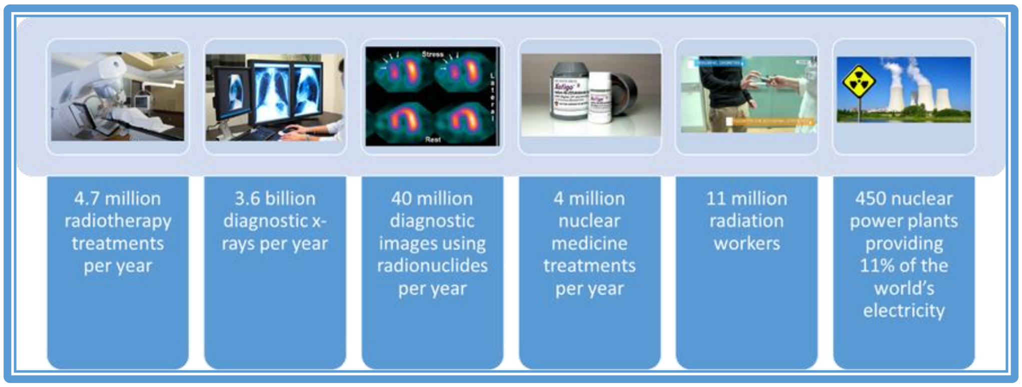
Strategy 2018-2028

Consultative Committee for Ionizing Radiation (CCRI)

Contents

1. Executive summary

Ionizing radiation has been used 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 the risk of 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 general 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 whilst 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 for long-term large-scale exercises through optimizing use of resources at NMIs/DIs and the BIPM in order to avoid the problems of shipping hazardous materials or sensitive equipment. There will 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.

The CCRI has also taken note of the recent introduction of the revised SI and the development of KCDB2.0 and the needs expressed by CCRI members, observers and stakeholders, and in response, adapted its policies and procedures. This work will continue, and the BIPM Ionizing Radiation Programme will be guided 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 the liaison with RMO TC-RIs will be a key focus point.

2. 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, including in health care, manufacturing, environmental stewardship, and security. A brief summary is given below and further information can be found in the bibliography. Implications for the CCRI strategy are highlighted.

External beam radiotherapy

Perhaps the clearest example of the benefits of ionizing radiation metrology can be found in radiotherapy. Effective cancer treatment relies on delivering a radiation dose that is sufficient to destroy tumour cells while minimizing the dose to surrounding healthy tissue (which can even be fatal, if critical organs are damaged). There is clinical evidence that the difference between under- and over-treatment with radiotherapy needs to be around 2.5 % - in practice, this accuracy is difficult to achieve (primary standards can be realized with an accuracy or around 0.3-0.5 %). For this reason, the international validation and measurement traceability scheme 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 radiotherapy 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), but their use is expected to decline.

Metrology for external beam 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.

The need to optimize the delivery of radiation to the specific target while minimizing damage to healthy tissue is driving the development of new technologies for which the radiation field is small and the treated volume conforms closely to the tumour. Such beams present a challenge for accurate measurement of the radiation dose and has led to the development of small-field dosimetry.

In the longer term, particle (hadron) therapy continues to show promise for more accurate delivery of the ionizing radiation to the tumour. 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 being studied, such as the use of ultra-short high-dose rate pulses.

Brachytherapy

Brachytherapy (the use of small, sealed radioactive sources to treat cancer) 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 tumour. The use of ^{60}Co sources may expand over the next few years, replacing the widely used ^{192}Ir sources, as ^{60}C has a longer half life and is therefore more cost-effective. The era of electronic brachytherapy has already begun, with miniaturized x-ray sources replacing radioactive sources; these devices eliminate some of the risks associated with conventional brachytherapy (loss of sources, radiation leakage, accidents in transportation and radioactive waste handling) so there has been significant expansion in the use of the technique for cancers of the breast, skin, gastrointestinal tract, and other tissues.

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

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. 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 CERN, which has invested in a new facility (Medicis) to produce pre-clinical batches of radionuclides. In parallel with this, accurate nuclear data are needed to underpin production of the radionuclides and support accurate patient dosimetry.

