EURADOS
European Radiation Dosimetry Group e. V.

EURADOS Report 2017-02
Neuherberg, April 2017

EURADOS Stakeholder Workshop on June 30th, 2016

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Content:

Introduction

On June 30th, 2016, the "First EURADOS Stakeholder Workshop" was held at the Helmholtz Center Munich (HMGU) in Neuherberg, Germany. The workshop was jointly organized by the HMGU and the EURADOS Office in conjunction with the 57th EURADOS Council meeting, which took place on June 29th and July 1st, also at the HMGU.

In the frame of the "European Joint Programme for the Integration of Radiation Protection Research", the CONCERT project funded by the European Commission is supposed to provide an umbrella structure for radiation protection research in Europe. In this project, EURADOS leads Task 2.4 on the "Development of Strategic Research Agenda, roadmap and priorities for research on dosimetry". While a first version of the EURADOS Strategic Research Agenda (SRA) has already been published, this workshop was intended to develop the SRA further by asking for feedback and input from international organisations with interest in the dosimetry of ionizing radiation.

1. History of SRA development

In 2012, the EURADOS Council recognized the need to actively contribute to the identification of future research needs in radiation dosimetry in Europe and encouraged all eight EURADOS working groups (WGs) to collect the required information, depending on their field of expertise. In February 2013, the Council established a dedicated Task Group (TG) to collate this information and produce a draft first version of a EURADOS Strategic Research Agenda (SRA) for dosimetry. An advanced version of the SRA was distributed in January 2014 among the EURADOS Voting Members and Working Group Chairs, for discussion. This version was produced with major input from all EURADOS WGs and the Voting Members. It included what – according to the EURADOS community – should be done to improve dosimetry during the next decades and be funded in future calls issued by the European Commission. The SRA was published as EURADOS Report 2014/01, which can be downloaded from the EURADOS website (www.eurados.org). In early 2016, a condensed version of the EURADOS SRA appeared in *Radiation Protection Dosimetry* (Radiat. Prot. Dosim. 168, 223-234, 2016).

In the past, this SRA version has already been presented by members of EURADOS to the scientific community on various occasions including, for example, at the 5th MELODI Workshop in October 2013 in Brussels, Belgium; the OPERRA meeting in Jan 2014 in Rome, Italy; the German Radiation Protection Association in April 2014 in Munich, Germany; the IRPA 2015 Congress in June 2014, in Geneva, Switzerland; the 6th MELODI Workshop in October 2014 in Barcelona, Spain; the Health Physics Society meeting in July 2015, in Indianapolis, USA.

The current EURADOS SRA version includes five visions for dosimetry. For each vision, key challenges in dosimetry research were identified that were considered important for the next decades. These visions will also be used to steer the EURADOS research programs and the working group activities. The first vision describes scientific developments required towards updated fundamental dose concepts and quantities (Vision 1). The second vision includes scientific developments needed towards improved radiation risk estimates deduced from epidemiological cohorts (Vision 2). The third vision deals with efficient dose assessment for radiological emergencies (Vision 3). The fourth vision identifies work towards integrated personalized dosimetry in medical applications (Vision 4). Finally, the fifth vision identifies efforts needed towards improved radiation protection of workers and the public (Vision 5).

2. Organisation of the First EURADOS Stakeholder Workshop

It was acknowledged from the beginning that the EURADOS SRA was a moving target and that continuous efforts are needed to improve and update the SRA. At its meeting in July 2015 in Braunschweig, Germany, the EURADOS Council decided to organize a one-day workshop where relevant stakeholders should be invited and asked to provide their view on the current version of the EURADOS SRA. The date proposed for the workshop was June 30th, 2016. It was further decided that for this effort, emphasis should be placed on international organisations expected to be interested in an improved dosimetry of ionizing radiation. A list of potential stakeholders was then developed, the workshop program was drafted, and invitations were distributed.

2.1. Participants

Altogether, 23 international organisations accepted the EURADOS invitation and sent delegates to explain their view on the EURADOS SRA. The following organisations were present (listed in alphabetical order):

European Radioecology Alliance (ALLIANCE), European Association of Nuclear Medicine (EANM), European Federation of Organisations for Medical Physics (EFOMP), European Nuclear Installations Safety Standards Initiative (ENISS), European Society of Radiology (ESR), European Society for Radiotherapy and Oncology (ESTRO), European Association of National Metrology Institutes (EURAMET), Heads of the European Radiological Protection Competent Authorities (HERCA), International Atomic Energy Agency (IAEA), International Agency for Research on Cancer (WHO/IARC), International Commission on Radiological Protection (ICRP), International Commission on Radiation Units & Measurements (ICRU), International Labor Organization (ILO), International Radiation Protection Association (IRPA), International Organization for Standardization (ISO), International Solid State Dosimetry Organization (ISSDO), Multidisciplinary European Low Dose Initiative (MELODI), Nuclear Energy Agency (NEA), European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery (NERIS), Nuclear Generation II and II Association (NUGENIA), Particle Therapy Co-Operative Group (PTCOG), Realizing the European Network of Biodosimetry (RENEB), Social Sciences and Humanities (SSH).

Participants of the Workshop

2.2. Workshop Programme

After a short introduction given by W Rühm, the Chair of EURADOS and acting director of the HMGU Institute of Radiation Protection, M Atkinson (director of the HMGU Institute of Radiation Biology) introduced the HMGU Department of Radiation Sciences. A summary of the EURADOS Strategic Research Agenda was then given by F Vanhavere from SCK-CEN, the Vice-Chair of EURADOS, followed by an overview on the CONCERT project given by N Impens (SCK-CEN) who leads the CONCERT work package 3 on "Priority Research and Joint Programming Needs in the Perspective of European Integration".

The rest of the day was devoted to the presentations of the invited stakeholder organisations. In their presentations, the stakeholders were asked to briefly introduce their organization and why they are interested in the dosimetry of ionizing radiation. After that they were asked to address the following questions raised by the EURADOS Council in advance: 1) Which vision or challenge included in the EURADOS SRA needs further improvement? 2) Are there any important topics missing? 3) What are the five most important challenges in the EURADOS SRA (please give rank)? 4) In which field should your organization and EURADOS collaborate in the future?

