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D 2.9 - Annual SRA Statements from MELODI, ALLIANCE, NERIS and EURADOS

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CONTENT

Abstract

D 2.9 - Annual SRA Statements from MELODI, ALLIANCE, NERIS and EURADOS

Annual SRA Statements from MELODI, ALLIANCE, NERIS and EURADOS have been compiled by collecting the SRA Statements from the platforms. This material serves as input for Joint Programming (WP3). While there will be no more RTD calls during the CONCERT project, there will be calls organized by Euratom and national funding bodies.

Each platform considered the same criteria for prioritization and provided a ranked list of priorities as summarized below. As in 2016, the criteria for prioritization were:

- Feasibility (research judged to be achievable in the near future)
- Importance in terms of improved radiation protection system
- Relevance for operational radiation protection (BSS implementation)
- Multidisciplinarity (biology, epidemiology, dosimetry)
- Synergy with other radiation research platforms (ALLIANCE, EURADOS, NERIS, EURAMED, European Medical Associations –ESR, ESTRO, EANM, EFRS, EFOMP)
- Timeliness
- Avoidance of overlap of topics with other calls or topics that have been recently funded and outcome from projects that have recently ended.

In 2017, the overall research priority for **MELODI** is

- to explore the shape of the dose-response relationship for radiation-induced health effects (cancer and non-cancer outcomes).

Other priorities for MELODI are:

- To understand the potential impact of individual susceptibility on radiation-induced health effects
- To identify, develop and validate biomarkers for radiation exposure, early and late radiation effects on risks of cancer and non-cancer diseases
- To understand the health effects related to inhomogeneous dose distributions, differences in radiation quality and internal emitters
- To explore and define the role of epigenetic modifications in radiation-induced health effects
- To explore the roles of specific target cells for radiation-induced late developing health effects

MELODI notes the relevance of the above priorities to the recently published 2017 ICRP research priorities (http://www.icrp.org/docs/ICRP%20Research%20Priorities%202017.pdf). MELODI encourages, where appropriate, (1) the use of archived biological materials from prior EU funded research, (2) the integration of experienced laboratory networks (such as e.g. RENEB), (3) the integration of expertise from outside the conventional fields of radiation research, in particular expertise from the medical research field where appropriate.

In 2017, the ranked list of research priorities by **ALLIANCE** are:

Two priorities with impact expected mainly in terms of reduced uncertainty in exposure and dose assessment and increased human and wildlife radiation protection:

- Environmental availability and impact of radionuclides in terrestrial, freshwater, estuarine, brackish and marine ecosystems (including human and non-human foodwebs) and their interactions with atmosphere, incorporating physical, chemical and/or biological processes. Validated process-based model with robust parameterisation, characterisation of variability and uncertainty, and guidance to obtain fit-for-purpose models which can satisfy the goals of fundamental research;
- Development of models/tools, and datasets for their calibration and validation and guidance to select and evaluate the effectiveness of different remediation strategies in long-lasting exposure situations (*e.g.*, nuclear accidents, NORM/TeNORM) ;

Two priorities with impact expected mainly in terms of reduced uncertainty in effect assessment and increased wildlife radiation protection:

- Biomarkers of exposure and effects in living organisms as operational outcomes of a mechanistic understanding of intra- and inter-species variation of radiosensitivity under chronic low dose exposure situations, with a focus on the added value for both human and non-human radiological protection;
- Multiple stressors and modulation of radiation effects in living organisms;

The ALLIANCE encourages, where relevant openness to other disciplines to integrate their skills and knowledge into radioecology, and capitalisation of best practices, tools and data in the various fields of research needed. Additionally, research combining “lab-field-modelling” approach and fit-for-purpose applications will be appreciated.

