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D2.10 Joint research needs and priorities addressing radiation protection research relevant for medical use of radiation and communication/risk perception in radiation protection field (3)

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Abstract

This deliverable consists of two separate sections addressing the research needs and priorities of radiation protection research. The first section is relevant for medical use of radiation, and the second section addresses the issues related to social sciences and humanities in radiation protection R&D, reflecting the outputs of CONCERT Tasks 2.5 and 2.6, respectively.

Medical use of radiation (CONCERT Task 2.5):

The European Alliance for Medical Radiation Protection Research (EURAMED) represents a consortium of associations involved in the application of ionising radiation in medicine, namely the European Association of Nuclear Medicine (EANM), the European Federation of Organizations for Medical Physics (EFOMP), the European Federation of Radiographer Societies (EFRS), the European Society of Radiology (ESR) and the European Society for Radiotherapy and Oncology (ESTRO) with the goal of jointly improving medical care and its medical radiation protection issues through sustainable research efforts. Since October 1st, 2017 EURAMED is a non-profit organisation registered in Austria.

For the first time the five medical societies joined forces and agreed on a collaboration to improve the application of ionising radiation in medical care by developing and exploring common research strategies and by actively promoting the translation of results into clinical practice. The first edition of a strategic research agenda (SRA) for medical radiation protection was approved by the boards of the five societies in November 2015 and published in July 2016 (also reported in full in D2.8 of CONCERT in 2016). Meanwhile there is a peer-reviewed publication in imaging insights from February 2017 for citation possibilities.

During 2016 EURAMED and its individual medical associations provided strategic guidance and input to the development of the Horizon 2020 project MEDIRAD. The project, which investigates implications of medical low-dose radiation exposure, received 10 million Euros in funding from the European Commission and started in June 2017. MEDIRAD brings together over 70 scientists from 33 organisations and 14 countries and will significantly improve our scientific understanding and practice of radiation protection in the medical field.

The purpose of EURAMED is achieved by promoting research and teaching and by publication of scientific and professional information, especially a strategic research agenda in the field of medical radiation protection research, thereby increasing the science base in medical radiation protection. EURAMED pursues its purpose by co-operating with relevant national, European and international scientific organisations active in its field of interest and in particular with national and international bodies promoting the interests related to medical radiation protection and medical radiation protection research as well as with patient organisations and the public at large.

The vision of EURAMED is to lead the European research activities in medical RP and to assume an umbrella function for the harmonisation of practice to advance the European RP safety culture in medicine. EURAMED complements existing established European platforms (MELODI, EURADOS, NERIS and ALLIANCE) in several other fields of radiation protection and will thus create visibility for the medical field in this context.

The mission of EURAMED is to jointly improve medical care through sustainable research efforts in medical radiation protection, to identify common research areas defined in a common strategic research agenda, to serve as a platform for medical radiation protection research, linking researchers and clinicians, adopting a harmonised approach to lobbying at European level to impact the European research funding landscape, and to develop an aligned approach and response to European research calls.

Creating a Strategic Research Agenda for Social Sciences and Humanities in Radiation Protection (CONCERT Task 2.6):

The collection of the research topics was discussed at the Radiation Protection Week in Oxford (19-23 September 2016) with task 2.6 members, SSH community and platforms, and the most urgent topic for an SSH research was identified (CONCERT 2.2). In addition, the Strategic Research Agenda (SRA) for Social Sciences and Humanities (SSH), developed based on a broad stakeholder engagement process, has been part of the debate at the RICOMET Conference 2017 (June 27th to 29th, Vienna). This was the third conference on risk perception, communication and ethics in radiological protection. The conference has been attended by 130 delegates and has been live streamed from the IAEA venue on the RICOMET Facebook Group. (CONCERT D2.8).

The SRA for Social Sciences and Humanities Research in radiation protection is structured in six research lines addressing societal challenges related to Health and wellbeing, Secure, safe and resilient societies, Communication, collaboration and citizenship and Integration, impact and reflexivity:

- Effects of social, psychological and economic aspects on radiation protection behaviour and choices of different actors
- Holistic approaches to governance of radiological risks
- Guiding principles for Responsible Research and Innovation in Radiation Protection
- Stakeholder engagement and participatory process in radiation protection research, development, policy and practice as well as their role in decision making.
- Risk communication
- Radiation protection culture

Each of these research lines includes a number of specific research topics relevant to a future European research agenda in the field of radiation protection. Creating and updating the SRA for Social Sciences and Humanities is a live and constantly developing process and the output will be regularly adopted according to the state-of-the-art and societal needs. This will be done by a continuous engagement of the SSH community in radiation protection field and other stakeholders, especially technical and research platforms.