It was agreed that the EURADOS Council will prepare minutes of the workshop to be distributed among the participants. Based on these minutes, a report will be prepared. Based on the comments received from the participants, EURADOS will update its Strategic Research Agenda, and produce and publish a second SRA version.

At the end of the Workshop, members of the EURADOS Council (P Olko, Poland; Ž Knežević, Croatia; E Fantuzzi, Italy) gave a short summary of the comments received. The following discussion revealed that the format of the Workshop including about 10 minutes presentations given by the invited organisations was very efficient and well received. Short summaries of the presentations prepared by the participating organisations are given at the end of this report, in alphabetical order.

The EURADOS Council Members and EURADOS WG chairs wish to express their sincere gratitude to all those who accepted the invitation and gave comments and feedback on the current version of the EURADOS SRA.

3. Contribution by the participating organisations, presented in alphabetical order

3.1. ALLIANCE (European Radioecology Alliance)

Representative: Nick Beresford (CEH, UK)

The ALLIANCE maintains and enhances radioecological competences and experimental infrastructures in Europe, with an international perspective, and addresses scientific and educational challenges related to the assessment of the impact of radioactive substances on humans and the environment.

N. Beresford identified challenges within EURADOS SRA which are important for radioecology: establishing correlations between track structure and radiation damage; improving of understanding of radiation-induced effects from internal emitters, identifying characterizing new markers of exposure, exploring exposure pathways not yet considered or validated and implementing new biokinetic models for intake of radionuclides. He also emphasized that EURADOS could contribute to wildlife dosimetry (non-human biota), because the effects of radiation on wildlife (most especially from field studies) are a contentious issue with implications for regulators and industry.

3.2. EANM (European Association of Nuclear Medicine)

Representative: Mark Konijnenberg (Erasmus MC, Nethelands)

EANM aims at advancing science and education in nuclear medicine for diagnosis, treatment, and prevention of diseases. Dosimetry and radiation protection form a prominent role in the mission and vision of EANM. They have worked on a number of dosimetry-related projects, and have prepared various relevant guidelines and documents. EANM research priorities include dosimetry and radiation protection for radiopharmaceuticals with emphasis on radiobiology (dosimetry for α- and β-emitting radionuclides used for molecular radionuclide therapy; effects of inhomogeneous dose distributions; the role of biomarkers in radiation risk assessments), dose-effect relations (deterministic effects in normal organs after nuclear medicine therapy, and low dose (rate) effects and radiation-risk based approaches in non-targeted tissues), and implication of the 2013/59/EURATOM Directive.

Konijnenberg emphasised the importance of Vision 1 (fundamental dose concepts) in the EURADOS SRA, because short-ranged α- and β-emitters show high levels of inhomogeneity at both cellular and tissue level, and are increasingly used in nuclear medicine (^{223}Ra-Xofigo and ^{177}Lu-Lutathera). As far as radiation risk estimates is concerned (Vision 2), dose-effect relations after radionuclide therapy are not well characterized, while at low dose rates, the effect of inhomogeneous dose distributions and repair mechanisms are important. Vision 3 might benefit from mentioning that dose assessment for radiation emergencies could benefit from SPECT / PET imaging for quantification and localisation of internal radionuclides. For Vision 4 (personalized dosimetry in medicine) a discussion of patient-averaged ICRP-based dosimetry vs. a radiation-risk based approach might be useful. Furthermore, for pediatric applications at present only adult pharmacokinetics is applied in pediatric mathematical phantoms. Finally he added that for Vision 5 (radiation protection of workers and public) it should be kept in mind that nuclear medicine

patients form a source of exposure and possible contamination, and that uniform rules are needed in such cases for restrictions of daily-life activities, patient care, family members, etc.

3.3. EFOMP (European Federation of Organisation for Medical Physics)

Representative: Virginia Tsapaki (Konstantopoulio General Hospital, Athens, Greece)

EFOMP stands for the European Federation of Organizations for Medical Physics. It serves as an umbrella organisation to national medical physics societies across Europe. Currently EFOMP has 35 national members and represents more than 5,000 physicists and engineers working in the field of Medical Physics. Its mission is to support the development of medical physics as a research field and profession.

Virginia Tsapaki presented EFOMP and their main activities. She emphasized that at present the main focus of EFOMP includes individualized dosimetry in all fields of medical dosimetry such as diagnostic radiology, nuclear medicine molecular therapy, proton therapy, and also personnel and specially eye dosimetry in high dose medical applications. Within the EURADOS SRA she pointed out three major visions representing common interests that might be subject of future collaboration: Vision 3 - Efficient dose assessment for radiological emergencies, Vision 4 - Integrated personalized dosimetry in medical applications, Vision 5 - Improved radiation protection of workers and public. Another major filed of common interest is in the field of education and training.

3.4. ENISS (European Nuclear Installations Safety Standards Initiative)

Representative: B. Lorenz (ENISS, Germany)

ENISS brings together decision-makers, operators and specialists from the nuclear industry with regulators on an European level, in order to identify and possibly agree upon the scope and substance of harmonized safety standards. ENISS provides the nuclear industry with the platform that it needs to exchange information on new national and European regulatory activities, to express its views and provide expert input on all aspects related to harmonization of safety standards. Another task of ENISS is to strengthen the industry influence in the revision work of the IAEA Safety Standards. At the European level, ENISS is also cooperating with the European Commission on regulatory issues in the area of nuclear safety, waste management and decommissioning.

In Vision 2 he identified some aspects for further improvements. In most of the epidemiological studies the exposure by natural background and medical exposures is not adequately accounted for. An example is the INWORKS study which investigates occupational exposures of in average 1 mSv/a and ignores medical and background radiation of up to 6 mSv/a with significant differences between US-population and UK-citizens. He noted that in this area there is an enormous potential to get new knowledge if epidemiological studies would be focussed on background radiation and medical exposure. According to ENISS the most important challenges formulated in the EURADOS SRA are: a) to improve epidemiological studies b) to develop accurate and on-line personal dosimetry c) to update operational quantities for external exposure, d) to identify and characterize new markers of exposure and e) to improve dose estimates in interventional radiology (although this is not their field of expertise, but it is interesting from the radiation protection point of view). ENISS has no direct interest in research but is strongly endorses if research could contribute

towards simplification of the current radiation protection system, because ENISS is involved in implementing radiation protection regulations and recommendations.