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 phantoms containing accurate, traceable, quantities of radionuclides, which can then be used to mimic the distribution in the human body in order to assess the performance of imaging systems used on patients. The quantified images then enable a more accurate estimate of radiation dose for the therapeutic radiopharmaceutical to improve the safety and efficacy of the treatment. This field, which combines biological, dosimetry and radionuclide metrology, is at an early stage.

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 decay data that will be needed.
A new Working Group will consider how to harmonize the approaches to quantifying medical images and individual patient dosimetry.

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 likely to continue. New, high-dose, diagnostic procedures such as CT-scans 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 the dose from natural background radiation for the first time.

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

Next generation nuclear power

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 (material effects).

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. However, as for ITER, the fusion power will have to be determined from the neutron diagnostics, with a strong constraint on the uncertainty which must be 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. In the longer term, addressing this challenge is likely to involve the metrology community.

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 (eg cross section data) to underpin the work and will maintain a watching brief and revise the strategy as needs are clarified.

Nuclear decommissioning

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 (166 nuclear power reactors built since the 1950s have already shut down and a further 183 reactors are scheduled for decommissioning in the 2020s) while others are being constructed. Some nuclear plants are closing earlier than anticipated due to falling electricity prices. 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

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.

estimated to be in excess of 60 billion Euro 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.

The measurement of radioactivity on material surfaces may grow in importance for nuclear decommissioning based on two ISO standards (8769 and the 7503 series).

Radionuclide metrology has a large part to play in this process – this has been recognized in the EU which is supporting scientific collaborations through the EMPIR and Horizon2020 programs. Accurate, reliable, measurements enable the wastes to be disposed of cost-effectively and safely; however, such measurements involve measuring the radioactivity content of diverse materials.

Naturally occurring radioactive materials

Recent studies have shown that the risk from exposure to radon and other naturally occurring radioactive materials has been under-estimated. Such concerns have been reflected in recent regulations in the EU, which has expanded the ionizing radiations regulations (and hence the need for metrology) to cover workplaces that were previously exempt.

Radiation sterilization and processing

The market for single-use disposable medical devices has undergone an 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, orthopaedic implants, gloves, containers, eye droppers and perfusion sets), about 50 % of the devices produced, are sterilized using ionizing radiation per 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.

The CCRI will organize regular comparison exercises to assure traceability of high dose rate measurements

Medical devices are subject to strict regulations; accurate dosimetry is essential for dose setting, process validation and process control so that there is documentary evidence that the process consistently results in a sterilized product. A traceable dose measurement with an accuracy of better than 8 % (95 % confidence level) is needed.

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, which will require the development of a measurement traceability chain to relate back to the original ^{60}Co systems.

The largest industrial application of high-dose irradiation is modifying polymer properties for insulators, tyre manufacturing, tubing, adhesives and composites; other applications include wastewater treatment, and synthesis of nanoparticles. In all of these applications, only precise and accurate measurements can ensure that adequate dose is delivered for the desired effect without causing structural damage.

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 system for the radionuclides of interest, including alpha-particle emitting isotopes.

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.

In order to derive as much information as possible about suspect items in transport containers, increasingly sophisticated mixed-field interrogation systems (neutrons and gammas) 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.

Radiation protection

The international measurement system for dosimetry for 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 tangible risks to the workforce – the excess risk for a worker exposed to the whole-body dose limit of 20 mSv/year over 40 years is about 3 %, which can be compared to the risk of industrial fatalities (the probability of a fatal accident in the workplace is about 0.003 % per year).

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.

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 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 power laser facilities producing high energy radiation fields. 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.

The measurement of airborne radioactivity (gaseous or as aerosols) is also being studied (such as the EU projects MetroERM and MetroPreparedness), and is also become increasingly important in supporting monitoring for the Comprehensive Test Ban Treaty.

Ionizing radiation due to cosmic rays have a non-negligible impact on the dose delivered to the population on earth and to the aircrew, the neutron contribution dominating above 2000 m altitude. 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 (photons, neutrons, ...) generated in the spacecraft walls, especially during solar events. Ionizing radiation metrology will therefore have to focus in the coming decades on high energy particles, especially ions and neutrons.

