# Strategy 2030+

## Consultative Committee for Ionizing Radiation (CCRI)

3rd edition

December 2023

# Contents

# EXECUTIVE SUMMARY

This document provides an overview of the CCRI strategy to 2030 and beyond. The strategy was developed by CCRI members in consultation with the wider ionizing radiation metrology community and key stakeholders and was first published in 2011.

Strategies such as this need to be living documents. This third version, adopted by the CCRI in January 2024, realigns the strategy adopted in June 2021 with the CIPM 2030+ strategy. As the previous version, it responds to the wider strategic review that had been undertaken by the CIPM and focused on five areas:

- The evolving needs for metrology, including responses to cross-cutting international challenges such as health, climate & the environment, food and the digital revolution.
- The most pressing scientific and technical challenges for metrology itself (including those catalyzed by the implementation of the new SI).
- Relationships with other international organizations.
- Encouraging inclusivity and wider involvement of states and economies in the Metre Convention.
- Modernizing the operations of the organisation.

A consultation exercise was carried out during 2020 to consider the impact of this CIPM review and recent developments in the field on the CCRI strategy. This involved the CCRI, Sections and Working Groups and the RMO Technical Committee Chairs. The feedback from the consultation had been incorporated in the 2nd edition of the strategy and aligned with the planned final CIPM 2030+ strategy, to be presented in 2025 at the occasion of the celebration of the 150 year-anniversary of the Metre Convention, in this 3rd edition.

The rationale for the strategy remains unchanged. Ionizing radiation has been in use over more than a century for many beneficial applications in healthcare, material production and characterization, and in supporting a secure energy supply. However, ionizing radiation is known to cause material and physical damage, including potential carcinogenesis. Accurate metrology is key to unlocking the benefits while ensuring that ionizing radiation can be controlled and used in a way that does not put patients, radiation workers, the public or the environment at risk.

There are significant changes taking place in the applications of ionizing radiation due to improvements in healthcare, environmental protection issues for the nuclear industry (particularly for decommissioning nuclear sites), and emerging needs to support the next generation of nuclear power stations and nuclear forensics. Ionizing radiation is used within a strict and changing regulatory framework due to the potential risks; regulatory constraints on the use and transport of radioactive materials can also make the day-to-day business of running comparison exercises or maintaining necessary equipment for metrology difficult. These changes mean that the international measurement system must continue to evolve while maintaining the existing, established, ways of working.

The strategy of the CCRI is therefore to increase the range of comparison exercises to cover emerging requirements, and to reduce the number of long-term large-scale exercises through optimizing use of resources at NMIs/DIs and the BIPM in order to avoid difficulties associated with shipping hazardous materials or sensitive equipment.

The CCRI aims to enable institutes to participate more fully in meetings through widespread adoption of video-conferencing technologies while encouraging in-person opportunities for discussion and dynamic collaborations in real time. There will also be an increased focus on building capabilities at smaller NMIs/DIs by organizing knowledge transfer workshops and increasing secondments to the BIPM, working in partnership with NMIs/DIs and liaison organizations such as the IAEA. The CCRI will also co-ordinate joint research projects to address priority issues of benefit to NMIs and DIs and will support initiatives towards recognition of ionizing radiation metrology as a scientific profession.

The CCRI has taken note of the revised SI, the development of the KCDB 2.0, and the needs expressed by CCRI members, observers and stakeholders and, in response, has adapted its policies and procedures. This work will continue, and the BIPM Ionizing Radiation Program will be encouraged to expand its coordination role, to align with the research and development activities of the leading NMIs and DIs, and to adapt to meet the growing needs of NMIs, especially those with emerging capabilities. The relationship with the key stakeholders such as the IAEA and the ICRU will be strengthened and closer links with other international organizations, such as the ISO and the CTBTO, will be forged; the liaison with RMO Ionizing Radiation Technical Committees (TC-IRs) will be a key focus point.

# 1. Scientific, economic, and social challenges

The main drivers that influence the future strategy of the CCRI encompass the wide array of uses of ionizing radiation. A brief summary is given below, showing how ionizing radiation metrology is involved in the five "Metrology Grand Challenges" as well as in cross-cutting activities. Further information can be found in the bibliography. Implications for the CCRI strategy are highlighted.

**a) Climate change and environment**

> *The CCRI will keep the needs of climate change science under review and will propose comparisons and other actions as appropriate.*

Measurement of air pollution and source attribution of greenhouse gases in the atmosphere can be traced by surveying concomitant naturally-occurring radioactive gases such as radon. An improvement of metrological traceability of radioactive measurements to be able to measure the very low levels of these radionuclides in the troposphere is needed. In addition, nuclear decommissioning has implications for the environment as well as for surrounding populations with the potential of releases into the surrounding air. The measurement of airborne radioactivity (gaseous or as aerosols) is being studied (e.g., the EU projects MetroERM and MetroPreparedness) and is also becoming increasingly important in supporting monitoring for the Comprehensive Test Ban Treaty.

Proper calibration of dose rate meters and TLD dosimeters for measurement and interpretation of dose rates in the environment, whether ambient or from contamination surveys in areas around incident sites (e.g., Chernobyl, Fukushima) is the task which may require development of task-specific techniques and methods (dose assessment and dose reconstruction).