3.5. ESTRO (European Society for Radiotherapy & Oncology)

Representative: Marco Schwarz (Trento, Italy)

ESTRO is a non-profit scientific organisation that fosters the role of radiation oncology, in order to improve patients' care in the multimodality treatment of cancer. ESTRO's mission is to promote innovation, research, and dissemination of science through its congresses, special meetings, educational courses and publications.

The main ESTRO vision for 2020 is that every cancer patient in Europe will have access to state of the art radiation therapy, as part of a multidisciplinary approach where treatment is individualized for the specific patient's cancer. In this context, research and development in radiation dosimetry is needed particularly with respect to new radiotherapy techniques. Given the growing number of proton radiotherapy centers worldwide the need for development and improvement of reference dosimetry is obvious. He emphasized the importance of micro-/nano-dosimetry to link physics and radiobiology. The debate on constant vs variable relative biological effectiveness (RBE) in clinical application is still ongoing. The topics presented by ESTRO are in compliance with EURADOS SRA Vision 4 (Towards integrated personalized dosimetry in medical applications), especially in the areas of modern external beam radiotherapy (in-vivo for QA, new radiotherapy techniques, calibration aspects, ...) and internal microdosimetry in radiotherapy and medical imaging (alpha and Auger emitters, nanoparticles,...). Vision 2 (Towards improved radiation risk estimates deduced from epidemiological cohorts) is also considered important. Another inportant area of interest beween ESTRO and EURADOS is education and traning. He noted that ESTRO together with EFOMP has developed the Core Curricula for Medical Physicists and organizes training courses for medical physicists.

3.6. EURAMET (The European Association of National Metrology Institutes)

Representative: Ulrike Ankerhold (PTB, Germany)

EURAMET is the Regional Metrology Organisation (RMO) of Europe with the mission to develop and disseminate an integrated, cost effective and internationally competitive measurement infrastructure for Europe. EURAMET coordinates the collaboration between National Metrology Institutes (NMIs) within Europe in fields such as research in metrology, traceability of measurements to the SI units, international recognition of national measurement standards and related calibration and measurement capabilities (CMC).

The vision or challenge within the EURADOS SRA that need further improvment as seen by EURAMET is in the area of medicine which is a strong strong driver for new technologies using ionsing radiation. The development of new treatment and diagnostic methodologies such as diagnostic radiology and nuclear medicine (key words: PET/CT, PET/MRT, modern CT, modern nuclear therapy, ...) represents a main challenge radiation protection dosimetry in medicine (workplace field characterisation, development/characterisation of dosemeters, realisation of traceability chains, preparation of guidelines; training of medical staff, harmonization). U. Ankerhold noted that the EURADOS SRA covers all possible future challenges in applied dosimetry. She criticized, however, that some topics are described rather detailed while others are given in more general form (e.g., chapter 3.5.2 <=> chapter 3.5.4). This should be improved and more

balanced. The most important challenges in the EURADOS SRA seen by EURAMET are: applied dosimetry for medical application of ionising radiation (workers and public), especially out-of-field dosimetry, optimization of dose and risk estimations in diagostic radiology, new biokinetic models for intake of radionuclides, improved neutron dosimetry techniques, improved radiation risk estimates, and efficient dose assessment for radiological emergencies.

EURAMET and EURADOS should collaborate in the future on the following dosimetric challenges: providing traceability and comparability, bringing the findings into practice, harmonization in practice, standardisation, and education and training.

3.7. EUTERP (European Training and Education in Radiation Protection)

Comment sent after the Workshop by Richard Paynter (EUTERP Chair, UK)

The objectives of EUTERP are a) to encourage and support harmonization of education and training requirements for radiation protection experts, radiation protection officers, and radiation workers, facilitating the mobility of these professionals; b) to promote the integration of radiation protection education and training systems into general vocational training and education infrastructures; and c) to act as a central focus for the sharing of information on training events, standards, developments, and all other related information.

As the assurance of radiation protection ultimately depends on the ability to measure and interpret radiation doses, EUTERP commends EURADOS training activities that will assure the harmonization of dosimetry practice and measurements throughout Europe, for which the traceability of measurement standards and results to national standards using the international system (SI) is clearly important. The relevant outcomes of the EURADOS SRA will feed into aspects of the training referenced in EUTERP's first objective. This will require EUTERP to monitor the progress of the EURADOS SRA and identify those topics in dosimetry, which need to be reflected in radiation protection training.

In particular, EUTERP's third objective is very relevant to the EURADOS activities and therefore EUTERP offers the use of its website to promote EURADOS training events and to disseminate relevant training information.

3.8. HERCA (Heads of the European Radiological Protection Competent Authorities)

Representative: An Fremout (European Radiological Protection Competent Authorities)

HERCA was created in 2007 to initiate an exchange of knowledge and experiences in order to facilitate practical and harmonized solutions to important regulatory issues in radiation protection. HERCA is a voluntary association of the Radiation Safety Authorities in Europe where they work together in order to identify common significant radiation protection issues and propose harmonization and/or practical solutions towards a common approach for these issues, whenever possible. HERCA is also a forum for the Radiation Safety Authorities to share information and experience, in particular with regard to the practical transposition of European legislation and international recommendations. The goal of HERCA is to contribute to a high level of radiation protection throughout Europe.

HERCA considers the EURADOS SRA a very comprehensive agenda, covering a wide range of topics with the aim to significantly advance dosimetry in various applications. The SRA covers most of the current problems in dosimetry. The process of stakeholder involvement initiated by EURADOS is an

important step to ensure the coherence of the topics and priorities covered by the SRA with the needs of the regulatory community. The input given in the following is a compilation of comments that were collected in the HERCA working groups on outside workers, medical applications and emergencies.

On Vision 1 it was noted that updating fundamental dose concepts and quantities could also have important implications and opportunities in medical applications, and it was suggested to closely looking at the common aspects in Visions 1 and 4. Indeed, quantities that predict health effects rather than absorbed dose averaged over an organ or a tissue could be of help for the justification and optimization process, the assessment of the hazard in unintended or accidental exposures, and the communication with the patient or the public.