Regulatory changes

High-activity sealed radioactive sources are a risk to security as they could be used for radiological terrorism. 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 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. Minimizing the use of sealed sources in metrology will require the development of innovative new approaches.

The CCRI will co-ordinate international efforts to reduce the dependence on sealed radioactive sources for metrology and will aim to reduce the need for shipping hazardous materials for comparison exercises.

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.

Technological changes

One of the main changes in radionuclide metrology in the last few years has been the adoption of digital signal processing techniques ('list mode data'), similar to the technology used on 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.

To test the new approaches to list mode data, the CCRI will organize comparisons of data analysis software.
The CCRI will also seek to encourage engagement with the academic community, to embed the SI in research measurements and to identify new technologies for applications in the field.

Improvements in the sensitivity and affordability of mass spectrometers has already begun to influence radionuclide metrology, leading to research needs in linking mass to activity. Such instruments are particularly useful for measuring long-lived species such as the actinides, where mass spectrometry promises to enable measurements at levels significantly lower than can be done by conventional means.

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 radiation are particularly damaging, potentially leading to "single-point upsets."

Changes in the metrology community

At present, based on capabilities published in the Appendix C of 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.

3. 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 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.

In support of the CCRI and its members, 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.

4. Strategy

In line with the CCRI's vision, the 2018-2028 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.

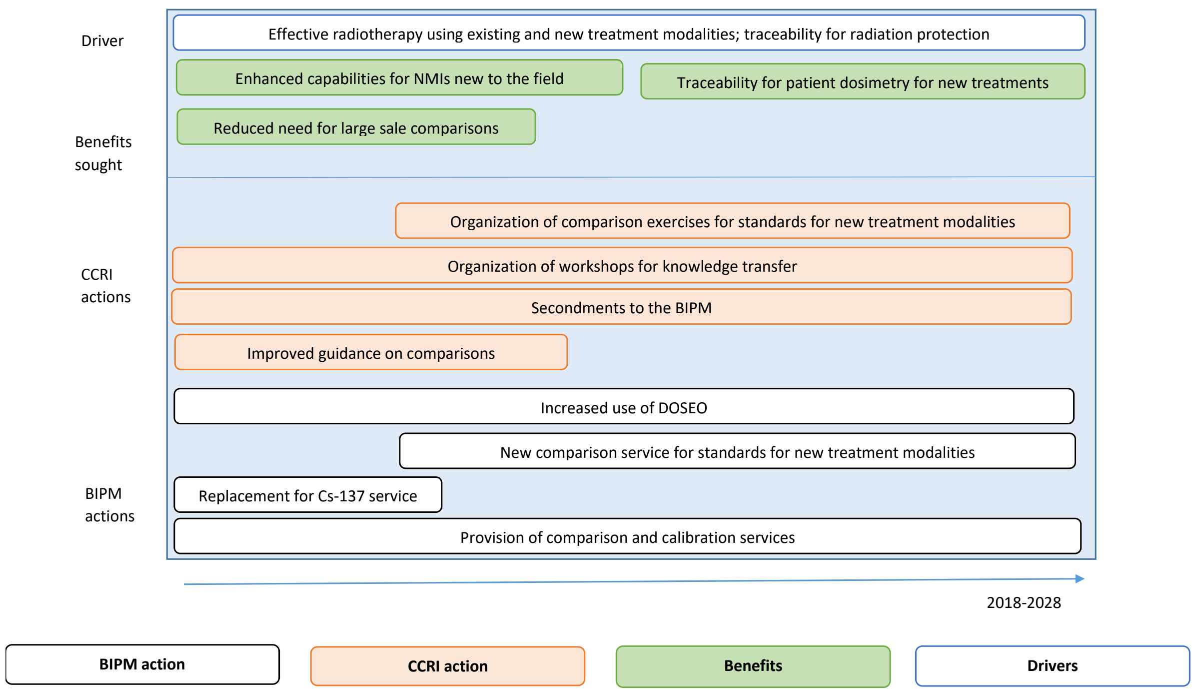
- **To progress the state of the art** for issues identified by stakeholders of benefit to NMIs/DIs and the BIPM, through supporting the organization of targeted joint research projects.

