL also commemorates the World Metrology Day by arranging a day-long seminar on the suggested theme by BIPM each year and releasing the theme poster. The ideas behind the themes are communicated to common people through FM radio, television interviews, newspapers, and social media. In addition, the need to implement the changes suggested by BIPM, e.g., the revisions of SI units, are communicated to the concerned government departments, as described in Chaps. 2 and 3.
Table 21.16  Themes of last five World Metrology Days

| Year | Theme of world metrology day | Brief description |
|------|-----------------------------|------------------|
| 2020 | Measurements for global trade | To create awareness amongst masses that metrology ensures that products fulfill the quality expectations and meet standards and regulations. Metrology plays a key role in facilitating fair global trade. The message that metrology is behind the scientific discovery and innovation, manufacturing, trade, which in turn improves the quality of life and protect the environment |
| 2019 | The International System of Units—Fundamentally better | To create awareness that on 16 November 2018, the CGPM has agreed to the implementation of new revised SI units based on the fundamental constants of and will come into force worldwide on 20 May 2019 |
| 2018 | Constant evolution of the International System of Units | To create awareness that the CIPM has in principle agreed upon the new definitions of SI units, in which each SI unit is linked to quantum laws of physics, and will be presented in the next CGPM meeting for approval. The new SI units have the advantage for further improvements to meet the future needs of science and technology |
| 2017 | Measurements for transport | To create awareness that transport plays a key role in our daily life and the measurements are responsible for advancement in transport. A range of measurements also control the quality of food, clothes, goods, etc. as well as the quality of raw materials they are made from, and that too without any environmental impact |
| 2016 | Measurements in a dynamic world | To create awareness that measurement science is changing with a rapid pace and it has an impact on the world around us |

21.7.2  Indian International Science Festival

To promote the scientific temper amongst young minds and the masses, the MoST and Ministry of Earth Science (MoES) in association with Vijnana Bharti (VIBHA) conceptualized the India International Science Festival (IISF). IISF is a uniquely intellectualized festival that showcases science and technology with the same freshness and flair that takes place in arts or music festivals. VIBHA is a non-profit organization and started from a movement on “Swadeshi Science”, which in a larger picture can be epitomized as Atmanirbhar Bharat. Swadeshi science represents development of indigenous science and technology to cater to the national needs with the appropriate linkage of traditional, modern, and spiritual sciences. VIBHA is engaged in the popularization of science to the masses and a collective application of ancient science and modern technology. The first IISF-2015 was organized at the Indian Institute of Technology, Delhi during 4-8 December 2015, which was a mega success. CSIR-NPL organized the second India International Science Festival (IISF-2016) during December 7-11, 2016 under the theme of “Science for the Masses” [25]. The Hon’ble Home Minister of India, Shri Rajnath Singh inaugurated IISF-2016 in the benign presence of Hon’ble Union Minister for Science and Technology and Earth
Fig. 21.9 The inauguration of IISF-2016 by Hon’ble Home Minister of India, Shri Rajnath Singh

Sciences Dr. Harsh Vardhan and other dignitaries namely Dr. K. Vijay Raghavan, Dr. Girish Sahani, Dr. V. P. Bhatkar, Dr. M. N. Rajeevan, and Dr. D. K. Aswal, as shown in Fig. 21.9. In IISF-2016, India’s quest for self-reliance in science and technology was demonstrated through mega exposition of outstanding achievements in metrology, space, defense, atomic energy, indigenous products by grassroots innovators, new scientific findings of young researchers, industry-academia interactions, etc. IISF-2016 had ~10,000 participants along with additional thousands of visitors (common public) every day. The participants included young school students from rural India, college students, young researchers, innovators, farmers, politicians, renowned scientists, ministers, diplomats from abroad as well as the common public. Shri Rajnath Singh emphasized that he would rather not like India to emerge as a Super Power, but aim to be a “guru” or teacher for the world. He proposed an addition to the popular slogan of ‘Jai Jawan, Jai Kisan, Jai Vigyan’, the term ‘Jan Vigyan’ that is science for the masses.