In Vision 3, the SRA identifies a number of very important and worthy research lines in the area of nuclear and radiological emergencies, with emphasis on the estimation of individual doses. Because in the aftermath of a nuclear accident, decision makers will have to rely on estimates of population dose it is suggested, however, to consider improving and refining population dose estimates in these scenarios.

As far as medical exposures are concerned (Vision 4), development of markers for monitoring patient exposure in medical diagnostics and treatment is important. Improved models for biokinetics and dosimetry of internal exposure should also include those for radon and thoron, because present dosimetry parameters for radon and in particular thoron exposure are still subject to great uncertainty.

For Vision 5, the development of strategies for dosimetric reference levels for specific groups of radiological workers and their radiologic activities and practices could support the optimization process and to set dose constraints. The development of operator on line systems where workers can check their doses could be useful.

In general, continued focus should be placed on eye dosimetry, to develop robust measurement and calibration protocols as well as dose models for estimating eye doses. Additionally, harmonization of quality assurance and quality control of dose estimates derived from measurements and computations as well as organisation of inter-comparisons would be highly recommended.

According to HERCA the most important challenges formulated in the EURADOS SRA are: a) development of dose concepts that predict health effects, b) optimisation of dose estimations in interventional radiology, c) establishment of out-of-field dosimetry for photon and particle therapy, d) development of strategies and methods to increase measurement capacity in case of radiological emergencies, and e) quantification of doses after accidental internal contamination.

Collaboration between EURADOS and HERCA could include a) science-based policy recommendations, b) harmonization and development of clear concepts, c) education and training, and d) intercomparisons and calibration as the basis for quality of dose assessment.

3.9. IAEA (International Atomic Energy Agency)

Representative: Krista Wenzel (IAEA, Austria)

K Wenzel presented the views of IAEA, Radiation Safety and Monitoring Section. IAEA is interested in rradiation protection criteria and standards, radiation protection of patients, occupational radiation protection, and radiation safety technical services. These services include measurement

of samples and material from around the world, radioactive material composition and/or enrichments that are sometimes unknown, and monitoring of IAEA staff and non-staff who are on IAEA missions and potentially exposed to a broad range of radiation types. Of particular interest is the RADSED project ("Enhancing Radiation Safety through Efficient and Modern Dosimetry), which is the IAEA 10-year project for individual dosimetry with the goal to meet IAEA needs for modern and efficient dosimetry systems and to provide capability comparisons to IAEA Member States.

IAEA considers the EURADOS SRA as a comprehensive, well-referenced document. Of particular interest for the Agency are calibrations of detectors and instruments in high-energy and pulsed neutron fields, bio-dosimetry at occupational levels, Monte Carlo simulations and validation of measurements, and wound monitoring. The EURADOS SRA already mentioned the need for validation of the NCRP wound model with human data, and the need for new and improved measurement systems based on high-resolution spectrometry for environmental monitoring. It is recommended to develop methods that allow for an early estimation of wound contamination, to assess the need for intervention, if any (e.g., surgical removal, DTPA administration, etc.). The IAEA interest in biodosimetry research at typical occupational levels is noted. It is not currently a priority, but may become of interest based on biodosimetry studies of low doses from medical imaging.

3.10. IARC (International Agency for Research on Cancer) Representative

Representative: Isabelle Thierry-Chef (IARC, France)

IARC is the cancer agency of the World Health Organization (WHO) with objective to promote international collaboration in cancer research. The Agency is inter-disciplinary, brings together skills in epidemiology, laboratory sciences and biostatistics, to identify the causes of cancer so that preventive measures may be adopted and the burden of disease and associated suffering is reduced. In the field of ionizing radiation IARC works in the following areas: environmental exposure, occupational exposure and medical exposure. Main visions of interest between EURADOS and IARC activities are Vision 2 (Towards improved radiation risk estimates deduced from epidemiological cohorts), Vision 4 (Towards integrated personalized dosimetry in medical applications) and Vision 5 (Towards improved radiation protection of the workers and the public). I. Thierry-Chef emphasised that for the activities of nuclear workers neutron dosimetry should be improved (recorded doses are currently not integrated in the cumulative doses of workers), and tritium doses should also be taken into consideration in whole body doses. Furthermore, there is a need for development of more realistic models for radionuclide deposition which should include organs of interest/concern (heart, arteries). In the area of medical exposures there is a need for improved paediatric phantoms (with varying height and weight fat distribution), real time organ dose estimates, out of field dosimetry and dosimetry of secondary neutrons in proton therapy, and also dosimetry with respect to the treatment of thyroid cancer (radioiodine intake vs other treatment modalities).

IARC suggested the following ranking: 1) To optimize dose estimation in interventional radiology, 2) To improve out-of-field dosimetry for photon and particle therapy, 3) To establish reliable patient dosimetry in CT examinations, 4) To improve neutron dosimetry, and 5) To refine, validate and implement new biokinetic models.

As long-term activities IARC suggested 1) to identify and characterize new markers of exposure / to improve retrospective dosimetry, 2) to include internal microdosimetry in radiotherapy and imaging, and 3) to develop accurate and on-line personal dosimetry for workers.

3.11. ICRP (International Commission on Radiological Protection) – Committee 2

Representative: Nina Petoussi-Henss (HMGU, Germany)

ICRP is an independent, international organisation with more than two hundred volunteer members from approximately thirty countries across six continents. These members represent the leading scientists and policy makers in the field of radiological protection. ICRP helps to prevent cancer and other diseases and effects associated with exposure to ionising radiation, and to protect the environment. The ICRP mission is to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionising radiation. Aim of these recommendations is: To contribute to an appropriate level of protection for people and the environment without unduly limiting the desirable human actions that may be associated with radiation. Committee 2 of ICRP develops references models and data, including dose coefficients, for the assessment of exposures to radiation from both internal and external sources.

N. Petoussi presented specific research and development goals of ICRP within Committee 2 which are: a) development of quantities – operational and protection (with ICRU), b) evaluation of the reliability of key ICRP biokinetic models used for inhaled and ingested radionuclides, c) development of voxel & mesh-type phantoms, d) development of improved / new biokinetic models for internal emitters / pharmaceuticals, e) development of external dose coefficients from environmental exposures of the public, and f) dosimetry in emergency situations. These goals are in compliance with EURADOS Visions 1, 3, 5.