- **To expand the coverage of services 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.

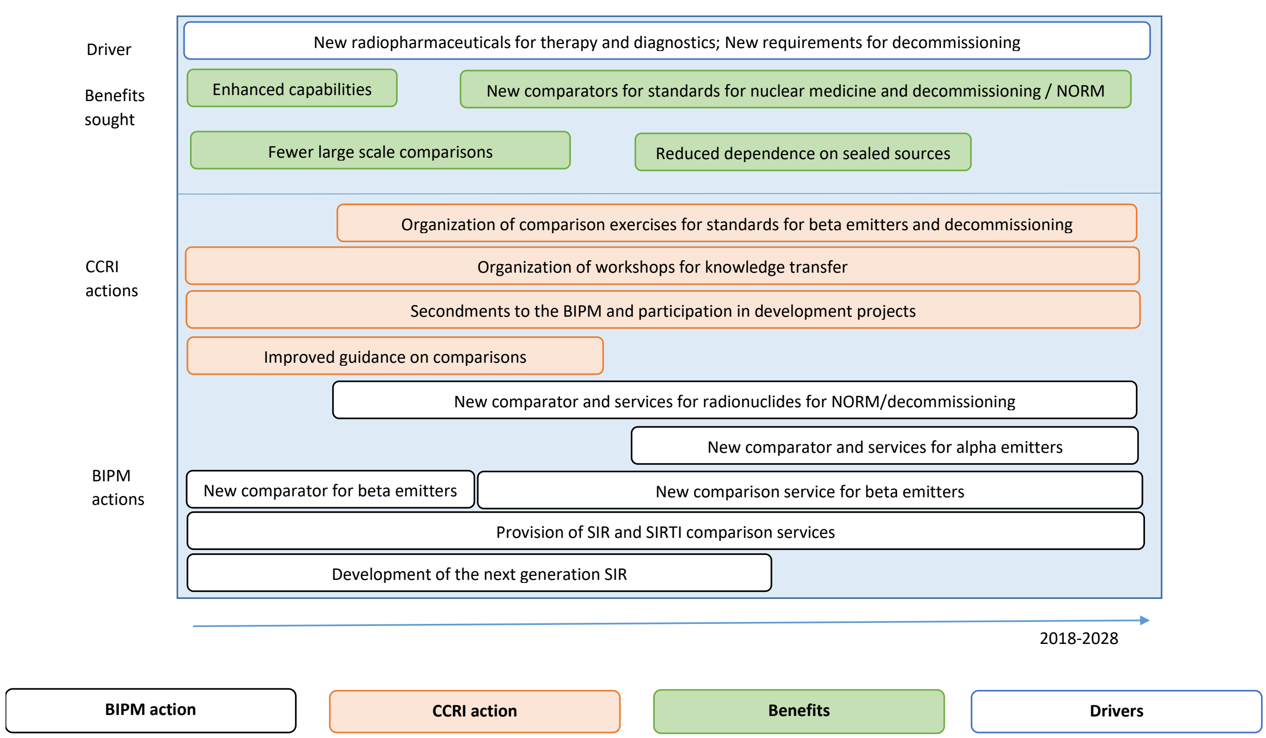
5. Activities to support the strategy

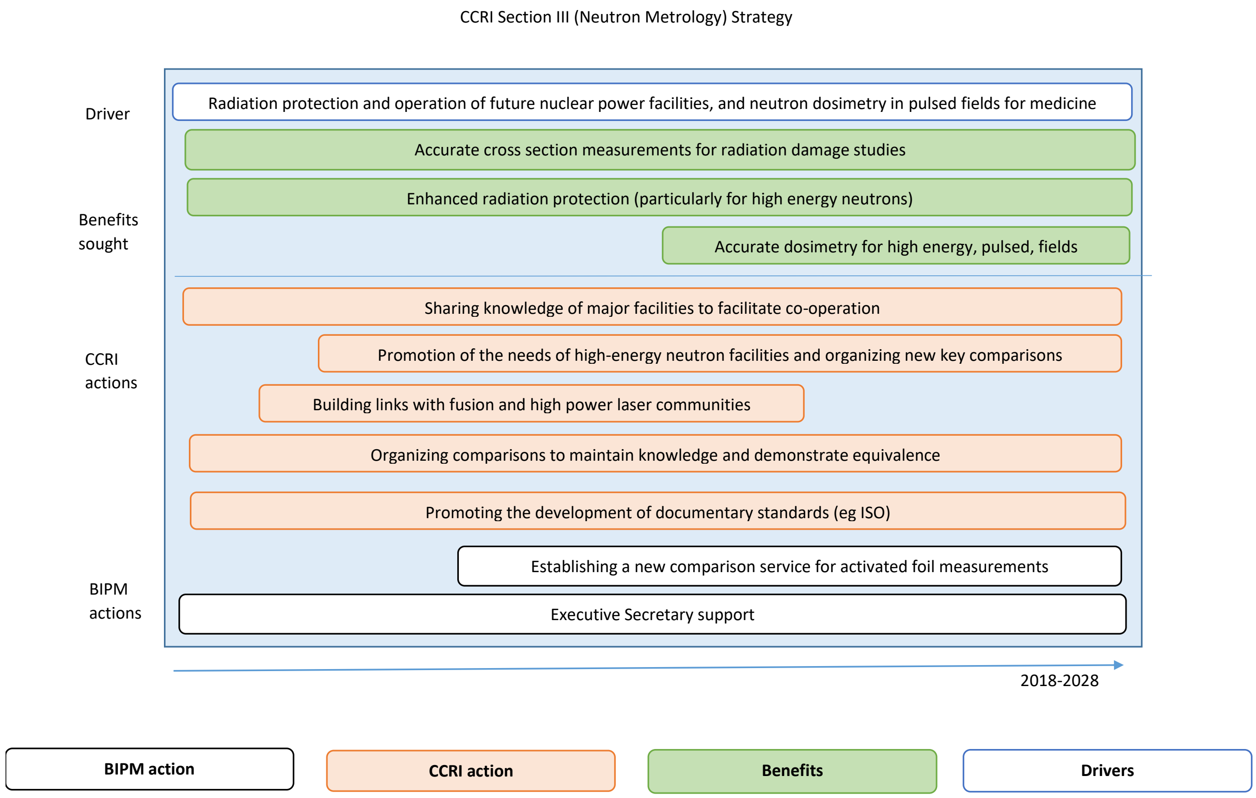
The CCRI and BIPM activities are aligned to meet these aims. There will be an increased emphasis on work to clarify and simplify the procedures for comparisons, activities to share knowledge, and collaborative research projects. The diagrams below summarize the main activities and they are discussed in more detail in the following sections.

CCRI Section I (Radiation Dosimetry) Strategy



CCRI Section II (Radionuclide Metrology) Strategy





5.1. Progressing metrology science

Most of the developments in ionizing radiation metrology, of course, take place at the individual NMIs and DIs; the CCRI will continue to provide a forum to exchange information on such developments. Some specific collaborative actions are planned to contribute to developments at the international level, through supporting the establishment of virtual project teams under the auspices of existing Working Groups. These projects will be initiated by the CCRI.

Dosimetry

A main driver in radiation dosimetry is the development of new primary standards and comparisons for the new treatment modalities. The priorities will be determined by the CCRI to advise the BIPM, the CCRI will then co-ordinate new comparisons based around the primary standard.

The BIPM will also ensure the continued provision of comparison exercises and the Key Comparison Reference Values for Dosimetry. The CCRI, key stakeholders and the BIPM will work together to ensure continuity in this essential field of work, making use of external facilities where appropriate.

Radioactivity

The actions are aimed at addressing two main issues. First, reducing the need for comparisons that require the distribution of radioactive sources to multiple recipients, which often face significant logistical issues with shipping radioactive sources. The actions here lie largely with the BIPM to expand the scope of its on-demand services to compare national standards of pure beta-particle emitters and long-lived radionuclides. The CCRI will promulgate the use of the new services and guide the specification of the instrumentation to ensure it is fit for purpose.