In 2017, the ranked list of priorities by NERIS are:

- **Assessment of and communication of uncertainties**. Investigation of data uncertainties (model or monitoring results) and how they can be communicated, e.g. in model results and in Decision Support Systems (DSS) to help decision-makers to understand the radiological situation. This includes also work on model sensitivity, validity of model results and inter-comparisons of models and measurements.
- **Robust decision-making.** Structuring the decision processes and the protective strategies at national, regional and local levels with the help of formal decision aid tools, such as multi-criteria analysis and based on feedback from stakeholder processes. Development of guidance on the use of DSS in the various phases of an event based on feedback from stakeholder processes and from Fukushima experience in emergency response and recovery.
- **Countermeasure strategy preparedness.** Development of sustainable preparedness strategy at Local, National and European levels based on the analysis of countermeasures for relevant accident scenarios. Ensuring that parameters governing the radiological consequences can be identified in time to enable optimized remediation.
- **Atmospheric dispersion modelling.** To make more reliable forecasts of atmospheric dispersion, including data assimilation and improved inverse modelling (to determine source term and/or source location) in different environments (e.g. urban areas) and/or at different spatial scales (near range to global scale)
- **Local radio-ecological models.** Development and integration in general DSS of local radio-ecological models interlinked with monitoring information and the more global and food chain dose models. Investigate the capability of such models to be operated by local stakeholders as farmers or local communities. Link with ALLIANCE.

- **Monitoring strategies.** Optimised use of monitoring resources, including mobile units and trans-border issues. Integration of new monitoring technologies (e.g. drones). Development of processes and tools for integrating the monitoring results from experts and lay people into a common operational picture (monitoring crowdsourcing). Information fusion (radiological and non-radiological). Link with EURADOS but focus on strategy and integration, less on the improvement or development of new measurement methods/techniques.

The current version of the EURADOS SRA includes five visions. Each of these visions includes a number of so-called challenges described in more details by the required research lines. A total of 18 challenges were ranked according to a survey among the EURADOS Voting Members and EURADOS Council Members. Based on this ranking and in cooperation with the other platforms, for the first CONCERT Call challenges 1 and 3 were chosen. For the second CONCERT Call challenges, 2 and 4 were chosen. At the present stage (July 2017) it is too early to judge whether and how the successful proposals of the first Call will contribute towards the identified challenges 1 and 3. Furthermore, it is currently not known which proposals of the second Call will be funded. It is obvious, however, that a combination of challenges 2, 5 and 6 will require a high priority in the future. These first 6 challenges are:

1. To quantify correlations between track structure and radiation damage
2. To improve neutron dosimetry techniques
3. To quantify doses after accidental internal contamination
4. To develop accurate and on-line personal dosimetry for workers
5. To improve out-of-field dosimetry for photon and particle therapy
6. To improve dosimetry in modern external beam radiotherapy

MELODI statement 2017

MELODI (Multidisciplinary European Low Dose Initiative) is a European Platform dedicated to low-dose ionizing radiation risk research. The purpose of the MELODI Association is to integrate national and European activities in low-dose and low-dose rate radiation research, to define priority scientific goals and to facilitate effective implementation of research. The Strategic Research Agenda (SRA) of MELODI identifies the priority goals and the specific resources, infrastructures and training capabilities needed to further develop low-dose risk research.

Prior to EU research funding calls, MELODI develops a short statement indicating its view on current research priorities, which serves as an input for defining call topics. The research priorities are identified from the MELODI SRA, which is gradually enriched by the contributions of its members, ongoing and completed research projects and the findings of the MELODI workshops organized annually since 2009. The current MELODI SRA, which forms the basis for the definition of the priorities can be downloaded from http://www.melodi-online.eu/sra.html.

In the 2015 statement, MELODI has identified six ranked research topics, which have been used as input for defining priorities for the first call in CONCERT - European Joint Programme for the Integration of Radiation Protection Research. In this statement, the highest ranked topic was “To investigate the shape of the dose response relationship for radiation-induced effects”. Assuming that this topic will be largely covered in the first CONCERT call, the MELODI statement of 2016 for the second CONCERT call included the same research topics; however, the previously highest ranked topic moved to the lowest priority for the second call.

With respect to the 2017 MELODI statement, the six previously defined research topics in 2015 and 2016 are still considered to be among the current research needs. Recent and ongoing research funded within OPERRA (Open Project for European Radiation Research Area) and CONCERT involved only small pilot projects (SOPRANO, EURALOC, DIMITRA, VIBRATO, LDLensRAD) related to the originally highest ranked MELODI topic “To explore the shape of the dose-response relationship for radiation-induced health effects”. The new EU project MEDIRAD has a specific focus on cardiovascular diseases from RT in breast cancer patients and cancer following CT among children, which constitute very specific exposure situations in specific populations. For this reason, the investigation of the shape of the dose-response relationship

for radiation-induced health effects is still a key research question and defined as overall priority for 2017, followed by an equal ranking of the other five topics.