Based on the broad input from SSH and Radiation Protection communities, a preliminary list of the most important research themes was identified, as follows.

1. Stakeholders' sense-making of ionising radiation concepts, risks, uncertainties and link with behaviour in different exposure situations. Possibly focus on low doses and include risk communication, mental models, method for pluralistic analysis of risk and uncertainties with stakeholders.
2. Legal instruments for public information and participation and their application. Analysis of participatory tools and methodologies, in particular ethical principles guiding deliberative processes.
3. Analysing and increasing awareness of radiation protection R&D and ethical principles guiding RP research; harmonisation of radiation protection approaches.
4. Holistic approaches to accident and post-accident management (psychological aspects and socio-economic aspects, governance, articulation of roles of different stakeholders...) and role of local knowledge in decision-making (citizen-based measurements and data production, articulation between institutional data and citizen-sourced data, ...)
5. Ways to build/ transmit radiation protection culture => transversal issue.
6. Risk communication for medical applications.

Towards the end of 2017, first steps to build a joint roadmap for radiation protection research have been taken (D3.4 of CONCERT). The challenges for SSH in the Joint Roadmap is defined as "Enhancing integration of radiation protection science with society". The Joint Roadmap for Radiation Protection Research (abbreviated as Joint Roadmap) is intended as a guide to plan radiation protection research over the next decades. The Joint Roadmap will promote long-term research to assess the effects of ionizing radiation on humans and the environment, and to develop tools to improve practical radiation protection related to different situations resulting in exposure to ionizing radiation. The Joint Roadmap aims to improve the radiation protection system, to answer priority radiation protection questions and to support decision making".

1 Section 1: Medical use of radiation

1.1 Identification of joint research needs and priorities addressing radiation protection research relevant for medical use of radiation in Europe

Reflecting the change of funding strategies for research projects within Europe, and the goal of jointly improving medical care in terms of optimising radiation protection by sustainable research efforts, the medical associations involved in the application of ionising radiation have identified research areas of interest and agreed upon these in a common strategic research agenda (SRA) endorsed by the medical associations. The European Alliance for Medical Radiation Protection Research (EURAMED) represents a consortium of associations involved in the application of ionising radiation in medicine, namely the European Association of Nuclear Medicine (EANM), the European Federation of Organizations for Medical Physics (EFOMP), the European Federation of Radiographer Societies (EFRS), the European Society of Radiology (ESR) and the European Society for Radiotherapy and Oncology (ESTRO) with the goal of jointly improving medical care and its medical radiation protection issues through sustainable research efforts.

1.2 Common strategic research agenda (SRA) for radiation protection in medicine

The first edition of a strategic research agenda (SRA) for medical radiation protection was approved by the boards of the five societies in November 2015 and published in EIBIR website in July 2016 and also reported in full in Deliverable 2.8 of CONCERT in 2016. For dissemination within the medical community, a Statement on the Common strategic research agenda for radiation protection in medicine was published in *Insights Imaging* (2017) 8:183-197. DOI 10.1007/s13244-016-0538-x

The research that is seen to be necessary and most urgent for effective medical care, under the best harmonised practice, and efficient in terms of radiation protection can be summarised to the following five main research topics and subtopics, as described in the SRA:

1. Measurement and quantification in the field of medical applications of ionising radiation
 - a. Measurement of exposure
 - b. Individual dosimetry
 - c. Quality metrics for medical applications
 - d. Sources and influences of uncertainty

2. Normal tissue reactions, radiation-induced morbidity and long-term health problems
 - a. Exposure associated cancer risk: dose-, dose distribution-, and dose rate-dependence
 - b. Non-cancer effects in various tissues and radiobiology-based effect models for individual morbidity endpoints
 - c. Individual patient-related radiation sensitivity and early biomarkers of response and morbidity
 - d. Radiobiological mechanism-based, endpoint-specific, protective (normal tissues) or synergistically sensitising (tumour tissues) strategies