Naturally occurring radioactive materials (NORM)

Recent studies have shown that exposure to radon, considering the apparently increasing levels from construction materials and increased time spent indoors, and other naturally occurring radioactive materials may have been underestimated. Such concerns have been reflected in recent regulations in the EU, which has expanded the regulations surrounding environmental ionizing radiation (and hence the need for metrology) to cover workplaces that were previously exempt.

Climate change

There is increasing interest in applications of ionizing radiation metrology in the field of climate change science. In addition to their effect on human health, both ionizing and UV radiation have an impact on terrestrial ecosystems. When cosmic rays interact with Earth's atmosphere, ozone is depleted, which increases exposure to solar ultraviolet radiation. Metrological data and measurement methods for these radiations are therefore also required to support environmental and climate sciences.

Cosmic rays can also be used as a probe: for example, measurement of cosmic-ray neutrons can be used to assess soil moisture content, an important parameter for global climate modelling. This new method represents a complex metrological challenge; aiming to solve the gap between point-scale humidity sensors and satellite remote sensing.

### b) Health and life sciences

External beam radiation therapy

*Metrology for radiotherapy contributes to effective cancer care. The CCRI will maintain the existing 'tried and tested' measurement infrastructure and seek to extend that infrastructure to new treatment modalities.*

Perhaps the clearest example of the benefits of ionizing radiation, and the most evident impact of its metrology, can be found in external beam radiation therapy. Effective cancer treatment relies on delivering a radiation dose that is sufficient to destroy tumor cells while minimizing the dose to surrounding healthy tissue (which could be fatal if critical organs are damaged). There is clinical evidence that the difference between under-treatment and over-treatment is about 2.5 % - in practice, this accuracy is difficult to achieve (primary standards can be realized with an accuracy of about 0.3-0.5 %). For this reason, the international validation and measurement traceability chain is very short – from the BIPM to the NMIs/DIs, then often straight to calibrated instruments in the hospital.

The World Health Organization estimates that the number of new cases of cancer per year will increase by 70 % over the next 20 years. External beam therapy remains one of the major treatment methods; most irradiations are carried out using linear accelerators; there are more than 11000 accelerators worldwide and the Director General of the IAEA has stated that there remains a shortfall of 5000 such radiotherapy machines in the developing world. High-activity radionuclide sources ($^{60}$Co) are still widely used (2200 units) and linear accelerators may not be a practical proposition for some settings. The IAEA has also indicated that there is increasing interest in orthovoltage therapy, particle therapy and ultra-high dose-rate therapy (FLASH).

The need to optimize the delivery of radiation to targets that are very well-defined, and often hypofractionated, is driving the development of new technologies for which the radiation field is “small” and the treated volume conforms closely to the tumor. Such beams present a challenge for accurate measurement of the radiation dose, leading to the development of small-field dosimetry.

In the longer term, particle (hadron) therapy continues to show promise for more accurate delivery of ionizing radiation directly and solely to the tumor. There are approximately 50 such facilities in use worldwide with a further 22 planned for construction; the global market is predicted to reach 3 billion USD by 2025. Other treatment modalities are also being studied, such as the use of ultra-short high-dose rate pulses.

Boron-capture neutron therapy has also been identified as a growing field in certain countries. This method will profit in future from potentially new sources for epithermal neutrons based on high power accelerators able to deliver high neutron fluence rates. The challenge to characterize these novel neutron fields will raise the demand of innovative neutron spectrometry instrumentation.

Brachytherapy

> *The CCRI will continue to support comparison exercises for brachytherapy and review the need to adapt the protocols as the field develops.*

Brachytherapy (such as the use of small, sealed radioactive sources to treat cancer directly within the body) has been practiced since the early days of radioactivity when radium needles were used – it is one of the most effective methods to deliver high radiation doses directly to a tumor. The use of $^{60}$Co sources has expanded over the past few years, owing to a longer half-life and fewer source management issues. The era of electronic brachytherapy has already begun, with miniaturized x-ray sources instead of radioactive sources; these devices eliminate some of the risks associated with conventional brachytherapy (loss of sources, leakage of these “sealed” sources, accidents in transportation and radioactive waste handling) so there has been expansion in the use of the technique for cancers of the breast, skin, gastrointestinal tract, and other tissues. The IAEA expects use of brachytherapy to increase, in line with the predicted increase in the cancer burden in low- and middle-income countries (LMICs) in the coming decades.

Nuclear Medicine

Nuclear medicine is expanding significantly, with developments in new cancer therapies (such as $^{223}$Ra), the growth in theranostics (radiopharmaceuticals used for both diagnostic imaging and therapy), the use of colloids as delivery mechanisms for radionuclides such as beta-particle emitters, and the early-stage developments in using Auger-emitting radionuclides for therapy. The worldwide market for nuclear medicine is predicted to grow from 9 billion USD in 2020 to 13 billion USD in 2024.

The potential in this field has been recognized by research facilities such as CERN and TRIUMF where pre-clinical batches of radionuclides are now being produced. In parallel with this, accurate nuclear data are critical to underpin production of the radionuclides and support accurate patient dosimetry. A pan-European project (PRISMAP) has been launched to coordinate the production of medical isotopes.