Criteria for prioritization

- Feasibility (research judged to be achievable in the near future)
- Importance in terms of improved radiation protection system
- Relevance for operational radiation protection (BSS implementation)
- Multidisciplinarity (biology, epidemiology, dosimetry)
- Synergy with other radiation research platforms (ALLIANCE, EURADOS, NERIS, EURAMED, European Medical Associations –ESR, ESTRO, EANM, EFRS, EFOMP)
- Timeliness
- Avoidance of overlap of topics with other calls or topics that have been recently funded and outcome from projects that have recently ended.

List of priorities (for detailed description see Annex):

Overall priority: To explore the shape of the dose-response relationship for radiation-induced health effects (cancer and non-cancer outcomes).

Other priorities:

- To understand the potential impact of individual susceptibility on radiation-induced health effects
- To identify, develop and validate biomarkers for radiation exposure, early and late radiation effects on risks of cancer and non-cancer diseases
- To understand the health effects related to inhomogeneous dose distributions, differences in radiation quality and internal emitters
- To explore and define the role of epigenetic modifications in radiation-induced health effects
- To explore the roles of specific target cells for radiation-induced late developing health effects

> We note the relevance of the above priorities to the recently published 2017 ICRP research priorities (http://www.icrp.org/docs/ICRP%20Research%20Priorities%202017.pdf).

MELODI encourages, where appropriate, (1) the use of archived biological materials from prior EU funded research, (2) the integration of experienced laboratory networks (such as e.g. RENEB), (3) the integration of expertise from outside the conventional fields of radiation research.

ANNEX: Description of MELODI 2017 priorities

Priority title	**To explore the shape of the dose-response relationship for radiation-induced health effects**
Priority description	There are major uncertainties concerning the magnitude of cancer risk following (1) Protracted exposures in the order of 100 mSv or less, and (2) organ specific risks following acute or protracted doses of a few hundred millisievert, particularly for inhomogeneous exposures. Another major uncertainty is related to the magnitude of risk of non-cancer diseases at doses below about 500 mSv. Research is required to quantify the magnitude of cancer and non-cancer risk at low-doses and dose-rates. This can be achieved by mechanistic studies such as for example well-designed experimental animal studies and large (molecular) epidemiological studies with precise dosimetry, information on important confounders and possibly access to biological samples.
European relevance	Per definition, the priority is of top importance for **MELODI**. By the need of improved dosimetry for key epidemiological cohorts the priority is linked to **EURADOS**. The implications of improved risk estimates for emergency management link the priority to **NERIS**. The enhanced risk characterizations may link the priority to **ALLIANCE**. Improved knowledge of health risk will also be of importance for the optimization of ionizing radiation applications in medical diagnostics and therapy (**EURAMED**), and for the **BSS** implementation in the future, as evidence can be expected to be taken in to account in ICRP recommendations.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	This priority needs intensive collaboration of epidemiology, dosimetry, radiation biology, systems biology, experts of pathogenesis, mathematical modelling, statistics, radiation protection and emergency measurement. Expertise outside of the traditional fields of radiation research needs to be integrated. -MELODI (2016): p.9-14; chapter 3.1 and 3.2 -ALLIANCE (Sept 2013): p.6; Challenge 3; topic 3 -NERIS (April 2014): p.20, Topic 5.8 Health surveillance -EURADOS (May 2014): p.11-19; 3.2; p.35; 3.5.1 -EURAMED (Nov 2015): chapter 3.2.1, 3.2.2, 3.2.3
Impact: decreased uncertainty	The research will decrease uncertainty with respect to the shape of the dose-response-relationship for cancer and non-cancer diseases in the low dose range.
Impact: increased radiation protection	Improved health risk estimates together with an improved assessment of uncertainties will strengthen the robustness of present radiation protection system. This will especially be the case for i) regulating occupational exposures; ii) optimizing radiation therapy for patients with good prognosis (long time risks of diseases in relatively low exposed tissues); iii) deciding about appropriate diagnostic applications of radiation in medicine (especially for procedures leading to exposures of several tens of mSv in total; and iv) regulating emergency situations (involving reference levels from a few tens to 100 mSv).
Impact: increased quality and reliability	Experimental animal studies with well validated animal models and key informative large size cohorts, information on important confounders, and precise dosimetry will improve the quality and reliability of currently available risk estimates on the dose-response relationship.
Feasibility	The priority is feasible in terms of scientific and technological competences available in Europe. Key informative cohorts with the potential for access to biological samples and appropriate animal models for many endpoints are available.