She also presented goals on dosimetry relevant for ICRP: a) evaluation of dosimetric models used to calculate doses to organs, tissues and target cells within tissues, for external and internal exposures, b) development of individual dosimetry, and evaluation of dosimetric assessment and uncertainties that include microdosimetric considerations, c) radiation quality and RBE evaluations for cancer and non-cancer diseases in relation to the use of radiation weighting factors in calculating equivalent dose, and d) development of improved methods for the evaluation of transfer pathways and dosimetry relevant to uptake and internal distribution of environmentally relevant radionuclides to different organs of different reference animals and plants. The presented ICRP goals for R&D in dosimetry are in compliance with EURAODS SRA, Visions 4 and Vision 5.

3.12. ICRP Committee C3; together with ESR (European Society of Radiology)

Representative ICRP C3: Reinhard Loose (Klinikum Nürnberg, Germany)

Representative ESR: Guy Frija (Hôpital Européen Georges Pompidou, France)

ESR is a non-profit organisation dedicated to promoting and coordinating the scientific, philanthropic, intellectual and professional activities of radiology in all European countries. The Society's mission is to serve the health care needs of the general public through the support of science, teaching and research, and the quality of service in the field of radiology.

The focus of ICRP Committee 3 is on doses from medical radiation exposures. C3 develops reference models and data, including dose coefficients, for the assessment of medical exposures to radiation.

The most relevant EURADOS SRA topics identified for ICRP C3 and ESR are in Vision 1 the challenge of updating operational quantities for external exposure; all topics addressed in Vision 4, and in Vision 5 the topic on developing accurate and on-line personal dosimetry for workers. Training on

and intercomparisons of dosimeters used in individual monitoring are also considered important. From the ICRP and ESR point of view research is needed in the field of CT which is considered as modality with highest medical exposure. Several gaps are identified in the EURADOS SRA, for example „intelligence" of CT scanners to determine patient dimensions is missing, such as detection of body mass by table sensors, patient length and diameter by scout/topogram and/or individual slices, automatic organ detection of fully or partly exposed organs, reporting of organ doses etc. In fluoroscopic interventional procedures there is a need for harmonizing the recording and reporting of skin dose mapping and peak skin dose, and criteria for non-justified unintended overexposures are missing, although required by the EU Basic Safety Standards (BSS). For occupational exposures, individual or ambient dose monitoring are important, while for staff and patients protective devices etc. are important. It was also emphasized that there is a great need for harmonized approaches in medical dosimetry such as guidance as to where dosimeters should be worn (under or above apron / or both), for the introduction and use of electronic dosimeters, eye lens dosimetry, software for dose recording, storage, reporting and management (which is in the focus of ICRP and IAEA) etc. Other research needs that were identified by ICRP and ESR are work on individual radio-sensitivity, non-cancer radiation effects of staff and patients (eye, cardiovascular), establishing and updating DRL's, use of effective dose (ICRP C2), justification (how to quantify benefit and risk), radiation risk of patients in medicine (age, disease, loss of lifetime, outcome), communication with patients, and risk perception of patients.

3.13. ICRU (International Commission on Radiation Units and Measurements)

Representative: Hans Georg Menzel (CERN, Switzerland)

ICRU is an organisation which develops and promulgates internationally accepted recommendations on radiation-related quantities and units, terminology, measurement procedures, and reference data for the safe and efficient application of ionizing radiation to medical diagnosis and therapy, radiation science and technology, and radiation protection of individuals and populations.

The areas of interest that were identified in medical applications by ICRU are: Non-equilibrium dosimetry for small fields like IMRT and tomotherapy and smaller treatment volumes; dosimetry for ion beam therapy, incl. radiation quality specification for treatment planning, dosimetry in magnetic fields (MRI-linac combinations are becoming clinical), and dosimetry for treatment planning in radiopharmaceutical therapy (RPT). New dosimetry approaches are needed for cell-specific agents that contain radiolabels. In the radiation protection area it is most probably that ICRU will revise operational quantities in the future. Furthermore, competence and experience in neutron dosimetry needs to be constantly maintained and dosimetry for specific exposure situations (oil industry, transport of spent fuel, …) should be taken into consideration. In the area of radiation effects the most important topics identified by ICRU are: physical basis for improved understanding of biological mechanisms (microdosimetry, nanodosimetry, track structure) and bio-effect modelling, and -effective dose concepts in radiation therapy. These topics are in accordance with Vision 1 and Vision 4 of the EURADOS SRA.

3.14. ILO (International Labour Organization)

Representative: Shengli Niu (ILO, Switzerland)

ILO is a tripartite organization where worker and employer representatives participate at an equal status as governments. Currently, 187 countries are members of ILO. Standard-setting is one of ILO's major means of action, to improve conditions of life and work worldwide.

ILO standards are Conventions and Recommendations adopted by the International Labour Conference. Convention (No. 115) and Recommendation (No. 114) are dealing with the protection of workers against ionizing radiations. C.115 and R.114 lay down basic principles and establish a fundamental framework for radiation protection of workers. They also contain provisions which concern the protective measures to be taken, the monitoring of radiation, and the medical supervision of workers.

Radiation Protection Convention, No. 115, applies to all activities involving exposure of workers to ionizing radiations in the course of their work. It requires that each ILO member who ratifies the convention shall give effect to its provisions by means of laws or regulations, codes of practice or other appropriate methods. ILO ranks EURADOS visions as follows: Vision 5 (Towards improved radiation protection of workers and the public, Vision 1 (Towards updated fundamental dose concepts and quantities), Vision 2 (Towards improved radiation risk estimates deduced from epidemiological cohorts), Vision 3 (Towards an efficient dose assessment for radiological emergencies), and Vision 4 (Towards integrated personalised dosimetry in medical applications)

3.15. IRPA (International Radiation Protection Association)

Representative: Klaus Henrichs (IRPA Secretary, Germany)

IRPA is the international association of radiological protection practitioners, joining through national or regional Associate Societies. IRPA is recognized by its members, stakeholders and the public as the international voice of the radiation protection profession contributing to the enhancement of radiation protection culture and practice worldwide.