3. Optimisation of radiation exposure and harmonisation of practices
 - a. Patient-tailored diagnosis and treatment including an expert system for optimisation
 - b. Full exploitation and improvement of technology and techniques
 - c. Clinical and dose structured reporting
 - d. Protection of staff, patients, carers and general public
4. Justification of the use of ionising radiation in medical practice
 - a. Risk / benefit assessment and communication
 - b. Improvement of use of evidence-based guidelines
5. Infrastructures for quality assurance
 - a. Data coding, collection and management
 - b. Biobanks
 - c. Developing key performance indicators for quality and safety
 - d. Audit systems
 - e. Education and training metrics

The subtopics defined for each topic describe the specific research aspects that are identified as areas of great importance regarding research for establishing optimal radiation protection in the field of medical applications.

It is important to highlight that the approach to improve the use of ionising radiation in medicine by pure fundamental research would lack impact and influence unless having immediate consequences for and being translatable to everyday clinical practice. It is also important that the results of the research are not only translatable but really translated into daily routines. Therefore it is essential that the research is undertaken in a concise manner by persons educated and trained for good medical practice. The results have to be evaluated in clinical practice and have to be made public in a way that it is easy to access (results and implementation guidelines available on the internet) and to implement the methodologies developed. It is also essential that the same level of importance is placed on educating the staff working in the field to guarantee a direct clinical impact and to ensure high-level, standardised medical care and related radiation protection fully exploiting and profiting from all research conducted with regard to radiation protection in the medical field throughout Europe.

In the meantime it had been identified, that in a future version of the SRA new additional research topics will have to be implemented. These topics will be additional priorities to be described in such a new version in more detail. Here we will just name them:

- Using artificial intelligence and neural networks for improving medical applications of ionising radiation with respect to radiation protection.
- Establishing Radiomics for individualised medicine and its application in medical radiation protection.

1.3 Launching the MEDIRAD project

During 2016 EURAMED and its individual medical associations provided strategic guidance and input to the development of the Horizon 2020 project MEDIRAD. The project, which investigates implications of medical low-dose radiation exposure, received 10 million Euros in funding from the European Commission and started in June 2017. MEDIRAD brings together over 70 scientists from 33 organisations and 14 countries and will significantly improve our scientific understanding and practice of radiation protection in the medical field.

1.4 Establishing the EURAMED platform

Since October 1st, 2017 EURAMED is a non-profit organisation registered in Austria. The purpose of EURAMED is achieved by promoting research and teaching and by publication of scientific and professional information, especially a strategic research agenda in the field of medical radiation protection research, thereby increasing the science base in medical radiation protection. EURAMED pursues its purpose by co-operating with relevant national, European and international scientific organisations active in its field of interest and in particular with national and international bodies promoting the interests related to medical radiation protection and medical radiation protection research as well as with patient organisations and the public at large.

The mission of EURAMED is to jointly improve medical care through sustainable research efforts in medical radiation protection, to identify common research areas defined in a common strategic research agenda, to serve as a platform for medical radiation protection research, linking researchers and clinicians, adopting a harmonised approach to lobbying at European level to impact the European research funding landscape, and to develop an aligned approach and response to European research calls.

The administrative office of EURAMED is run by the European Institute for Biomedical Imaging Research (EIBIR) and can be contacted at mhierath@eibir.org. Membership to EURAMED will be possible in the near future as soon that the general assembly has decided on the rules of membership in this organisation.

1.5 Developing EURAMED roadmap

Roadmaps are being developed by the platforms and the social sciences and humanities community dealing with radiation protection issues. While the Joint Roadmap presents the overarching R&D challenges, the individual roadmaps intend to develop the R&D challenges within the respective radiation protection research disciplines and serve as guides for the research community. EURAMED has already started the process of developing such a roadmap for the medical radiation protection research priorities. As research in this field has not been covered in a sufficient way for many years there is a tremendous need for funded research activities. Due to this large field it is decided that the roadmap of EURAMED will highlight to do research on an exemplarily level first showing how certain aspects can be addressed in research and implemented into clinical practice. The roadmap also shows proposed time frames of these kind of projects. Assuming that projects are really on specific clinical

examples, instead of all applications of investigated procedures, budgets, which would be necessary at least, are mentioned. These general aspects would not be changed... in the final version of this EURAMED roadmap. A first approved version, which will be published online, will hopefully be available by January or February 2018.