> *The therapeutic use of radiopharmaceuticals is predicted to expand significantly. The CCRI will facilitate comparisons of primary standards for emerging radionuclides and encourage the measurement of the nuclear data that will be needed.*

Accurate patient dosimetry for nuclear medicine therapy is a complex task which includes determining the distribution of the radiopharmaceutical in the body. NMIs are working in partnership with hospitals and academia to quantify images from scanners (SPECT/PET) through the development of standardized phantoms containing accurate and traceable quantities of radionuclides, that can then be used to mimic the distribution in the human body to assess the performance of imaging systems used on patients. The quantified images enable a more accurate estimate of radiation dose from the therapeutic radiopharmaceutical to improve the safety and efficacy of the treatment. This field, which combines biology, dosimetry and radionuclide metrology, is at an early stage but quickly developing.

Diagnostic radiology

There was a 50 % increase in the number of diagnostic medical examinations from 2.4 billion per year to 3.6 billion per year over the period 1996-2008, a trend that is believed to be continuing. New diagnostic procedures have resulted in a significant increase in collective dose to the population; in some countries, the collective annual radiation dose from medical x rays now exceeds that from natural background radiation. It should be noted that dosimetry in radiology is subject to very high uncertainties at present.

> *The increased use of diagnostic radiology (CT scans) emphasizes the need to maintain primary standards and comparisons in this field.*

Radiation sterilization and processing

The market for single-use disposable medical devices has undergone enormous growth in recent years, and this has driven the need for high dose-rate irradiation facilities to sterilize these products rapidly and cost-effectively. At least 12 million $m^3$ of medical devices (including surgical blades, sutures, orthopedic implants, gloves, containers, eye droppers and perfusion sets), about 50 % of all devices produced, are sterilized using ionizing radiation each year. The key advantage of the technique is that it can be applied to the final packaged product, avoiding the need for an aseptic room to package devices after sterilization.

Medical devices are subject to strict regulations; accurate dosimetry is essential as documented evidence that the process consistently results in a sterilized product. It is therefore a requirement that "Dosimetry used in the development, validation and routine control of the sterilization process shall have measurement traceability to national or International Standards and shall have a known level of uncertainty (ISO 11137-1)." The known dose measurement uncertainty is used to determine limits for an acceptable process.

There are about 200 irradiation plants worldwide, mostly using very high-activity $^{60}Co$ sources. However, there is an increasing number of accelerator-based facilities, both e-beam and x-ray, which require a measurement chain traceable to national standards but also, for comparability of delivery, relating back to the original $^{60}Co$ calibrations.

Radiation protection

> *The CCRI will ensure that the infrastructure for radiation protection metrology is maintained and promoted. New comparisons may be needed for radiation protection in new facilities such as high-energy neutron fields and pulsed fields.*

The international measurement system for dosimetry to support radiation protection is the cornerstone of all national regulatory systems designed to minimize the risks to the health of 22 million people worldwide who are potentially exposed to ionizing radiation in the workplace. These people are employed in commercial nuclear-power generation and decommissioning, in academic and government laboratories, food processing, industrial imaging and laboratories, weld-defect inspection, leak tracing, automobile-steel testing, mineral-deposits discovery, and as well as surgeons and other medical/dental personnel. It is worth emphasizing that these are significant potential risks to the workforce.

Developments in neutron dosimetry at NMIs include new detectors and spectrometry systems, as well as neutron calibration facilities, able to cover the very wide energy range of neutron fields in the workplace such as those needed for radiation protection at nuclear reactors and at high-energy accelerators. The new accelerators for hadron therapy, for example, produce high-energy secondary neutrons which produce an unwanted additional radiation dose risk for patients and operators.

A recent development concerns the rapid development of high-power laser facilities producing high energy radiation fields (such as those for lithography). The new challenge for ionizing radiation metrology is to determine reference values at these facilities for any type of ionizing radiation (especially neutrons) in a very intense and short single burst.

Ionizing radiation due to cosmic rays, too, has a non-negligible impact on the dose delivered to the population on earth and particularly to aircrew, with the neutron contribution dominating above 2000 m altitude. More recently, the displacement of the magnetic-field anomaly on the land surface of South America and the opening of sea and air routes at the level of the poles exposes certain populations to higher risks with regard to cosmic radiation. In addition, the development of space tourism and the proposed Mars exploration will expose people to high doses due to high-energy ions and their secondary particles (e.g., photons & neutrons) generated within the spacecraft walls, especially during solar events. Ionizing radiation metrology will therefore need to focus in the coming decades on high energy particles, especially ions and neutrons.

The ICRU/ICRP Report No. 95 on operational quantities for external radiation exposure will not impact the realization of primary standards but will affect instrument manufacturers and other end-users.

The importance of radiation protection metrology has been recognized by EURAMET and a new European Metrology Network (EMN) is to be established in this field. The self-sustaining EMN will have a key role in outreach and in coordinating radiation protection metrology and will engage with other RMOs in this field.

**c) Food Safety**

Food security depends partly on reliable storage capacity and food sanitation. Using ionizing radiation to treat a variety of food products to control pests, extend shelf life, and reduce spoilage and premature sprouting (particularly in areas with undependable refrigeration). Already approved and used in many countries (including India, China, the US, Australia, and South Africa, impacting more than 3 billion people) for a variety of edible products, food irradiation for sanitary purposes depends on well-controlled radiation dosage to obtain the desirable effect without affecting flavor, texture, or cooking behavior. Therefore, metrologically-sound dosimetry for high dose e-beam and source-based food irradiation facilities is critical not only for food safety but also to assure regulatory compliance as the technology expands to other economies.