As a general remark K Henrichs said that, on a longer time scale, each of the five EURADOS visions will contribute to the improvement of radiation protection. However, even more important is the fact that working on those visions would help secure urgently needed expertise and competences, because such research programs will attract young scientists to the field of radiation protection. He expects that on a shorter time scale, improvement for radiation protection will come from EURADOS efforts on harmonization, and education and training.

Vision 1 is focused on nano-dosimetry and an improved understanding of biological effects at the cellular and subcellular levels. Although of great scientific importance, this vision is unlikely to have any significant impact on radiation protection practice for many years, until the results are incorporated into standards and regulations. To accomplish the goal of Vision 2, RP professionals responsible for dosimetry programs will need to increase monitoring, often with multiple dosimeters per person, and begin the monitoring of persons currently unmonitored, such as radiation therapy patients. In addition, workplace monitoring must also ensure that both radiation and chemical exposures are captured. Consequently, increased collaboration between RP and industrial hygiene professionals will be needed. This, realization of Vision 2 will require significant additions and revisions to worker monitoring procedures. Vision 3 requires fundamental research with wide-scale implementation of revised dosimetry procedures, and will have significant impact

on radiation protection personnel involved in emergency planning and response. In many countries it is already acknowledged that the number of radiation protection professionals available to respond to a large-scale radiological emergency is well below anticipated needs, with few additional resources envisioned. Consequently, the research goals of automation proposed in Vision 3 is absolutely essential to future success, and should perhaps receive increased prioritization in the overall research program. Vision 4 will also increase the demands on RP's in medical settings to provide monitoring for exposed patients; again, emphasis needs to be placed on automating the collection of monitoring data. In addition, greatly increased cooperation and collaboration between medical providers and radiation protection professionals will be required. Finally, Vision 5 is considered by IRPA as the "bottom line" of the entire EURADOS SRA. Although implementation of new or revised instruments, dosimeters and procedures is always disruptive, it should not have adverse impacts on the practice of radiation protection, as the practitioners are already committed to continuous quality improvement.

Following IRPA, harmonisation and education and training are the most promising areas for a significant improvement of RP. These fields are clearly where IRPA can make its maximum contribution to the goals of the EURADOS SRA, by giving input as well as serving as a conduit for the transmission and implementation of improved methodologies and instrumentation from the EC to the rest of the global RP community. European participants in the SRA, through their participation in national RP associations (and therefore IRPA) can communicate their results at IRPA regional and international congresses and teach continuing education courses, thereby improving dosimetry practice throughout the world.

3.16. ISO (International Organization for Standardization)

Representative: Alain Rannou (IRSN, France)

ISO is a Network of 163 national standardization bodies. ISO develops international standards for products, services, processes, materials and systems and for conformity assessment, managerial and organizational practice,

Within ISO/TC 85 "Nuclear energy, nuclear technologies and radiological protection", Sub-committee 2 "radiological protection" develops standards to protect individuals (workers, patients, members of the public) and the environment against all sources of ionising radiations in planned, existing or emergency exposure situations linked to nuclear, medical, industrial and research activities, and natural radiation sources (radon, cosmic radiation, …).

In order to improve the understanding of spatial correlations of radiation interaction events and to quantify correlations between track structure and radiation damage, A Rannou suggested collaboration with EURADOS on the establishment of reference fields, harmonisation of experimental protocols and qualification of codes. For updating the operational quantities for external exposure, collaboration is proposed in the establishment of calibration procedures. In Vision 2 ISO suggested collaboration in harmonisation of techniques / procedures and evaluation of uncertainties, in order to improve retrospective dosimetry for exposure pathways already considered. In Vision 3 ISO identified harmonisation of experimental protocols, qualification of codes, harmonisation of techniques / procedures, and harmonisation of dose calculation as potential areas for collaboration. This would lead towards an efficient dose assessment in case of radiological emergencies. ILO is also interested in the harmonisation of dose calculations / measurements, establishment of calibration procedures for dose measuring devices and intercomparison protocols as mentioned in Vision 4. Finally, in Vision 5 areas for collaborations are

harmonisation of internal exposure measurement and dose calculation, establishment of calibration procedures for personal active dosemeters, and characterisation of radiation fields at workplaces.

A. Rannou made some general conclusions from the ISO point of view. He emphasized that standards may be developed once research findings are mature enough to reach international consensus. Standards in turn foster harmonisation and use of good practices. Therefore, ISO activities may benefit from EURADOS outcomes and vice versa. Experts both involved within ISO and EURADOS activities are key persons for promoting co-operation between the two organisations.

3.17. ISSDO (International Solid State Dosimetry Organization)

Representative: Eduardo Yukihara (PSI, Switzerland)

ISSDO is a non-profit organisation with the goal of promoting and assisting in the organisation of, and ensuring the continuity of the triennial conference known as "The International Solid State Dosimetry Conference". ISSDO also assists in the organization of the Marko Moscovitch School.

E. Yukihara suggested areas of research which are in the focus of SSD conferences. The following topics considered important by ISSDO are in compliance with the EURADOS SRA, especially with the challenges formulated in Vision 4: research in the area of small field dosimetry in radiation therapy, independent verification (e.g. for postal audits), more convenient and precise dose characterization, ion beam therapy beams, LET-dependent (LET: linear energy transfer) efficiency of solid-state detectors, solid state detectors suitable for RBE studies (semiconductor micro- and nano-dosimetry, FNTD, 2D/3D dose distributions) and new luminescent materials, techniques and instrumentation (OSL, RPL).

Possible ISSDO/EURADOS collaborations could include the organization of satellite meetings during the International Solid State Dosimetry Conferences and special sessions dedicated to EURADOS SRA. From the ISSDO point of view, such a collaboration would also foster cooperation between European and non-European partners and bridge the gap between "basic" and applied research.