IISF-2016 was well organized and had numerous dedicated programs, which are briefly outlined below.

21.7.2.1 Pre-event Activities

A National level competition was one of the themes used as the curtain raiser event to propagate the activities of IISF 2016 to the masses. In this program regional problems were taken up, and for which the scientific solutions were invited from the public and researchers. For this, several CSIR, DST, and DBT labs across the country had an open day for the public. In addition, the burning issues of society in different parts of the country were shared through photos/videos and write-ups in the web portal of IISF-2016.
21.7.2.2 Events for Students

(a) **Science Village**: The Science Village was a unique experimental concept of CSIR-NPL which was introduced for the first time in the country with an intention to reach the unreached and was well coupled with the ‘Sansad Adarsh Gram Yojna’ of GoI (see Fig. 21.10a). The Science Village program was sculpted in such a way that 1769 students were selected and nominated by the Honorable Members of Parliament (Lok Sabha and Rajya Sabha) from their respective adopted villages in their constituencies, under the aegis of Pradhan Mantri Sansad Aadarsh Gram Yojana and therefore the Science Village demonstrated a mass representation from the rural part of India. The concept of Science Village emanated from the fact that in India there exists a large gap in terms of scientific awareness between the urban and rural population, in spite of India hosting a majority of its citizens in its rural countryside. The untapped potential of students belonging to the villages and small towns needed to be utilized and brought at par with that of the students from the metropolitan cities. This was needed at a time when India is reclaiming its past scientific glory. But the task to execute it required microscopic planning and was undeniably mammoth in nature. The Science Village was distributed under 8 different houses named after renowned scientists produced by our country, namely, K. S. Krishnan, A. P. J. Abdul Kalam, Aryabhatta, J. C. Bose, S. Chandrasekhar, Srinivasa Ramanujan, H. J. Bhabha, and C. V. Raman. In a 5 day long program these students were exposed to hands-on science experiments in physics and chemistry, visit mega science expo, visit to INSPIRE projects, interaction with scientists, know your capital (Delhi Visit), visit CSIR-NPL laboratories, and introduced to SI units, international science film festival, night sky watching laser shows, and popular talks from speakers like Dr. Suresh Prabhu, Hon’ble Union Minister for Railways, Shri. Anil Madhav Dave, Hon’ble Union Minister of State for Environment, Forest and Climate Change and Dr. G. Satheesh Reddy, Scientific Advisor to

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**Fig. 21.10** a Hon’ble Minister of S&T &ES Dr Harsh Vardhan inaugurating Science Village, b a glimpse of DST-INSPIRE national camp, and c 550 school students dressed up as Albert Einstein during IISF 2016
the Defense Minister. The exposure received by the students motivated many of
the participates to take science as a career option.

(b) DST-INSPIRE National Camp: The innovative science models and presenta-
tions created by students were exhibited in this camp, as a part of ‘Innovation in
Science Pursuit for Inspired Research (INSPIRE)’, a program sponsored and
managed by the DST for attracting young talent from schools and encouraging
the pursuit of science. Around 560 selected awardees from all over the country
displayed their projects in this event (see Fig. 21.10b). These participants were
selected to display their achievements/innovations after two levels of screening.
The first screening was done at the District level, where 10,000 students were
shortlisted out of 140,000 contestants. The second level screening was done
at the State level, where these 560 projects were selected for IISF-2016 and
were evaluated by a high-level Jury for National Award. This program encour-
ages young innovators to take up science as a career that reinforces the human
resource for the national R&D base.

(c) Dressing students as lookalikes of Einstein: With an objective to develop
an awareness among students about the phenomenal contributions of Albert
Einstein to modern-day science, 550 school students dressed to look like the
great Einstein (see Fig. 21.10c). This gathering of lookalikes of Albert Einstein
was aimed to break the earlier world record of Berkeley’s Black Pine Circle
School (USA).