### d) Energy

Next generation nuclear power

> *In the long term, small modular reactors and fusion reactors will result in new demands for metrology for neutrons, radiation protection and environmental protection. The CCRI will encourage the measurement of key data (e.g., cross-section data) to underpin the work and will maintain a watching brief and revise the strategy as needs are clarified.*

There is a strong interest in developing small, simple, nuclear power reactors (Small Modular Reactors) for electricity and heat production; one advantage of small reactors being the much lower capital investment needed. The implications for metrology, while unclear at present, will undoubtedly affect NMI efforts in radiation dosimetry (for radiation protection), radionuclide metrology (for environmental impact) and for neutron measurements (radiation protection and material effects). A widespread network of distributed SMRs presents a new challenge for accurate monitoring, potentially overlapping with IoT (Internet of Things) concepts.

Much of the research associated with fusion reactors is currently focused on radiation damage to materials. Neutron metrology needs in the sector are not yet well-defined. For ITER the fusion power will have to be determined from the neutron diagnostics, with a strong constraint on the uncertainty (expected to be not less than 10 %). The instrumentation will therefore have to be calibrated with an accuracy of a few percent; this will be difficult to achieve given the extreme temperatures and electromagnetic fields in which the instrumentation will be operated. As ITER and other facilities develop, addressing this challenge needs certainly to involve the metrology community.

Nuclear decommissioning

> *The safe disposal of radioactive waste from legacy nuclear sites is a matter of public concern. The CCRI will develop new comparison schemes to underpin CMCs for the reference materials needed. Similar concerns apply to naturally-occurring radioactive materials.*

The first-generation nuclear power stations and fuel reprocessing facilities, begun in the mid-1950s, are reaching the end of their useful working lives – by 2050, more than half of the world's current nuclear power stations will have closed (about 200 nuclear power reactors built since the 1950s have already shut down and between 200 and 400 reactors are scheduled for decommissioning by 2040) while others are being constructed. Many of the nuclear sites constructed in the 1950s and 1960s must be decommissioned, while ensuring that the large quantities of potentially radioactive waste resulting are disposed of safely and cost-effectively. The cost of decommissioning the facilities is estimated to be in excess of 60 billion Euros for the Sellafield (UK) site alone; the global market is around 5 billion Euro/year with the cost of disposal of the radioactive waste a significant percentage of this figure.

An increasing amount of radioactive waste will also come from the dismantling of particle accelerators used in research and medical applications, due to the radioactivity induced by their high energy beams and secondary particles.

Radionuclide metrology has a large part to play in this process – this has been recognized, for example, in the EU, which is supporting scientific collaborations through the EMPIR and Horizon2020 programs. Accurate, reliable measurements enable the waste to be disposed of cost-effectively and safely; however, such measurements involve measuring the radioactivity content of diverse materials. These measurements will also have to be supported by accurate activation data requiring beta, gamma, and neutron measurements. The measurement of radioactivity on material surfaces may grow in importance for nuclear decommissioning based on two ISO standards (8769 and the 7503 series).

#### e) Advanced manufacturing

Another recent manifestation has been the adoption of digital-signal processing techniques (‘list-mode data’) in radionuclide metrology in the last few years. Similar to the technology used in nuclear physics experiments, this has led to the development of a new IEC standard (IEC63047) to harmonize data formats, driven by the application of the technology by first responders in the event of a radiological incident such as a terrorist attack.

The miniaturization of electronic devices (the evolution of CMOS technology) has made them more sensitive to ionizing radiation. The interaction of ionizing radiation with the device can result in data errors or degradation; neutron and alpha-particle radiations are particularly damaging, potentially leading to “single-event upsets.” New measurements and standards, such as for low-level alpha particle emissions, must be developed to evaluate the low ambient levels of these radiation environments, pushing the limits of detection beyond conventional measurements.

#### f) Digital transformation

The impact of the digital revolution on metrology is expected to be significant in the coming decade; including increased internet connectivity of instrumentation, larger data volumes and the use of Machine Learning /Artificial Intelligence. This issue is a priority for CIPM with a long-term aim of establishing a framework that allows all aspects of the international measurement system (measurement results, uncertainties, traceability and provenance) to be accessed and interpreted digitally, enabling machine-to-machine communication and analysis. Near term aims include the adoption of Digital Calibration Certificates (DCCs). This is therefore an area where CCRI will need to review our approach regularly and update the strategy accordingly: the CCRI task group on digital transformation was created in the first half of 2023. We are already seeing impacts in areas such as healthcare, where artificial intelligence algorithms are being used to enhance medical imaging; with other applications expected in the years to come.

#### g) New metrology

Mass spectrometry, an established metrological tool in chemistry and other areas, has only been incidentally used in radioactivity measurements for some time. However, improvements in the sensitivity and affordability of mass spectrometers have begun to expand the influence of these techniques in radionuclide *metrology*, leading to research needs in linking mass to activity. Such instruments are particularly useful for measuring long-lived species such as in the actinide series, for which mass spectrometry promises to allow measurements at levels significantly lower and more quickly than can be done by conventional means.