3.18. MELODI (Multidisciplinary European Low Dose Initiative)

Representative: Nathalie Impens (SCK-CEN, Belgium)

MELODI is a European platform dedicated to low dose ionizing radiation risk research. Melodi promotes progressive integration of national and European activities in low-dose research, by: a) Establishing and annually updating a long-term SRA for research on low dose risk for radiation protection in Europe, b) Identifying research priorities and developing a roadmap to guide national and EU research programmes and the preparation of EU calls, c) Establishing an integrated approach for education and training, c) Addressing the importance of research infrastructures, d) Promoting interdisciplinary collaboration. Three key research questions in MELODI SRA are: 1) Dose and dose rate dependence of cancer risk (research to improve the understanding of the mechanisms contributing to radiation risk, 2) Non-cancer effects and 3) Individual radiation sensitivity.

N. Impens emphasized major links between MELODI and EURADOS in the research on the impact of radiation exposure characteristics and the research on the effects associated with internal

exposures, due to different radiation qualities and inhomogeneous radionuclide distributions within the human body.

Research priorities in Melodi relevant for EURADOS relate to the MELODI key research question 1: a) To determine the cancer risk related to internal emitters in epidemiological studies b) To conduct experimental studies in vivo/vitro to test exposure scenarios where dose modulation plays a role c) To describe by complex systems biology and biomathematical approaches the role of spatial inhomogeneity of radiation exposure in cellular, tissue and organ levels in case of internal exposure of high LET radiation, and d) To determine the RBE for selected endpoints in experimental studies using up-to date technologies and in epidemiological studies through comparison of risk related to low- and high-LET.

As for the key research question 2 (non-cancer effects), research priorities relevant for EURADOS are: a) To investigate the biological mechanisms that govern the effects observed in tissues involved in non-cancer effects regarding specific exposure modalities and radiation qualities, b) To conduct epidemiological studies of internal emitter risk, c) To develop new and innovative ways in experimental studies to determine the RBE and to determine/compare the effects of acute versus chronic exposure.

As for the key research question 3 (individual radiation sensitivity), research priorities relevant for EURADOS are: a) To develop suitable cell, tissue and in vivo models for the quantification of the impact of dose inhomogeneities and radiation quality on individual radio-sensitivity and to conduct epidemiological studies, b) To characterize how internal exposure will influence the formation of candidate biomarkers identified in response to low-LET external exposure, and c) To study how dose distributions and RBE can vary between individuals.

From the MELODI point of view, most relevant challenges are covered by EURADOS SRA Visions 1, 2, 3 and 5. According to MELODI, the improvement of radon dose coefficients (cfr Basic Safety Standards), which is implicitly part of the improvement of biokinetic and dosimetric models and also of the improvement of biokinetics of internal emitters, should be more explicitly mentioned.

3.19. NEA (Nuclear Energy Agency)

Representative: Aleksandr Rakhuba (NEA, France)

NEA was founded in 1958. Currently it includes 31 member countries, seven standing technical committees, and 75 working parties and expert groups. The Committee on Radiation Protection and Public Health (CRPPH) is closest to the field discussed in the EURADOS SRA. The CRPPH is responsible for radiation protection studies and has the following goals: to provide its members with a high-level, visible forum for exchange and discussion, to seek common understanding of these issues, to advance the "state-of-the-art" in radiation protection theory and practice, to advance concepts to better adapt radiation protection to broader social dimensions, and to promote international co-operative projects.

In Vision 1 of the EURADOS SRA, NEA suggested to address more clearly the relationship of effective dose to an individual's risk; to call for guidance in the use of the unit "Sievert" for both effective and equivalent doses, and in the use of Sv and Gy for thyroid dose measurements; and to work towards more simplicity in expressing dose and in its relationship to risk. NEA also suggested addressing post-accident recovery situations in Vision 5.

In general, NEA is very interested in clarification of the use of concepts and units, and EURADOS might come up with a *recommendation* that would then go to ICRU which is working on

reconciling the issue of having Sv as the unit to choose for dose quantities. Furthermore, a clear EURADOS statement would be considered useful that a clarification on how effective dose is used is needed, how it is related to risk of an individual, and whether the recommendations of IRPA and ICRP with regard to collective dose and risk estimates are applicable (or not).

3.20. NERIS (The European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery)

Representative: Wolfgang Raskob (KIT; Germany)

The mission of the NERIS Platform is to establish a forum for dialogue and methodological development between all European organisations and associations taking part in decision making of protective actions in nuclear and radiological emergencies and recovery in Europe. The main NERIS objectives are: a) Improving the effectiveness of current European, national and local approaches for preparedness, b) Promoting more coherent approaches in preparedness and recovery, c) Identifying gaps and needs for further developments, d) Addressing new and emerging challenges in the field of preparedness, and e) Maintaining and improving know-how and technical expertise in preparedness among all interested stakeholders in Europe. W. Raskob presented three main research areas in NERIS: a) new challenges in atmospheric and aquatic modeling, b) new challenges for better dose assessments and decision support based on improved knowledge, and c) new challenges in stakeholder involvement and local preparedness and communication strategies.

Although for NERIS Vision 3 of EURADOS SRA is most important, NERIS is also interested in Vision 1, because they are interested in an accurate dose concept although they are not necessarily doing research on it. EURADOS Vision 3 fits to the NERIS Key Topic 3 (Improvement of existing Decision Support Systems) and to their priority 6. NERIS suggested addressing better the analysis of the radiological situation after a radiological accident (source-term, scenarios, etc.), supporting decision-making processes during emergency and recovery phases, optimizing the use of monitoring resources including mobile units and trans-border issues, integrating new monitoring technologies (e.g.; drones) and developing processes and tools for integrating the monitoring results from experts and lay people into a common operational picture (monitoring crowdsourcing). Furthermore, topics on how to use monitoring efficiently in the optimization of recovery countermeasures, assimilation of information and modelling information, and identifying the need for further medical programs are also possible links to EURADOS.

NERIS is also interested in Vision 5. W. Raskob emphasized the importance of keeping information flow and possibly setting up a common working group on monitoring or other topics identified. From the NERIS point of view, Visions 3 and 5 needs to be harmonised as they have common topics in terms of protecting the public. In the field of monitoring, rapid assessment of a radiological situation, quantification of uncertainties, and dose/risk assessment for medical follow-up EURADOS and NERIS could collaborate in the future.