21.7.2.3 Young Scientists’ Conclave

The Young Scientists’ Conclave (YSC) comprised of scientists/researchers/science
innovators/professionals below the age of 45 years, which later emerged as one of
the most fascinating events at IISF2016 due to the innovative deliberations under
various national flagship programs of GoI, such as Swachh Bharat, Swastha Bharat,
Namami Gange, Smart City, Digital India, Make in India, Green Energy, Sustain-
able Development and cleaner production, Materials for sustainable development,
and Indigenous Science and Technology. 21 plenary lectures on themes of national
importance, Agriculture, Health, Water, Information technology, Space and defense,
and Energy, were delivered to ignite the young minds by eminent scientific leaders.
To echo the call of Hon’ble Prime Minister to the youth to become the job giver
rather than a job seeker, workshops on patent filing, copyright, proposal drafting,
and ethics were organized. The youngsters, who have established successful start-
ups, were given platforms to present their journey and exhibit their ideas in the
pavilion. YSC achieved the objective of scouting, augmenting, and propagating the
national needs of the young researchers and stimulated them to play a constructive
role in transforming the nation into Sashakt Bharat.
21.7.2.4 Industry-Academia Interactions

Industry-academia interactions were one of the major events during IISF-2016 and had ~950 participants (45% from industries, 40% from academia, and remaining 15% from media, laboratories, and other organizations) from all over India. The main emphasis was placed on theme-based technical discussions, including technologies available with national laboratories (e.g. CSIR, DRDO, DST, DBT, MoES, ISRO, ICAR, ICMR) for commercialization; industry-oriented curriculum development, entrepreneurs for executing laboratory ideas to implementable technologies in small industries; metrology for time and frequency, electrical, and electronics metrology; mechanical and optical metrology; environment pollution monitoring Initiatives; and agriculture and industries.

21.7.2.5 International Science Film Festival

In the extravagant journey of bridging the gap between scientific temperament and communication, extraordinary science films from various nations were screened during IISF-2016, as listed in Table 21.17. These films demonstrated the concept of science for sustainability, advancement, prevention, growth, and prosperity. Besides the screening of these science films, it also focused on interactive sessions with eminent scientists, filmmakers, and communicators of India. The international science film festival was inaugurated by Mr. Ofi Akunis, Hon. Minister of Science, Technology and Space, Israel (see Fig. 21.11). The science film festival set a benchmark of green thoughts and ideas and inculcated a practical approach in the minds of people, both with scientific backgrounds as well as non-scientific backgrounds, making the idea of “Science for masses” a reality with necessity. The film festival kept the viewers engrossed, physically, emotionally, and practically, and was successful in decoding the essence of science for masses and science for the future. The program had aimed at understanding the value and need of simplification of complexity in different domains of science for its acceptance in layman’s life.

National NGOs’ Conclave

IISF-2016 also organized the National non-governmental organizations (NGOs) conclave. 71 NGOs from all over the country participated and discussed various key points related to specialized field works done by them in the areas of environment, agriculture, women empowerment, child development, and education, renewable energy, health, rural development, and science and technology. NGOs vowed to make India a prosperous and healthy nation by spreading the fruits of science into the villages (Fig. 21.12).
Table 21.17 The list of International films screened during IISF-2016

| Country | Science films |
|---------|---------------|
| Canada  | The connected universe |
| France  | Soil for food security and climate |
|         | A future without water |
|         | Perfect project towards the autonomous car |
|         | CNES-ISRO space research collaboration |
| Germany | Quantum physics: tap-proof by randomness |
|         | Light gets on your nerves |
|         | Clouds: more shades in the greenhouse |
| Israel  | Israel space agency |
|         | Israel inside: how a small nation makes a difference |
| Norway  | Bio-economy: an ocean of opportunities |
|         | Arctic mission |
|         | Drifting with the ice-life on the arctic expedition |
|         | iProcess |
|         | Harvesting and cultivating seaweed |
|         | Thin ice studies in the arctic-N-ICE2015 |
| Russia  | Secret of nature: wild Russia-Siberia |
|         | Look up-roscosmos |
| Sweden  | Innovative Swedish eye-tracking technology company looks to the future |
|         | Sweden leading the world of innovation |
|         | Swedish design can help millions |
| UK      | Changing climates: the impact inspiring change |
|         | The farms of the future |
|         | Changing lives in the Indian Himalayas |
| USA     | Weapons of mass destruction |
|         | Gravity |
|         | Racing extinction |