1.5.1 Joint roadmap with other European radiation research platforms: The challenge to optimise medical applications of ionising radiation

The vision of EURAMED is to lead the European research activities in medical RP and to assume an umbrella function for the harmonisation of practice to advance the European RP safety culture in medicine. EURAMED complements existing established European platforms (MELODI, EURADOS, NERIS and ALLIANCE) in several other fields of radiation protection and will thus create visibility for the medical field in this context. In particular, many of the objectives of the EURAMED SRA are closely linked with the objectives of MELODI for low dose risk and the objectives of EURADOS for dosimetry of medical and occupational exposures.

Towards the end of 2017, first steps to build a joint roadmap for radiation protection research have been taken (D3.4 of CONCERT). The Joint Roadmap for Radiation Protection Research (abbreviated as Joint Roadmap) is intended as a guide to plan radiation protection research over the next decades. The Joint Roadmap will promote long-term research to assess the effects of ionizing radiation on humans and the environment, and to develop tools to improve practical radiation protection related to different situations resulting in exposure to ionizing radiation. The Joint Roadmap aims to improve the radiation protection system, to answer priority radiation protection questions and to support decision making. The Joint Roadmap will also highlight the needs with regard to research infrastructure, education & training, and discuss some principles to determine research priorities and budgets.

Based on an overview of realistic exposure contexts and scenarios, the first list of joint R&D challenges is proposed, based on the research disciplines of European radiation protection research platforms, namely MELODI, EURADOS, NERIS, ALLIANCE and EURAMED, and also Social Sciences and Humanities in the field of Radiation Protection. This proposal is primarily based on input from the research community and a number of radiation protection research program managers and program owners from European Member States.

The roadmap will be further developed through a broader stakeholder involvement: in 2018 a stakeholder involvement plan will be developed and implemented. A first draft joint roadmap will be ready in 2019.

It is the intention to regularly update the joint roadmap beyond CONCERT, as it is intended as a guide to plan radiation protection research over the next decades. Within this time frame, the joint roadmap for radiation protection research should take into account research progress and updated societal needs.

1.5.2 The challenge to optimise medical applications of ionising radiation

An important challenge in the joint roadmap deals with optimisation of medical applications of ionising radiation. The exposure of patients for medical diagnostic and therapeutic procedures is the largest man-made source of exposure to ionising radiation within Europe (RP180) on average for the population, although it is not homogeneously distributed within the population regarding age, gender

and other factors. Therefore, there is a big challenge to perform research on how the exposure can be optimised and how this can be implemented into clinical practice on the same level throughout Europe. To do so, two main sub-challenges have to be addressed:

- a) harmonisation of practices based on justification and optimisation
- b) individualisation and optimisation of medical procedures based on new diagnostic and therapeutic approaches, including exposure and image quality descriptors and patient specific risk and benefit considerations.

a) Harmonisation of practises based on justification and optimisation:

The amount of exposure to ionising radiation due to medical applications varies strongly between the different countries in Europe. This is partly based on whether ionising radiation diagnostic procedures are used for specific clinical questions (justification) and which procedures are used. There is also still a broad variety of exposure conditions throughout Europe or even within a single country for the same kind of therapeutic or diagnostic procedures (optimisation). Optimisation of doses delivered during external beam or radionuclide therapy is a major concern. In vivo dosimetry techniques applied during external beam therapy require continuous improvement, taking into account the rapid development of radiotherapy technology and techniques. The dose to patients in interventional procedures also requires optimization. The same is true for CT and PET examinations as well as multimodality imaging (CT/PET, MR/PET). Dose and imaging repositories need to be developed and harmonized at the European level to enable facilities to review and minimize doses and optimize protocols.