The concept of digital twins has emerged over recent years, particularly in the use of digitalization to predict impacts and effects in advance of using ionizing radiation. This approach has been in use within ionizing radiation metrology since decades and modern radiation transport algorithms can model real-life situations in exquisite detail. The CCRI community continues to expand and develop digitalization tools to improve dose delivery in medical applications, advanced manufacturing, radiation protection, and risk assessment, and can offer extensive expertise to other areas of metrology on this subject.

### h) Other topics

**Nuclear forensics**

The IAEA defines nuclear forensics to be “the examination of nuclear and other radioactive materials using analytical techniques to determine the origin and history of this material in the context of law enforcement investigations or the assessment of nuclear security vulnerabilities”. It requires the highest levels of accuracy and traceability, as the information may be used in criminal prosecutions. The issue for radionuclide metrology is to provide the international measurement infrastructure to give confidence in measurements of the radionuclides of interest, including alpha-particle emitting isotopes.

In order to derive as much information as possible about suspect items in transport containers, increasingly sophisticated mixed-field interrogation systems (neutrons and gamma rays) are being developed. These introduce new requirements for measurement techniques and standards, including the appropriate and metrologically-robust sources of gamma rays and neutrons which can be easily transported and handled for field work while maintaining their traceability.

**High dose irradiation**

> *The CCRI will continue to support the comparison of standards of alpha emitters, to confirm that the high accuracy needed for nuclear forensics is met.*

The largest industrial application of high-dose irradiation is modifying polymer properties for insulators, tires, tubing, adhesives and composites; other applications include wastewater treatment and synthesis of nanoparticles. These applications might have less strict regulatory requirements, but they also need precise and accurate measurements to ensure that the process is effective and efficient in delivering the desired effect.

**Regulatory changes**

High-activity sealed radioactive sources are a concern for nuclear safety and security agencies. Some countries are moving towards using the regulatory framework to encourage the use of such sources to be phased out, with limits on the allowable working life of sources. However, ionizing radiation metrology relies heavily on such sources for producing stable, well-characterized, beams for realizing primary standards in dosimetry and for checking the stability of transfer instruments in radionuclide metrology. The ionizing radiation metrology community will need to consider how best to respond to this challenge.

The availability of $^{252}$Cf radionuclide sources (used for calibrating neutron dosimeters) is also under threat; NMIs are investigating alternative techniques to produce a similar neutron spectrum.

Shipping radioactive materials for radionuclide and neutron measurement comparison exercises remains difficult; the World Nuclear Association quotes from a Euratom report that "multiple layers of regulations, lack of harmonization and over-regulation in transport authorities" are the main causes.

**Changes in the metrology community**

At present, based on capabilities published in the Key Comparison Database, about 37 member states have active programs of work in radiation dosimetry and 29 in radionuclide metrology. For radiation dosimetry, this is augmented by the IAEA/WHO network of Secondary Standards Dosimetry Laboratories.

There are about 15 NMIs/DIs working in the field of neutron metrology, with a steady program of investment in new facilities. The main difficulty is that neutron metrology requires large scale facilities such as experimental reactors and accelerators, especially for neutron energies above 20 MeV. Similar issues apply in other aspects of ionizing radiation metrology, as few institutes have access to proton therapy machines, medical imaging systems or mass spectrometers.

> *The CCRI will work to co-ordinate sharing access to major facilities needed for comparison exercises and for research projects.*
> *There will be an increased emphasis on knowledge transfer to support NMIs/DIs with less experience in the field.*

## 2. Vision and mission

As a mature field of science, the focus of the CCRI is on enhancing the impact of the work of its participating members on society, and on ensuring the science develops to meet future needs. The CCRI's vision is:

> A world in which the many benefits of ionizing radiation for healthcare, industry and technology can be realized by accurate, scientifically-rigorous, measurement, confident that the associated risks are constrained.

The mission of the CCRI is:

> To discuss, foster, enable and coordinate the development, comparison and promulgation of national measurement standards for ionizing radiation. We aim to enable all users of ionizing radiation to make measurements with confidence at an accuracy that is fit-for-purpose.

The mission of the BIPM Ionizing Radiation Department is:

> To support the CCRI in its mission, to promote the work of the international metrology community, and to provide services to NMIs and DIs that can be centralized in an efficient way.

During the 29th meeting of the CCRI in June 2023, the critical role of the BIPM laboratory services in the international measurement system was noted:

- for radiation dosimetry, the BIPM primary standards set the KCRV and are used to compare national standards on a 10-12 year rolling program and to calibrate secondary standards;
- for radionuclide metrology, the BIPM on-demand services (SIR/SRTI/ESIR) complement the large-scale comparison exercises and reduce the need to transport hazardous materials.

# 3. Strategy

In line with the CCRI's vision, the 2030+ strategy aims for an inclusive international measurement system for ionizing radiation. The aims of the CCRI strategy are:

- **To improve global comparability of measurements**, by making comparison exercises more accessible and faster, increasing the scope to cover emerging requirements, reducing the need for long-term large-scale exercises, using a risk-based approach to deciding comparison exercises and optimizing the use of resources at NMIs/DIs and the BIPM.

- **To build capabilities at smaller NMIs/DIs,** by organizing knowledge transfer workshops and increasing secondments to the BIPM, working in partnership with NMIs/DIs and liaison organizations such as the IAEA.

- **To progress the state of the art** for issues identified by stakeholders of benefit to NMIs/DIs and the BIPM, through supporting the organization of targeted joint research projects.