21.7.2.6 Mega Science, Technology and Industrial Expo

IISF 2016 Mega Science, Technology, and Industrial Expo were the main attractions for the visitors, which was aimed at showcasing the Indian contribution in the world of science, both ancient and modern, and to emphasize the inter-dependence of science-technology-innovation and society. In the mega-expo, the “working models” of outstanding technologies developed by various R&D Labs of ISRO, DRDO, CSIR, DST, DBT, MOES, ICAR, ICMR, Ministry of Urban Development, Ministry of IB, Ministry of Shipping, DAE, IITs for Unnat Bharat Abhiyan (Rural Development initiatives), and many other ministries/organizations like ONGC, IOCL, GAIL, etc., were displayed. In a special Vibrant India pavilion, 25 State Councils for Science and Technology, showcased the scientific programs of their respective states. AICTE had put up a special Pavilion on the technical education for the students. The expo was arranged theme-wise, i.e., agriculture; water; environment and energy; space and defense; health, medical, and biotechnology; unnat Bharath Abhiyaan, etc. In
Fig. 21.11 The international science film festival was inaugurated by Mr. Ofi Akunis. The (L-R): Dr. D. K. Aswal, Director, NPL, Mr. Peretz Vazan, Director General, Ministry of Science and Technology, Israel, Mr. Ofi Akunis, Hon. Minister of Science, Technology and Space, Israel, Dr. Harsh Vardhan, Hon'ble Minister of Science and Technology and Earth Sciences, GoI, H. E. Mr. Daniel Carmon, Ambassador of Israel to India, Prof. Ashutosh Sharma, Secretary, Department of Science and Technology, Govt. of India, Shri A. Jayakumar General Secretary, VIBHA

Fig. 21.12 Glimpses of Mega Science, Technology and Industrial Expo at IISF-2016, which was visited by more than 300,000 people
addition, a start-up pavilion with sessions for the youth to share their journey and products was also arranged.

To sum-up, through IISF 2016, CSIR-NPL along with VIBHA could demonstrate to the masses that India is on a path to self-reliance. On the other hand, IISF-2016 also brought policy-makers, ministers, parliamentarians, scientists, young innovators, students, and common citizens under one roof to realize the task of nation-building through science and technology.

21.7.3 Interaction with Society

CSIR-NPL also interacts with society through various programs. Every year, CSIR-NPL invites several thousand school/college students and teachers to visit its facilities on an open day, which is usually celebrated one day before or after the foundation day of CSIR, i.e., 26 September. Visitors are explained about the mandate of CSIR-NPL, SI, and derived units and their applications in all walks of life. Various advanced experiments are explained to them. In addition, students can visit CSIR-NPL anytime during the year, under the program known as ‘Jigyasa’. Also, start-ups, entrepreneurs, or any common person can approach CSIR-NPL anytime through ILG, PME, or HRD for discussion on any scientific subject, joint development of devices or to solve any social problem. Many of the collaborations listed in Table 21.13 are the outcome of such discussions.

21.8 Concluding Remarks

There is no doubt that India’s March towards a developed nation with a high economy and quality of life for each of its citizens can be achieved only when the manufacturing is promoted in the country. Recent government policies on the Atmanirbhar Bharat program to support MSMEs are to enhance the manufacturing of the country. In this chapter, we have elaborated that in order to make Atmanirbhar Bharat program a success, the coordination among the government, industries, academia, and civil society needs to be extraordinarily strong. For this, as suggested by Aswal model of inclusive growth, the metrology program of the country should be strengthened equal to that of developed economies. CSIR-NPL, being the NMI of the country, has been discharging its duties diligently over the past 75 years. CSIR-NPL has established 236 calibration and measurement capabilities (CMCs) at the key-comparison database of BIPM and has been participating in the Asia Pacific Metrology Program as its founder member. CSIR-NPL has been supporting Legal Metrology, NABL, and BIS in strengthening the quality-infrastructure of India. CSIR-NPL has generated new capabilities in the areas of IST with an uncertainty of <3 ns, development of indigenous certified reference materials under the trademark of BND®, new initiation on environmental monitoring, optical metrology, biomedical metrology, etc.
CSIR-NPL has been supporting the government, industries, academia, and society. However, there is enough scope for improvement, and some of the suggestions are as follows.