It is of uttermost importance to perform research to find a European consensus on which procedures should be applied in which situation and how best use can be made from existing technologies for various levels of technological equipment in different environments. This “European always best use for existing technology” should allow similar exposure conditions for similar indications and e.g. all patient sizes as well as similar diagnostic or therapeutic outcome throughout Europe. To achieve that, one key aspect of this challenge is how to transfer the defined and agreed upon procedures into clinical practice throughout Europe.

b) Individualisation of medical exposures:

Individualisation of patient exposure is a very promising approach to avoid unwanted hazardous effects in applying ionising radiation in medicine. This is in general true for diagnostic as well as for therapeutic procedures. The corresponding optimisation has to be performed for both types of applications separately, because therapeutic applications are most often associated with significantly higher exposures to at least some organs. Specific emphasis should be placed on pediatric applications of ionizing radiation. To answer this challenge it is necessary to include considerations along four lines of research:

Personalized dosimetry in medical imaging and radiotherapy is a cornerstone of individualised procedures in medicine based on ionising radiation. Article 56 of the new EU Directive 2013/59/EURATOM states that ‘For all medical exposures of patients for radiotherapeutic purposes, exposures of target volumes shall be individually planned and their delivery appropriately verified taking into account that doses to non-target volumes and tissues shall be as low as reasonably achievable and consistent with the intended radiotherapeutic purpose of the exposure’. The inhomogeneous spatial and temporal distributions of initial physical tracks, chemical radicals and later

on dynamical molecular biological progresses induced in the patient, needs to be investigated using modern approaches of micro- and nanodosimetry as well as patient-specific and equipment-specific dosimetric simulations, modelling, and biological assessments.

The next aspect is to evaluate risk of radiogenic cancer or other induced diseases of the individual patients based on the assumption that at least parts of the organs which are irradiated for diagnostic or therapeutic procedures meaning they are affected by illness are the origin of induced diseases again. The research here has to rely on dosimetric, biological and epidemiological investigations.

For medical diagnostic procedures, methods should be developed to determine the level of image quality performance necessary to produce images of appropriate diagnostic quality for specific clinical indications. These methods should take into consideration various parameters including patient body size, gender and, ideally, individual susceptibility. Ways have to be defined how to determine and predict such image quality In order to optimize the single procedure for single patients.

The process of stratification or individualization of procedures, diagnostic or therapeutic, has to be defined and followed upon in order to guarantee a harmonized application in clinical practice throughout Europe. It has to include determine personal risk factors, determine the individual situation of the patient, The exposure data need to be documented.

In addition to the inherent patient benefit from any medical approaches (justification), the generation of a very large European or even global cohort of patients exposed under controlled and well documented procedures, should provide the foundation for wider and more general studies on the effects of ionizing radiation in humans. This, however, also requires a sufficient - regarding time and time intervals after exposure as well as scoring systems particularly for morbidity - assessment of the consequences of radiation exposure. This presumably needs to be based on the establishment of national or preferably European-wide databases.

This already describes the most urgent priorities in the field of medical radiation research. As mentioned above it would also be important to implement the two tasks

- artificial intelligence

and

- radiomics

in the list of priorities.

It should also be mentioned that for all the listed priorities it will be very important to have ways to communicate risk and benefit to the patients to develop a more sophisticated approach to the empowerment of patients.

That means a list of priorities includes the following:

1. A common European approach for justification of procedures using ionising radiation on patients
2. Harmonisation of practises throughout Europe taking into account the tremendous achievements and developments on technologies and techniques in all fields of medical applications of ionising radiation (radiation therapy, diagnostic and interventional radiology as well as nuclear medical imaging and therapy) based on valid dosimetric and clinical outcome describing quantities.

3. Individualisation of medical procedures to optimise the benefit to risk ratio for individual patients based on patient parameters like age, gender, height, size and potentially individual susceptibility
4. Using artificial intelligence to optimise medical applications of ionising radiation for diagnostic or therapeutic purposes with respect to radiation protection
5. Correlating clinical endpoints with radiological information for future radiation protection approaches for the patients.
6. Developing a strategy based on individual benefit and risk communication for empowerment of patients

2 Section 2: Social Sciences and Humanities in radiation protection field (original title: Communication and risk perception)

Needs and priorities addressing radiation protection research relevant for Social Sciences and Humanities (SSH)

2.1 Societal challenges addressed by the SSH SRA

The need for multi- and transdisciplinary research and broader societal involvement in radiation protection is increasingly recommended at national and supra-national levels for all aspects of exposures to ionising radiation.