- **To expand the coverage of services supported by CMCs** through the introduction of concepts such as comprehensive CMCs based on core quantities, to improve the expression of capabilities in an effective way with continuous improvement, that meets the needs of our stakeholder community.

- **To coordinate the introduction of the SI Digital Framework in ionizing radiation metrology,** including moving to digitalization of services (such as digital calibration certificates), making data from comparison exercises machine-readable and machine actionable, and providing support for NMIs/DIs.

## 4. Activities to support the strategy

The actions listed below are intended to give a broad overview to guide the ionizing radiation metrology community; in addition, the community will adapt to address emerging needs.

| Aim | Examples of activities |
|---|---|
| To improve global comparability of measurements | - Oversee the strategy for international comparison exercises.<br>- Increase representation of international organizations on the CCRI, including the ISO and the CTBTO.<br>- Share information on work in the RMOs to improve comparability (such as the new EURAMET European Metrology Networks).<br>- Expand the use of the Digital Framework in ionizing radiation metrology such as encouraging access to data sets used in the final analysis of comparison results to facilitate data exchange.<br>- Co-ordinate use of the BIPM comparison and calibration services to optimize interlaboratory comparison exercises.<br>- Publish an explanation of the use of sealed reference sources in ionizing radiation metrology.<br>- Develop and maintain the measurement infrastructure, such as comparisons, to support the timely response to emerging needs in the stakeholder community.<br>- Coordinate the dissemination of best practice such as the introduction of ICRU-95 to the user community<br>- Optimize the engagement of the ionizing radiation community in the development of international standards such as ISO.<br><br>Expand the international reference system for radionuclide metrology beyond gamma-ray emitters to include beta-particle and alpha-particle emitting radionuclides. |
| To build capabilities at smaller NMIs/DIs | - Expand the use of teleconferencing technologies to support face-to-face meetings and increase accessibility to the wider community including organizing regular webinars.<br>- Coordinate capacity-building and knowledge-transfer activities with the IAEA and the RMOs.<br>- Expand training and mentoring support for comparison pilots and CMC reviewers.<br>- Maintain a database of major facilities and establish a process to enable access.<br>- Promote the work of the CCRI to a wider audience, by organizing regular scientific webinars and increasing social media presence. |

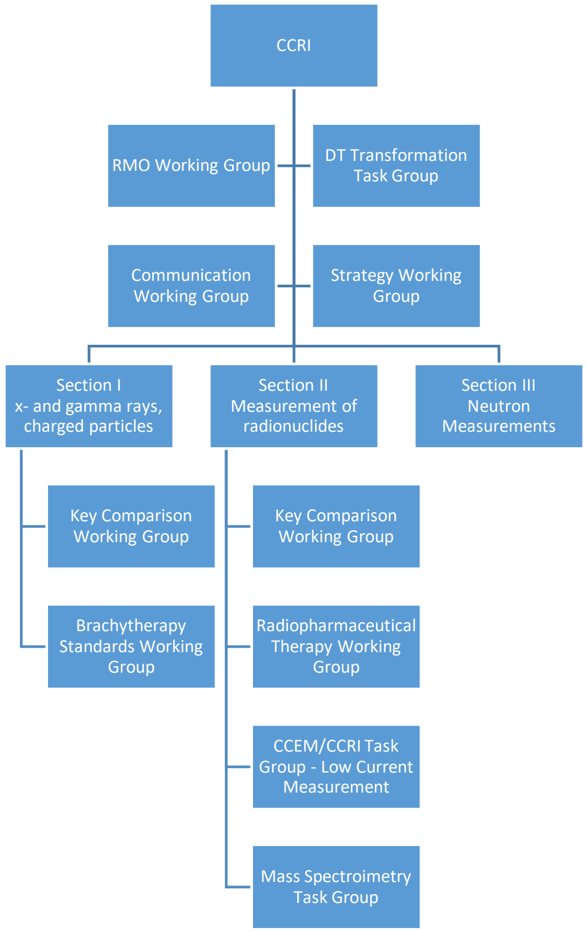
| Aim | Examples of activities |
|---|---|
| | - Support CIPM and IAEA initiatives towards recognition of metrology as a scientific profession. |
| To progress the state of the art | - Develop a metrology good-practice guide (and associated comparison program) for radiopharmaceutical therapy and quantitative imaging.<br>- Develop a good-practice guide for low electrical current measurement for radionuclide metrology (CCEM/CCRI Task Group).<br>- Establish a joint group with the CCQM on the use of mass spectrometry in radionuclide metrology.<br>- Review the use of artificial intelligence algorithms in diagnostic imaging and treatment planning and implications for metrology.<br>- Guide the BIPM laboratories on the development of new services for comparisons and calibrations.<br>- Where appropriate, encourage the measurement and evaluation of nuclear decay data to be included in protocols for comparison exercises, to add value to the exercises. |
| To expand the coverage of services by CMCs | - Develop and publish guidance on the interpretation of CMCs whilst maintaining backward compatibility.<br>- Maintain the Measurement Methods Matrix for radionuclide metrology.<br>- Develop 'how far the light shines' statements for comparisons for radiation dosimetry. |