Priority title	**To understand the *potential impact of individual susceptibility on radiation-induced health effects*.**
Priority description	Studies of carriers of BRCA1/2 mutations and studies of cancer patients have shown that single nucleotide polymorphisms (SNPs) in a number of genes can modify the radiation responses – either in the long term (risk of cancer) or in the short to medium term (adverse reaction to radiotherapy/interventional radiology procedures). Differences in sensitivity have also been observed in relation to gender, age at exposure, state of health, genetic and epigenetic make-up, lifestyle, and age attained. At present, there is insufficient information on the influence of individual radiation sensitivity on health risk estimates at low-doses/dose-rates. Research is required on the extent of variation of individual sensitivity in the population, on the factors contributing to this variation, as well as integration of mechanistic studies in the quantitative evaluation of health risk.
European relevance	Individual sensitivity is one of the three key policy questions in the **MELODI** SRA and one of the main research priorities in the HLEG. It is also important for **NERIS** in emergency response and surveillance after accidents – children, pregnant women and elderly/ill persons being priority groups for radiation protection in the case of an accident - ; for **ALLIANCE** in protection of non-human biota. Studies of radiation sensitivity obviously need adequate dosimetry, including biological dosimetry, and hence there is an important role for **EURADOS**. Individual sensitivity is extremely relevant for radiation protection of **patients** undergoing both diagnostic and therapeutic exposures, where the possibility of using other medical procedures (MRI for imaging, surgery/chemotherapy/hormone therapy/immune therapy for treatment) exist (EURAMED).
Multidisciplinarity; Reference to the strategic research agendas (SRA)	A multidisciplinary approach is needed to address this topic, including epidemiologists, biologists, clinicians, dosimetrists and modellers, as well as –for aspects related to response to radiation accidents – social scientists, ethicists and psychologists. -MELODI (2016): chapter 4.3 (Individual Radiation Sensitivity) -ALLIANCE (Sept 2013): p.26; Challenge 2, topics 1 & 2 -NERIS (April 2014): p.20; Topic 5.8, Health surveillance -EURADOS (May 2014): p.17; 3.2.2 and p.21; 3.3.1 -EURAMED (Nov 2015): chapter 3.2.1, 3.2.2, 3.2.3
Impact: decreased uncertainty	Individual differences in sensitivity raises ethical and policy question as to whether some individuals or groups are inadequately protected by the present system and regulations. Answers to this question are therefore urgently needed.
Impact: increased radiation protection	Identification of sensitive persons in the population can lead to better RP –in medicine (where approaches not involving IR can be used), in occupational settings as well as in the general population after, for example, accidents.
Impact: increased quality and reliability	Understanding the potential impact of individual susceptibility will contribute to a more realistic assessment of radiation health risks.
Feasibility	Scientific / technological competences needed for this topic are available in Europe. Different approaches can be considered, including (molecular) epidemiological studies of cancer patients or cohorts of genetically predisposed individuals, system modelling, studies of biomarkers, animal models.