This strategic research agenda aligns with recent proposals for more open and responsive modes of research and science policy-making, and attends to the following challenges put forward in contemporary EU-wide policy discourses on “Science with and for society” and “responsible research and innovation”: Health and wellbeing, Secure, safe and resilient societies, Communication, collaboration and citizenship and, Integration, impact and reflexivity.

Health and wellbeing comprises the social, mental and physical health of individuals as well as social factors such as the strength and diversity of social bond within a community and its capacity of autonomy. Achieving health and wellbeing requires investments on behalf of decision makers and research communities at a time of economic restraint and the aging of populations across Europe. Research in the field of SSH explicitly addresses these aspects and draws connections between health and wellbeing to ensure quality of life for all.

European nations face major natural hazards and human-induced threats. SSH research seeks to make significant contributions towards enhancing societal resilience and preparedness in the face of these threats by examining contemporary approaches to safety and security, and by opening a broader societal debate on the kinds of resilience that can, and should, be achieved.

SSH research on communication, collaboration and citizenship advances our understanding of how individuals and people are included and excluded, and how processes like communication and collaboration foster novel forms of identity, sense making and belonging. It does so with the aim of creating societies in which citizens thrive and feel confident to express themselves.

SSH research on integration, impact and reflexivity assesses the impact of research activities on the values and choices made by researchers in their communities. This includes giving due consideration to the societal and ethical implications of research agendas, processes, and outputs.

Recognizing the intertwined character of social and technical resonates with the idea that science and technology are open to individual creativity, collective ingenuity, economic priorities, cultural values, institutional interests, stakeholder negotiation, and the exercise of power and it is thus important to reflect on how this shapes the organisation of radiation protection research and the formulation of its policies.

Creating and updating the SRA for Social Sciences and Humanities is a live and constantly developing process and the output will be regularly adopted according to the state-of-the-art and societal needs. This will be done by a continuous engagement of the SSH community in radiation protection field and other stakeholders, especially technical and research platforms.

1400 individuals from radiation protection field were asked to contribute to the further development of research and priorities in Social Sciences and Humanities in June 2017. The e-mail addresses from the OPERRA questionnaire and the EAGLE and PLATENSO projects have been used for this purpose. Respondents were asked to share their opinion, remarks or give advice on the current version of the SRA for Social Sciences and Humanities. In addition, the Strategic Research Agenda (SRA) for Social Sciences and Humanities (SSH), developed based on a broad stakeholder engagement process, has been part of the debate at the RICOMET Conference 2017 (June 27th to 29th, Vienna). This was the third conference on risk perception, communication and ethics of exposures to ionizing radiation.

2.2 Research lines and topics in Strategic Research Agenda (SRA) for Social Sciences and Humanities (SSH) in radiation protection field (RP)

The SRA for Social Sciences and Humanities Research in radiation protection is structured in six research lines for which a joint European effort has been identified as need to address the contemporary challenges outlined above. Each of these research lines includes a number of specific research topics relevant to a future European research agenda in the field of radiation protection.

Following the cross-cutting approach, part of the research topics are linked with challenges and research needs identified by the radiation protection associations MELODI, ALLIANCE, NERIS, EURADOS and EURAMED. In particular, there is a stronger relation to NERIS challenges and key topics. Exchanging views on these joint challenges will be part of the further procedure to improve the SRA, set priorities and formulate projects.

Research line 1: Effects of social, psychological and economic aspects on radiation protection behaviour and choices of different actors

Research line 1 seeks to improve the understanding of behavioural aspects related to radiological risks, including the interrelation between behaviour, perception of radiological risks, economic aspects, knowledge, culture, historical memory and other potentially influencing factors.

Research line 2: Holistic approaches to governance of radiological risks

Research line 2 develops holistic and inclusive approaches for the governance of radiological risk situations by integrating technical assessments and social concern assessments (ethical, socio-economic, psychological and cultural aspects, governance issues, articulation of roles and contributions of different stakeholders including local actors and civil society, role of local and citizen knowledge...), raising awareness about the social scientific aspects and integrating them into knowledge building, framing of issues and the decision-making process together with technical assessments. Evaluation of radiological and non-radiological (i.e. social) aspects will serve as input for decision-making by the various stakeholders (including institutions but also actors without defined institutional role but having to take decisions vis-à-vis their own processes, professional practices, ways of life, ...).