# 5. Annex

## I. General information

| | |
|---|---|
| CCRI | Consultative Committee for Ionizing Radiation |
| Date established: | 1959 as the Comité Consultatif pour les Étalons de Mesure de Rayonnement (CCEMRI), renamed CCRI in 1997 |
| CC President: | Dr JT Janssen (NPL) |
| CC Executive Secretary: | Dr Vincent Gressier (BIPM) |
| Number of CC Members: | 13 (plus 10 official observers and 4 liaison organizations) |
| Meetings: | Every 2 years |

Structure of the CCRI committees




The CCRI has three objectives (CIPM-D-01-CC):

- To progress the state-of-the-art by providing a global forum for NMIs to exchange information about the state-of-the art and best practices,
- To define new possibilities for metrology to have impact on global measurement challenges by facilitating dialogue between the NMIs and new and established stakeholders, and
- To demonstrate and improve the global comparability of measurements. Particularly by working with the RMOs in the context of the CIPM MRA to plan, execute and monitor KCs, and to support the process of CMC review.

The CCRI's responsibilities are:

- to advise the CIPM on all scientific matters that influence ionizing radiation metrology, including the work of the Ionizing Radiation Department at the BIPM;
- to establish global compatibility of measurements through promoting traceability to national standards for radiation dosimetry, radioactivity and neutron metrology;

- to contribute to the establishment of a globally-recognized system of national measurement standards, methods and facilities;
- to contribute to the implementation and maintenance of the CIPM MRA;
- to review and advise the CIPM on the BIPM Ionizing Radiation Department’s measurements services;
- to act as a forum for the exchange of information about the activities of the CC members and observers; and
- to create opportunities for collaboration.

## II. List of key and supplementary comparisons and pilot studies

The BIPM offers on-demand comparison services (subject to availability) – these are listed below. The CCRI and RMOs also organize large-scale comparisons, these are listed on the KCDB.

| Comparison | Description | Pilot (Coordinating) Laboratory | Status |
|---|---|---|---|
| BIPM.RI(I)-K1 | Measurement of air kerma for $^{60}Co$ | BIPM | On-going |
| BIPM.RI(I)-K2 | Measurement of air kerma for low energy x-rays | BIPM | On-going |
| BIPM.RI(I)-K3 | Measurement of air kerma for medium energy x-rays | BIPM | On-going |
| BIPM.RI(I)-K4 | Measurement of absorbed dose to water for $^{60}Co$ | BIPM | On-going |
| BIPM.RI(I)-K5 | Measurement of air kerma for $^{137}Cs$ | BIPM | On-going |
| BIPM.RI(I)-K6 | Measurement of absorbed dose to water for high energy photon beams | BIPM | On-going |
| BIPM.RI(I)-K7 | Measurement of air kerma in mammography beams | BIPM | On-going |
| BIPM.RI(I)-K8 | Measurement of reference air kerma rate for $^{192}Ir$ brachytherapy | BIPM | On-going |
| BIPM.RI(I)-K9 | Measurement of absorbed dose to water for medium energy x-rays | BIPM | On-going |
| BIPM.RI(II)-K1 | Measurement of long-lived gamma-ray emitting radionuclides (SIR) | BIPM | On-going |
| BIPM.RI(II)-K4 | Measurement of short-lived gamma-ray emitting radionuclides (SIRTI) | BIPM | On-going |
| BIPM.RI(II)-K5 | Measurement of long-lived beta-particle emitting radionuclides (ESIR) | BIPM | Starting 2024 |

# III. Summary of work accomplished

The key accomplishments of the CCRI have been:

I. Establishing a traceability scheme for radiation dosimetry

The CCRI has developed a clear, robust, traceability scheme for radiation dosimetry that is well-established, accepted by NMIs and DIs, and results in reliable clinical measurements at an accuracy that is fit for purpose. There are three parts to the scheme:

**Part 1:** The BIPM primary standards are accepted as the international standard and set the Key Comparison Reference Value for defined quantities and radiation beams.

**Part 2:** Comparisons of a few key quantities and beams are sufficient to underpin claims for CMCs relating to a much larger number of quantities and beams.

**Part 3:** Comparisons at an agreed frequency are sufficient to demonstrate continued competence.

II. Reducing the requirements for large-scale comparisons in radionuclide metrology

There are more than 150 radionuclides that require accurate measurement, for diverse applications in nuclear medicine, the nuclear industry, environmental monitoring and the defense sector. To reduce the number of comparison exercises needed, the CCRI has devised a matrix approach (the Measurement Methods Matrix) that enables successful participation in a comparison for one radionuclide to be used as evidence of competence to realize standards of other radionuclides. The CCRI also worked with the BIPM to extend comparisons to cover short-lived radionuclides, using a stable travelling transfer instrument. As decided at the 2017 meeting of the RMO WG, comparisons in radionuclide metrology once every 15 years are sufficient to demonstrate continued competence.

By December 2023, a total of 278 comparisons among all three branches of ionizing radiation metrology were listed in the KCDB consisting of 201 Key Comparisons and 77 Supplementary Comparisons.

The details of the individual comparisons can be viewed on the KCDB.

III. Providing and disseminating key data

All applications of ionizing radiation metrology rely on the use of key data to convert instrument readings to quantities of interest. For example, in radiation dosimetry, published tables of stopping powers are needed; radionuclide metrology requires a knowledge of the half- life and emission probabilities of the radionuclide of interest.