3.21. NUGENIA (Nuclear Generation II&III Association)

Representative: J.P. Van Dorsselaere (IRSN, France)

NUGENIA is set up to be the starting point of a more ambitious and united community to advance the safe, reliable and efficient operation of nuclear power plants. NUGENIA provides, in a transparent and visible way, a scientific and technical basis by initiating and supporting international R&D projects and programs. Main technical areas for R&D are safety and risk of nuclear power plants (NPPs), severe accidents, core and reactor operation, integrity assessment of systems, structure and components, fuel development, and waste and spent fuel management and decommissioning, innovative light water reactor (LWR) design and technology, and harmonisation. Challenges to guide synergistic R&D topics are promoting a better synergy between radiation protection and nuclear safety issues, since both are interdependent. An orientation of research topics should be towards applied and/or technological research, which will as final outcome feed operational and practical goals. These topics should not duplicate research lines already addressed through the existing radiation protection platforms.

Two main sub-areas for cooperation with the radioprotection community were identified by NUGENIA: a) in TA2/SARNET "Severe accidents, STA 2.5: "Severe accident linkage to environmental impact and emergency management" (topics: near-field dispersion of atmospheric releases, liquid releases and impact, emergency preparedness and response), and b) in TA3 "Core and reactor operation", STA 3.5 "Radiation protection" (topics: radiological protection and occupational exposure, public and environmental radiation protection, European methodology guidance for epidemiology data base construction).

NUGENIA had first informal contact in 2015 with NERIS and ALLIANCE at ERMSAR-2015 (the periodic TA2/SARNET conference). With NERIS presidency first formal contact was in 2015, similarly foreseen in the future for ALLIANCE. Also NUGENIA had contact with OPERRA (N. Impens) who gave a lecture at the NUGENIA forum in April 2016. First discussions were made with TA2/SARNET and a preliminary plan for organizing a workshop with experts from both communities was developed, to identify R&D fields of joint interest. Preliminary ideas for joint research topics include geological and ground water contamination during a severe accident, and dosimetric applications; mixture toxicity; and methodology for improved European cohorts of nuclear workers.

3.22. PTCOG (The Particle Therapy Co-Operative Group) Representative

Marco Durante (GSI, Germany)

PTCOG is a non-profit worldwide organization of scientists and professionals interested in proton, light ion and heavy charged particle radiotherapy. The mission is to promote science, technology and practical clinical application of particle therapy, with the ultimate goal of improving treatment of cancer to the highest possible standards in radiation therapy.

3.23. RENEB (Realizing the European Network of Biodosimetry)

Representative: Ulrike Kulka (BfS, Germany)

RENEB is a Coordination Action project funded within the 7th EU framework EURATOM Fission Process. The purpose of the project is to bring together partners with a long-term commitment for bio-dosimetry in an effort to establishing an operational network for mutual assistance in large scale emergencies. RENEB has already links with different platforms (EURADOS, MELODI, ALLIANCE,

Medical associations, E&T platforms). EURADOS and RENEB have already established a very close cooperation through EURADOS WG10 on "Retrospective Dosimetry".

From the RENEB point of view, joint interests for cooperation are formulated in EURADOS Vision 2, especially in setting up of biobanks for physical and biological analyses. U. Kulka emphasized that in order to handle such large-scale studies in reasonable time, the use of laboratory networks such as RENEB as analysis platforms of bio-samples should be promoted.

The core challenges for RENEB are formulated in EURADOS Vision 3 (Efficient dose assessment for radiological emergencies). For dose assessment after internal contamination, efforts should be made to link internal dosimetry after incorporation of radionuclides with biological dosimetry methods. In order to handle a large number of dosimetric samples, strategies and methods to increase measurement capacity must be developed. Accordingly, methods allowing for high-throughput and cheap measurements should be further developed such as gene expression or protein biomarkers. Web-based scoring of captured images is emerging as a fast and easy method of performing chromosome analysis whilst involving laboratories spread all over the world. Networking of laboratories has been identified as a very useful approach to get fast and reliable dose estimates. Such networks have been or are in the process of being established, but they need to be maintained and their functionality has to be trained and practiced. For this reason, one of the joint actions between EURADOS and RENEB should be organizing joint exercises and training courses.

Furthermore, RENEB and EURADOS should collaborate in the future on an operational basis, to ensure high QA standards on permanent harmonisation, E&T, identification, validation and inclusion of new assays / biomarkers, technical improvement of existing assays, better dose assessment for partial body irradiation, better dose assessment for internal exposure, and on the impact of socio-economic aspects.

3.24. SSH (Social Sciences and Humanities)

Representative: Christiane Pölzl-Viol (BfS, Germany)

C. Pölzl-Viol gave a presentation on the view of the social sciences and humanities community. Her comments should be seen in relation to Task 2.6 of CONCERT, which is led by SCK-CEN, Belgium. The SSH community is currently in the process of forming an SSH platform and developing an SSH research agenda.

While there were no comments on Vision 1 of the EURADOS SRA, C. Pölzl-Viol suggested in Vision 2 (To explore exposure pathways not yet considered or validated), with respect to justification of exposure, the social and psychological aspects among the investigated cohorts to be considered. With regards to advances in retrospective dosimetry for exposure pathways already considered (Vision 2) as well as for radiological emergencies (Vision 3), the acceptability of detection limits and the communication of risks and uncertainties are important aspects. Advanced retrospective dosimetry and the consideration of respondents' needs and expectations could be enhanced for example by developing interview protocols following the state-of-the-art of social science methodologies. She also emphasized that it is important that citizens of contaminated areas themselves are directly involved in establishing and using tools or instruments for radioactivity measurements. The socio-psychological aspects of thyroid measurements performed in contaminated areas should also be included. As for medical applications of ionizing radiation (Vision 4), communication between doctors and patients should be improved, for instance

considering patients' needs and input in technology design. Finally, for the improvement of radiation protection of workers and the public (Vision 5), the ethical framework behind the current radiation protection concept (e.g. the optimal application of the ALARA principle) needs to be considered, and for example any potential changes in the behavior of workers using a new on-line dosimeter should be investigated. C Pölzl-Viol finished her presentation saying that integration of SSH in the EURADOS SRA is needed in general, because science is made for people and with people.