Priority title	**To explore and define the role of epigenetic modifications in radiation-induced health effects**
Priority description	In recent years, biological research has identified a range of processes that can modify cellular, tissue and whole organism phenotypes that do not require DNA mutation. Collectively these are termed epigenetic effects and these include modified DNA methylation, microRNA expression and histone acetylation. While there are indications in the literature that radiation can affect epigenetic endpoints, there remains a lack of understanding of dose- and dose-rate responses, and the relationship of the changes to radiogenic disease, although epigenetic phenomena have been linked to cancers and transgenerational effects. Research is required to define radiation dose-/dose-rate responses for individual epigenetic endpoints, determine radiation quality dependence and the relationship of such changes to radiogenic cancers, non-cancer diseases and hereditary/transgenerational effects.
European relevance	The proposed research is relevant to (i) **MELODI** in that it requires consideration of low-dose/dose-rate response and relevance for radiogenic disease and may identify biomarkers of exposure or effect (ii) **ALLIANCE** in that it will explore the relevance to transgenerational effects and population health (iii) **EURADOS** in that it will require a high standard of radiation dosimetry for cell culture systems, model organisms and a range of radiation qualities (iv) **NERIS** in that it may identify biomarkers of exposure or effect (v) **medical** applications in that biomarkers may be identified and through mechanistic understanding of effects, novel radio-protectors may be identified (vi) **BSS** implementation in the future, as evidence taken in to account in ICRP recommendations.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	The research topic is of European and wider relevance in that it will help to determine the appropriate risk-benefit assessment for radiation use in all sectors; in this way, by informing the system of protection the research will ensure that the population and non-human biota are neither under nor over protected; and this ensures effective and efficient resource usage. -MELODI (2016): chapters 4.1.1, 4.1.2, 4.1.3, 4.3.1 -ALLIANCE (Sept 2013): p.6; Challenge2, topics 1 & 4 -NERIS (April 2014): p.20; Topic 5.8, Health surveillance -EURADOS (May 2014): p.17; 3.2.2 and p.21; 3.3.1 -EURAMED (Nov 2015): chapter 3.2.1, 3.2.2, 3.2.3
Impact: decreased uncertainty	The research will improve the scientific evidence base for judgements in radiation protection. It will address the question whether endpoints in addition to DNA mutation need to be considered in selection of risk extrapolation models for cancer, and if epigenetic effects are important for judgements on risk extrapolation for non-cancer diseases. Detailed dose-/dose-rate response information will be generated.
Impact: increased radiation protection	The proposed research will provide evidence to inform judgements on one of the most fundamental aspects of the system of protection, namely, which is the best model for risk extrapolation for cancer and non-cancer diseases. The research thus informs judgements on dose limits and emergency reference levels.
Impact: increased quality and reliability	The understanding gained from carrying out this research will provide supporting evidence for judgements on the model used for risk extrapolation for all health endpoints and thus increase the quality and reliability of health risk assessment.
Feasibility	The proposed research topic is feasible; many methods that can carry out high-throughput epigenetic analyses have been developed and there is a growing body of technical competence in Europe.

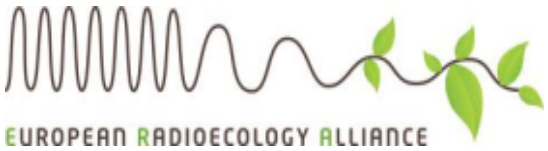
Priority title	**To identify, develop and validate biomarkers for exposure, early and late effects for cancer or/and non-cancer diseases**
Priority description	In recent years, the rapid development of technologies for "omics" research has opened up for a detailed biochemical analysis of cellular responses at each regulatory level in the cell machinery. Understanding interactions at the molecular levels and the use of new software's for pathway analysis have provided new insights in the mechanisms that regulate the cellular responses to different stressors. Identifying biomarkers for radiation-induced stress responses, as well as for early and late stages of diseases induced by radiation will provide a platform for a mechanistic understanding of the cellular responses to ionizing radiation.. If persistent biomarkers for exposure and radiation-induced diseases can be identified, the integration of them in epidemiological studies will have significant implications for risk estimates of low-dose/dose rate exposures. Research is required to define radiation dose/dose-rate responses for biomarkers of exposure, to determine their radiation quality dependence and the relationship of such changes to radiogenic cancers and non-cancer diseases.
European relevance	The proposed research is relevant to (i) **MELODI** in that it requires consideration of low-dose/dose-rate response and relevance for radiogenic diseases and may identify biomarkers of exposure or effect (ii) **ALLIANCE** in that biomarkers of exposure from the human model systems may be of relevance for the studies of other types of species and help to explore the relevance to transgenerational effects and population health (iii) **EURADOS** in that it will require a high standard of radiation dosimetry for cell culture systems, model organisms and a range of radiation qualities (iv) **NERIS** in that it may identify biomarkers of exposure or effect (v) **medical** applications in that biomarkers may be identified that can be used for diagnosis of individual sensitivity to radiotherapy/interventional radiology procedures and early detection of cancer and non-cancer diseases (vi) **BSS** implementation in the future, as evidence taken in to account in ICRP recommendations.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	The research topic is of European and wider relevance in that it will help to determine the appropriate risk-benefit assessment for radiation use in all sectors; in this way, by informing the system of protection the research will ensure that the population and non-human biota are neither under nor over protected; and this ensures effective and efficient resource usage. -MELODI (2016): Chapters 4.1, 4.2 and 4.3. -ALLIANCE (Sept 2013): p.6; Challenge2, topics 1 & 4 -NERIS (April 2014): p.20; Topic 5.8, Health surveillance -EURADOS (May 2014): p.17; 3.2.2 and 21; 3.3.1 -EURAMED (Nov 2015): chapter 3.2.1, 3.2.2, 3.2.3
Impact: decreased uncertainty	The research is expected to be of significance for the development of better risk estimates for other types of genotoxic stressors that are challenging the health of humans and other species. Biomarkers of exposure and diseases applied in epidemiology will significantly reduce the uncertainties of the present risk estimates in the low-dose/dose rate range as detailed dose-/dose-rate response information will be generated.
Impact: increased radiation protection	The proposed research will provide evidence to inform judgements on one of the most fundamental aspects of the system of protection, namely, which is the best model for risk extrapolation for cancer and non-cancer diseases. The research thus informs judgements on dose limits and emergency reference levels.