> The CCRI has been instrumental in ensuring that measurements worldwide use up-to-date key data, disseminating the use of the new dosimetry data in the ICRU 90 report and ensuring metrology institutes take the latest decay data from the Decay Data Evaluation Project (DDEP). The CCRI has also encouraged the re-evaluation of such data as needs arise.

National Metrology Institutes and Designated Institutes claim calibration and measurement capabilities (CMCs) in accordance with their capabilities as validated through comparisons, research outputs, accreditation scopes and other evidence. CCRI has developed a guideline for reviewers on how evidence supports CMC claims, information required on the approval of quality systems, etc.

## IV. USEFUL LINKS

The reports and websites below (among other publications) were used in reviewing the needs of the user communities. Unpublished presentations from conferences and meetings were also used for background.

**External beam radiotherapy**

https://dirac.iaea.org/Query/Map2?mapId=0
http://www.nupecc.org/pub/npmed2014.pdf
http://ptcog.web.psi.ch
https://academic.oup.com/jicru/article-abstract/os13/1/NP/2923522?redirectedFrom=fulltext
https://www-pub.iaea.org/books/iaeabooks/5954/Absorbed-Dose-Determination-in-External-Beam-Radiotherapy

Add IAEA TRS-483

**Brachytherapy**

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4932125/
http://www.brachyjournal.com/article/S1538-4721(15)00300-1/pdf
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5415885/
https://msu.euramet.org/current_calls/pre_norm_2018/SRTs/SRT-n09.pdf
Add IAEA TECDOC 1274

**Nuclear medicine**

http://www.nupecc.org/pub/npmed2014.pdf
http://cerncourier.com/cws/article/cern/66176
http://www.nucmedbio.com/article/S0969-8051(16)30219-0/abstract
http://www.snmmi.org/AboutSNMMI/Content.aspx?ItemNumber=29736

**Diagnostic radiology**

http://www.unscear.org/docs/publications/2008/UNSCEAR_2008_Report_Vol.I.pdf

https://www.iaea.org/publications/7638/dosimetry-in-diagnostic-radiology-an-international-code-of-practice

**Next generation nuclear power**

http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-power-reactors/small-nuclear-power-reactors.aspx

https://aris.iaea.org/Publications/SMR_Book_2020.pdf

https://www-pub.iaea.org/MTCD/Publications/PDF/PUB1944_web.pdf

**Nuclear site decommissioning**

https://www.oecd-nea.org/pub/activities/ar2017/ar2017.pdf
http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/nuclear-wastes/decommissioning-nuclear-facilities.aspx
http://www.decommissioning-emrp.eu/
http://insider-h2020.eu/context-2/
https://www.iaea.org/PRIS/WorldStatistics/ShutdownReactorsByType.aspx

**Naturally occurring radioactive materials**

https://www.who.int/ionizing_radiation/env/9789241547673/en/
https://radonovalaboratories.com/eu-directive-2013-59-euratom-offer-better-protection-towards-radon/
http://radoneurope.org/index.php/activities-and-events-2/working-groups/radon-regulation/

**Radiation sterilization and processing**

https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1313_web.pdf
https://www-pub.iaea.org/iaeameetings/50814/International-Conference-on-Applications-of-Radiation-Science-and-Technology-ICARST-2017
https://www.iaea.org/topics/medical-sterilization

**Nuclear forensics**

http://www.currentscience.ac.in/Volumes/110/05/0782.pdf
https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1687web-74206224.pdf
https://www.iaea.org/topics/nuclear-forensics

**Radiation protection**

http://earlywarning-emrp.eu/
http://www.unscear.org/docs/publications/2008/UNSCEAR_2008_Annex-B-CORR.pdf
https://www.iaea.org/newscenter/news/risks-and-challenges-radiation-exposure-work
http://www.wise-uranium.org/rdcri.html
https://www.bls.gov/news.release/pdf/cfoi.pdf
http://www-ns.iaea.org/tech-areas/communication-networks/orpnet/documents/cn223/1-mundigl-euratom.pdf
https://www.icrp.org/publication.asp?id=ICRU%20Report%2095
https://iopscience.iop.org/article/10.1088/1361-6498/abf94f/pdf
https://www-pub.iaea.org/MTCD/Publications/PDF/P074_scr.pdf

**Regulatory changes**

https://www.nonproliferation.org/wp-content/uploads/2015/07/Pomper-Moore-2015.pdf
https://www-pub.iaea.org/MTCD/Publications/PDF/Pub1794_web.pdf
http://www.world-nuclear.org/information-library/nuclear-fuel-cycle/transport-of-nuclear-materials/transport-of-radioactive-materials.aspx#ECSArticleLink4

https://www.iaea.org/sites/default/files/publications/documents/infcircs/2017/infcirc910.pdf

Report of NIST Neutron Physics Group to CCRI(III) 2016
https://www.iaea.org/publications/12360/security-of-radioactive-material-in-use-and-storage-and-of-associated-facilities

**Technological changes**

https://erncip-project.jrc.ec.europa.eu/networks/tgs/nuclear
https://ieeexplore.ieee.org/document/7437093

# V. Document revision schedule

| Document | Type of revision | Date of revision |
|---|---|---|
| CCRI Strategy Document 2018-28 | First version | |
| CCRI Strategy Document 2018-28 | 2nd Edition | 29 August 2021 |
| CCRI Strategy Document 2030+ | 3rd Edition | 15 December 2023 |