Second, many NMIs/DIs rely on sealed radioactive sources to check the stability of ionization chambers. A project will continue to reduce the dependence on these sources, using new technologies for low current measurement, and leveraging expertise even beyond the ionizing radiation community.

Where appropriate, the CCRI will encourage the measurement of nuclear decay data to be included in protocols for comparison exercises, to add value to the exercises.

Neutron metrology

The two main challenges for neutron metrology in the coming years are developing reference neutron fields providing high energy neutrons, as well as experimental standards able to determine neutron quantities in high-intensity pulsed fields. The difficulty is to reach these goals at the same time as maintaining staff experience and continuing to support existing lower-energy facilities with a small and decreasing manpower; the use of shared neutron facilities and specializing on a few type of neutron reference fields will be needed. The CCRI and the BIPM will have to be the driving forces to co-ordinate and support this evolution, the BIPM by becoming more actively involved in neutron metrology through activation foil comparisons and the CCRI by promoting neutron metrology for emerging needs and facilitating worldwide collaboration when large scale facilities are involved.

5.2. IMPROVING STAKEHOLDER INVOLVEMENT

The CCRI's actions are aimed at increasing the involvement of smaller NMIs/DIs in the international measurement system. The IAEA has a crucial role to play in this, due to its close links with dosimetry laboratories in many countries through the IAEA/WHO Secondary Standards Dosimetry Laboratory network. The IAEA will remain a guest member of the CCRI.

The BIPM will contribute to this work by expanding the number of short- and long-term secondments, and coordinating knowledge transfer activities. Where possible, this will involve expert staff from NMIs/DIs in helping to devise and deliver these activities. The BIPM will also continue to promote the international metrology community (IAEA, ICRU, ISO) in the development of international standards and best practice guides, along with representatives from the NMIs/DIs. BIPM staff will also publicize the benefits of the international measurement system at relevant conferences, such as IDOS and ICRM, and will attend RMO TC meetings as appropriate.

5.3. Promoting global comparability

The CCRI will continue the work with the RMOs to harmonize and simplify the process of CMC review, starting with a detailed review of current practice and working with the CIPM to clarify requirements of the CIPM MRA as applied to ionizing radiation. This work will include considering how the use of more comprehensive CMCs can be introduced whilst maintaining backward compatibility. Documents setting out the procedures are being revised and the documents will be made more accessible on the BIPM website.

The CCRI will keep under review the existing arrangements for 'how far the light shines' statements on the results from comparisons. The strategy for comparisons will also be kept under review.

The CCRI will continue to support the BIPM in making significant reductions in the timescales for organizing and reporting the results from comparisons, in order to encourage wider participation.

5.4. Work program of the BIPM laboratories

As discussed above, the work programme of the BIPM Laboratories is closely aligned to the work of the CCRI. Details are available on https://www.bipm.org/utils/en/pdf/CGPM/BIPM-work-programme.pdf. The main activities planned for 2020-2023 are:

Radiation dosimetry

- Maintain and improve the BIPM standards for x-ray and photon dosimetry, including use of the off-site DOSEO facility for high-energy photons
- Continue to provide air kerma comparisons and calibrations in ^{137}Cs, using the new IAEA irradiator
- Contribute to the development of guidance and protocols in the field, include ICRU and IAEA documents
- Start the development of a new primary standard for a priority field (to be chosen in consultation with the CCRI)

Radionuclide metrology

- Maintain and improve the BIPM comparators for gamma and beta emitting radionuclides
- Work in collaboration with NMIs/DIs to develop the next generator comparator for gamma emitters

Neutron metrology

- To increase involvement in this field with a view to developing a comparator for irradiated foils in the next programme

There will also be an increased emphasis on knowledge transfer and capacity building activities.