(i) The number of CMCs at KCDB, BIPM should be enhanced by initiating new metrological programs. In addition, all seven SI units based on fundamental constants of nature should be realized at CSIR-NPL. These activities would require high funding, a dedicated team of scientists, and collaborations with other NMIs on advanced fields of metrology.

(ii) Industry 4.0 is still evolving and the success will depend upon how soon its metrology gets developed. CSIR-NPL along with other national labs should initiate a program on the development of metrology for Industry 4.0. As discussed in Chap. 1, the development of digital SI units is an essential requirement for Industry 4.0. In addition, the operations in Industry 4.0 are expected to be accurate, fast, safe, and flexible, which in turn, would require touchless calibration. Consequently, an unprecedented requirement for digital metrology is evolving for the digital transformation of metrological services, and remote calibrations wherever possible to keep pace with the time-efficient error identification to minimize production delays [26, 27]. If the calibration/reference laboratories and the client laboratories can be connected by electronic means for data transport, instead of instrument transport, then the overall calibration process is possible on-line and in real-time. This would directly manifest into a saving of both time and money. This can be achieved through establishing a procedure to produce, transfer and control calibration data which will compare the values of the reference standards to the values of the artefacts without endangering accuracy and traceability necessary for calibration. This concept is referred to as touchless calibration. However, the new conformity assessment infrastructure would be feasible only with smart transmitter/sensors, high-speed data transfer, cybersecurity and reliability, and integrity of data processing, calculations and operations, and even robotics. Remote calibration technology currently appears feasible with the use of smart sensors, which can either be used remotely or transported after calibration to the test site and used for remote calibration. A remote calibration technology for disseminating pressure standard and calibration has been developed [28] which is one of the ways CSIR-NPL can disseminate SI units to Industry 4.0 in the foreseeable future. In the remote calibration, a transfer standard can be transported from a calibration laboratory to a client’s site where a calibration item is used. Using the transfer standard and the IoT, the calibration item can be calibrated on-site. For such remote calibrations, integrated transfer standards can also be newly developed in various other parameters for SI units, both basic and derived. In addition, since digital metrology is expected to be heavily reliant on data transfers, cloud computing, cybersecurity, simulations, and even artificial intelligence, etc., the metrological aspect of data transfer and IoT, e.g., validated statistical procedures, infrastructure for digital calibration certificates, metrology in the
analysis of large quantities of data, synchronized communication systems, and simulations are a few of the futuristic needs.

(iii) Currently, the dissemination of metrological traceability from CSIR-NPL to stakeholders also takes place through Legal Metrology and NABL. This needs to be further strengthened. All the calibration and testing laboratories falling under the ambit of central and state government/ministries should ensure that they obtain the metrological traceability to SI units from CSIR-NPL either directly or through Legal Metrology and NABL. This is a massive job, but once implemented, will reap huge benefits to the country by providing the much-needed uniform and consistent test results for quality control and quality assurance.

(iv) India to a major extent lacks in appropriate national agencies that can provide Type approval or certificate of conformity to indigenously developed products and to ensure the compliance of imported equipment for the local environmental conditions. Type-approval implies that a product has met a minimum requirement of technical, regulatory, and safety standards. Although BIS provides ISI marks for daily consumer products and Legal metrology issues, for the Type approval of certain medical devices, there are no agencies especially for high-end sophisticated analytical equipment, biomedical equipment, etc. Recently, the Ministry of Environment and Climate Change has notified CSIR-NPL as an institute for the Type-approval of environmental monitoring equipment. CSIR-NPL in coordination with ministries can ensure that the country creates the Type-approval for all the products made in India.

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