Research line 3: Guiding principles for Responsible Research and Innovation in Radiation Protection

Research line 3 aims at assessing how radiological protection research and development (R&D) is conducted, with the aim of inciting more socially responsive and ethically sound R&D and outcomes. This should enhance the impact of social science and humanities research on science and technology policy and research agendas in the field of radiation protection. The design of transdisciplinary discourses is an emphasis in this research line, for example through co-creative agenda setting processes between scientists and the public.

Research line 4: Stakeholder engagement in radiation protection research, development, policy and practice

Research line 4 aims at fostering stakeholder engagement in radiation protection research, policy and practice in ways that enhance responsiveness to societal needs and concerns. By stakeholder we denote anyone who has a stake in radiation protection research, its development or applications and/or is potentially affected by radiation protection R&D and the outcomes it generates.

Research line 5: Risk communication

Research line 5 aims at developing research to support communication about ionising radiation between different stakeholders and citizen-centred risk communication, in order to clarify choices and options in a variety of exposure situations and empower citizens and other stakeholders to make informed decisions.

Research line 6: Radiation protection culture

Research line 6 supports the development and building of a radiation protection culture among stakeholders in various exposure situations (planned, existing and emergency) and categories of exposure (occupational, patient, general public). This should:

- favour the understanding of radiation protection norms and standards
- favour better decision-making processes concerning the management of radiation exposure situations, and identification and implementation RP actions
- enable individuals, where relevant:
 - to reflect on their own protection and/or that of other individuals
 - to consider consciously radiation protection aspects in their activities or decisions
 - to make their own decision with regard to their own protection against ionising radiations
 - to participate to decision making processes related to the management of exposure situations

- enable professionals in RP field and other stakeholders to dialogue and share a common language, in a view to enhance the efficiency and reliability of the radiation protection system and its capacity to effectively answer the concerns of all concerned stakeholders.

2.3 Statement on the SSH research priority

Based on the broad input from SSH and Radiation Protection communities, a preliminary list of the most important research themes was identified, as follows.

1. Stakeholders' sense-making of ionising radiation concepts, risks, uncertainties and link with behaviour in different exposure situations. Possibly focus on low doses and include risk communication, mental models and method for pluralistic analysis of risk and uncertainties with stakeholders.
2. Legal as well as informal and non-formal instruments for public information and participation and their application. Analysis of participatory tools and methodologies, in particular ethical principles guiding deliberative processes.
3. Analysing and increasing awareness of radiation protection R&D and ethical principles guiding RP research; harmonisation of radiation protection approaches.
4. Holistic approaches to accident and post-management (psychological aspects and socio-economic aspects, governance, articulation of roles of different stakeholders...) and role of local knowledge in decision-making (citizen-based measurements and data production, articulation between institutional data and citizen-sourced data...).
5. Development and building of radiation protection culture among stakeholders in various exposure situations (planned, existing and emergency) and categories of exposure (workers, patient, general public), including characterization of RP culture, evaluation of the level of RP culture, highlighting the role of RP culture as well as development of tools, methods, processes to build, maintain and transmit RP culture. Research developments under this theme can also be integrated in a transversal way within radiation protection research topics identified by the RP Research Platforms.
6. Risk communication for medical applications of ionizing radiation.

2.4 Joint roadmap with other European radiation research platforms: Enhancing integration of radiation protection science with society

Towards the end of 2017, first steps to build a joint roadmap for radiation protection research have been taken (D3.4 of CONCERT). The Joint Roadmap for Radiation Protection Research (abbreviated as Joint Roadmap) is intended as a guide to plan radiation protection research over the next decades. The Joint Roadmap will promote long-term research to assess the effects of ionizing radiation on humans and the environment, and to develop tools to improve practical radiation protection related to different situations resulting in exposure to ionizing radiation. The Joint Roadmap aims to improve the radiation protection system, to answer priority radiation protection questions and to support decision making. The Joint Roadmap will also highlight the needs with regard to research infrastructure, education & training, and discuss some principles to determine research priorities and budgets.