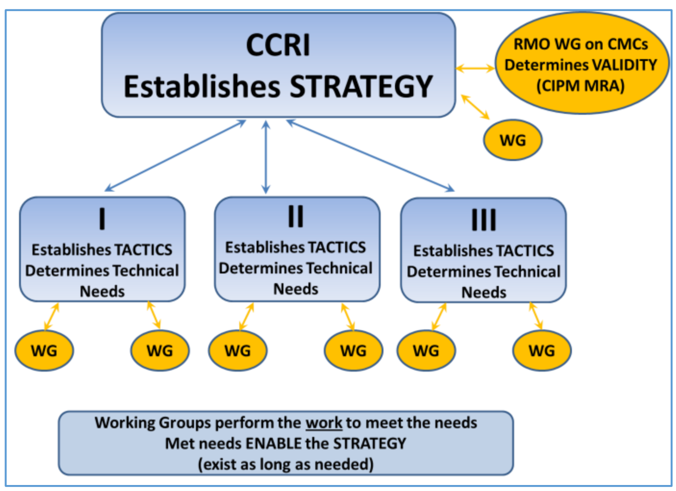
ANNEX

1. 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 Wynand Louw (NMISA)
CC Executive Secretary:	Dr Steven Judge
Number of CC Members:	8 (plus14 official observers and 3 liaisons)

Periodicity between Meetings and date of last/next Meeting: 2 years (1959…2015, 2017, 2019)

Working Groups:



The current structure of the CCRI (since 2015) allows for three distinct main Working Groups called Sections and associate sub-working groups:

Section (I):	Dosimetry (x and γ-rays, charged particles)
Section (II):	Measurement of radionuclides
Section (III):	Neutron measurements

Long Term Sub-Working Groups:
Working Group on IR CMCs (RMOWG)
Key Comparison Working Group (I)
Key Comparison Working Group (II)

Ad-hoc Working Groups:
Working Group for Strategic Planning (WG-IRS)
Brachytherapy Standards Working Group (BSWG(I))
Extension of the SIR to beta emitters using liquid scintillation (ESWG(II))

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 uncertainties of the BIPM's calibration and measurements services as published on the BIPM website;
- 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.

2. LIST OF KEY AND SUPPLEMENTARY COMPARISONS AND PILOT STUDIES

Two types of comparison are used in ionizing radiation dosimetry. 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 60Co	BIPM	On-going
BIPM.RI(I)-K5	Measurement of air kerma for ^{137}Cs	BIPM	Suspended, restarting end of 2019
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 emitting radionuclides (SIR)	BIPM	On-going
BIPM.RI(II)-K2	Measurement of long-lived beta emitting radionuclides (ESIR)	BIPM	Starts end of 2019
BIPM.RI(II)-K4	Measurement of short-lived gamma emitting radionuclides	BIPM	On-going

3. SUMMARY OF WORK ACCOMPLISHED

The key accomplishments of the CCRI have been:

1) 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.

2) 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.

3) Providing and disseminating key data

All applications of ionizing radiation metrology rely on the use of key data to convert the instrument readings to the quantity 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-measurement of such data as needs arise.

The BIPM RI program, CCRI Sections and RMO-TCRIs organizes key and supplementary comparisons to compare national measurement standards to the SIR and to each other. By April 2018 a total of 245 comparisons were listed in the KCDB consisting of 180 Key comparisons and 65 Supplementary comparisons. The status of the respective comparisons are:

Number	Status
68	Ongoing and approved for equivalence
49	Approved for equivalence
40	Approved and published
19	Approved for provisional equivalence

18	In progress
15	Ongoing
11	Draft B report were in progress
7	Abandoned
6	Draft A report were in progress
5	Published
3	Planned
3	Protocol complete

The details of the individual comparisons can be viewed on the BIPM KCDB website:
https://kcdb.bipm.org/

Procedures on how to conduct comparisons, such as in Section (II), are available at
https://www.bipm.org/cc/CCRI%28II%29/Allowed/17/CCRI%28II%2903-06.pdf

NMIs and Designated Institutes (DIs) 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.

4. USEFUL LINKS

The reports and websites below (amongst other publications) were used in reviewing the needs of the user communities. Unpublished presentations from conferences and meetings were also used for background. The links are correct at the time of writing.

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

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

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

Next generation nuclear power

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

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

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

Report of NIST Neutron Physics Group to CCRI(III) 2016

Technological changes

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

5. DOCUMENT REVISION SCHEDULE

Document	Type of revision	Date of revision
CCRI Strategy Document 2018-28	First version	