Impact: increased quality and reliability	The understanding gained from carrying out this research will provide supporting evidence for judgements on the model used for risk extrapolation for all health endpoints and thus increase the quality and reliability of health risk assessment
Feasibility	Many methods that can carry out high-throughput "omic" analyses have been developed and the bioinformatics needed for the transfer of these results into a mechanistic understanding is at hand.

Priority title	**To explore the roles of specific target cells for low-dose/low-dose rate radiation-induced late developing health effects**
Priority description	Currently, radiation risk extrapolation does not specifically include mechanistic considerations, but is more a statistical curve-fitting approach. To improve mechanistic understanding of radiogenic disease processes that can inform mechanistic approaches to cancer risk extrapolation several key pieces of information will be required. Most fundamentally, it is important to identify the cells at risk of conversion into the disease state, and enumerate these. For the case of cancer it is generally assumed that stem and early progenitor cell populations are relevant, but these are not generally well characterised, understood in their responses to low-dose/dose-rate radiation or enumerated. Research is required to clarify these aspects, and similarly to identify, enumerate and define radiation responses of target cell populations for other late-developing diseases such as circulatory diseases and lens opacities.
European relevance	The proposed research is relevant to (i) **MELODI** in that it requires consideration of target cells relevant for radiogenic diseases and low-dose/dose-rate response, providing important input for mechanistic models for risk extrapolation (ii) **EURADOS** in that it will require a high standard of radiation dosimetry for cell culture systems, model organisms and a range of radiation qualities (iii) **NERIS** in that in the longer term it will strengthen and improve risk estimation and thus exposure threshold for emergency action (iv) **BSS** implementation in the future, as evidence can be expected to be taken in to account in ICRP recommendations.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	The research topic is of European and wider relevance in that it will help to determine the best approaches to risk extrapolation for all late developing diseases; in this way , by informing the system of protection, the research will ensure that the exposed populations are neither under nor over protected, and this ensures effective and efficient resource usage. -MELODI (2016): chapters; 4.1.1, 4.2.1, 4.3.3 -ALLIANCE (Sept 2013): p.26; Challenge 2, 3.2.2.1 -NERIS (April 2014): p.18; Topic 5.1 -EURADOS (May 2014): p.17, 3.2.2
Impact: decreased uncertainty	The research will improve the scientific evidence base for judgements in radiation protection. It will address the issue of the improvement of risk extrapolation and strengthening the scientific evidence base for risk extrapolation.
Impact: increased radiation protection	The proposed research will provide evidence to inform judgements on a fundamental aspect of the system of protection, namely, which is the best approach for risk extrapolation for cancer and non-cancer diseases. The research thus in the long term informs judgements on dose limits and emergency reference levels.

Impact: increased quality and reliability	The understanding gained from carrying out this research will provide supporting evidence for judgements on the approach used for risk extrapolation for all health endpoints and thus increase quality and reliability of health risk assessment.
Feasibility	Many methods that can identify stem cells *in vivo* and *in vitro* have been developed, fundamental research in stem cell biology has developed an impressive range of methods for cell manipulation and imaging that can be utilised and there is a growing body of technical competence in Europe.