Based on an overview of realistic exposure contexts and scenarios, the first list of joint R&D challenges is proposed, based on the research disciplines of European radiation protection research platforms, namely MELODI, EURADOS, NERIS, ALLIANCE and EURAMED, and also Social Sciences and Humanities in the field of Radiation Protection. This proposal is primarily based on input from the research community and a number of radiation protection research program managers and program owners from European Member States. The roadmap will be further developed through a broader stakeholder involvement: in 2018 a stakeholder involvement plan will be developed and implemented. A first draft joint roadmap will be ready in 2019. It is the intention to regularly update the joint roadmap beyond CONCERT, as it is intended as a guide to plan radiation protection research over the next decades. Within this time frame, the joint roadmap for radiation protection research should take into account research progress and updated societal needs.

The challenge for SSH was defined as “Enhancing integration of radiation protection science with society”.

2.5 Enhancing integration of radiation protection science with society

Despite the recognized need for multidisciplinary approaches to research and innovation including social sciences and humanities (European Commission, 2014), radiation protection research is still, to a large extent, characterised by a divide between the technical content and the social context. Research and innovation in radiation protection needs to be better aligned with the values, needs and expectations of society. This situation can be observed across numerous fields and application domains: nuclear medicine, radiotherapy, naturally occurring radioactive materials, nuclear waste management, environmental remediation, emergency management, and decommissioning. The challenges faced by radiation protection R&D are substantial and attention to the societal dimensions is insufficient.

a. Communication, collaboration and engagement in the radiation protection field

Research on communication, collaboration and engagement is needed to advance our understanding of how people are included and excluded in radiation protection decision-making, and how processes of communication and collaboration foster novel forms of identity, sense making and belonging. The aim is to empower citizens to take informed decisions considering risks and benefits of exposures to ionizing radiation. Communication about ionizing radiation has to become citizen-centered, based on participatory approaches. This requires a good understanding of the public’s sense-making of ionising radiation concepts, risks and uncertainties, and their information needs, enhanced interaction and mutual understanding among the radiation protection stakeholders.

Whereas most results of radiation protection research are published in scientific journals or communicated using institution-centered expert language, there is a need to provide information in the right format and language to non-specialists, including the public, patients, policy makers, and victims of accidents, legacy sites or other exposure situations. Communication has to be developed as a multi-directional learning process between the stakeholders, and adapted to their concerns, needs and values. Moreover, participation of stakeholders in the decision-making process is essential for improving the efficiency and social robustness of decisions related to radiological protection. The main challenges associated with stakeholder participation are creating opportunities and venues for stakeholder engagement in radiation protection decision-making, and improving the understanding of the factors and criteria for successful stakeholder engagement in different exposure situations.

b. Integration, impact and reflexivity of radiation protection research

The need for multi- and transdisciplinary research and broader societal involvement in radiation protection is increasingly recommended at national and supra-national levels for all aspects of exposures to ionising radiation. Radiation protection should enhance integration of social and ethical

concerns into the system and the practice of radiological protection. It has to consider the social and ethical justification of exposures to ionizing radiation and develop radiation protection culture where appropriate. Recognizing the intertwined character of social and technical resonates with the idea that science and technology are open to individual creativity, collective ingenuity, economic priorities, cultural values, institutional interests, stakeholder negotiation, and the exercise of power. It is thus important to reflect on how this shapes the organisation of radiation protection research and the formulation of its policies. The impact of research activities on the values and choices made by radiation protection researchers in their communities should be examined. This includes giving due consideration to societal and ethical implications of research agendas, processes, and outputs, in line with the European-wide calls for Responsible Research and Innovation. Specifically, integrative governance approaches need to be established to foster the integration of technical and social issues. Radiation protection research should support reflexive, inclusive, anticipatory and socially engaged attitudes among the science, technology and innovation communities in the radiation protection field, and should strive towards multi- and trans-disciplinary research approaches. This also includes developing innovative and inclusive research governance frameworks (e.g. different than usual consultative panels) enabling stakeholders, including civil society actors, to effectively interact with the research process (like it is currently developed in other fields of European research like radioactive waste management). In addition, there are important ethical questions, for instance, concerning the application of the optimisation and limitation principles of RP. What exactly is “reasonable” and “tolerable” (or “acceptable”)? What does “taking into account economic and societal factors” actually mean? These questions should receive priority as well.

This challenge is linked to ICRP priorities:

Ethical and social dimensions of the system of radiological protection
Mechanisms for interaction with stakeholders