Priority title	**To understand the effects of inhomogenous dose distributions, radiation quality and internal emitters on health.**
Priority description	Many of the exposures to radiation encountered in the environment, occupationally and in medical settings can be to internal contamination, often to radiations of differing quality or involve other aspects of dose inhomogeneity. The current system of radiation protection makes use of radiation weighting factors to reflect spatial dose distribution differences between radiations of differing quality. The risk associated with all forms of dose inhomogeneity, internal contamination and radiation quality is not well understood. Research is required to determine the extent to which these radiation exposure characteristics modify dose-response relationships for health effects.
European relevance	The assessment of the impact of radiation exposure characteristics on the risk of cancer and non-cancer diseases is a priority of top importance for **MELODI**. Per definition there is clear link to EURADOS with respect to updated fundamental dose concepts and quantities and improved dosimetry for epidemiological studies. The implications of improved risk estimates for emergency management link the priority to **NERIS**. The enhanced risk characterizations may link the priority to **ALLIANCE**. Improved knowledge of health risk will also be of importance for the optimization of ionizing radiation applications in medical diagnostics and therapy (**EURAMED**), and for the **BSS** implementation in the future, as evidence can be expected to be taken in to account in ICRP recommendations.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	A multidisciplinary approach is needed to address this topic, including epidemiologists, biologists and dosimetrists. -MELODI (2016): 4.1.3, 4.2.3 and 4.3.3) -EURADOS (May 2014): Chapter 3.1, 3.2, 3.3.3 -EURAMED (Nov 2015): chapter 3.1
Impact: decreased uncertainty	The research will improve the risk assessment in case of dose inhomogeneity and internal contamination and provide an improved assessment of radiation weighting factors.
Impact: increased radiation protection	The research will improve the scientific evidence base for judgements in radiation protection.
Impact: increased quality and reliability	A better knowledge of the influence of these exposure characteristics on the risk estimation will lead to a higher quality and reliability of health risk assessment.
Feasibility	Research is feasible, because improved biokinetic and dosimetric models are available that can be used in epidemiological studies. Experimental studies in vivo or in vitro with different exposure scenarios where dose modulation plays a role can be conducted.



ALLIANCE Statement – June 2017

Short- to medium-term research priorities in radioecology to improve the scientific basis and reduce uncertainties in human and environmental risk assessments, increasing radiation protection of humans and wildlife

1. The ALLIANCE, the Strategic Research Agenda for Radioecology and the topical roadmaps

The European Radioecology ALLIANCE[1] (ALLIANCE) was founded in 2009 as a European structure capable of ensuring long-term governance of research in radioecology on the basis of the recommendation from FUTURAE[2], a 2006-2008 coordination action granted by the EC to produce an analysis of the state of radioecology in Europe. Since being officially registered in 2012 the ALLIANCE has progressively grown, going from the 8 founding members to 27 members, from 14 countries, in April 2017. The objectives of the ALLIANCE are to coordinate and promote research in radioecology. The ALLIANCE members recognise that their shared radioecological research can be strengthened by efficiently pooling resources among partner organisations and by prioritising group efforts along common themes. A major step in the prioritisation process was to develop a Strategic Research Agenda (SRA) for radioecology.

The Strategic Research Agenda[3] was initiated by the STAR[4] Network of Excellence and integrated in the research strategy implemented by the COMET[5] consortium, defines a long-term vision (20 years) of the needs for, and implementation of, research in radioecology. The SRA constitutes a reference document, initiated by researchers and consolidated through interactions with stakeholders. The SRA outlines three scientific challenges and fifteen associated research lines, as a strategic vision of what radioecology can achieve in the future *via* a prioritisation of efforts at the global scale. These challenges are: (1) to predict human and wildlife exposure in a robust way by quantifying key processes that influence radionuclide transfers and exposure; (2) to determine ecological consequences under realistic exposure situations; and (3) to improve

[1] www.er-alliance.eu/

[2] FUTURAE - A Future for Radioecology in Europe, 2002-2006, FP6 Euratom Fission, GA180506

[3] Strategic Research Agenda for Radioecology – An updated version with stakeholder input. Issued on 24/02/2014, 92 p. D-N°2.5. Contract Number: Fission-2010-3.5.1-269672. https://wiki.ceh.ac.uk/x/YoFsD.

[4] www.star-radioecology.org ; STAR - Strategic Network for Integrating Radioecology, 2011-2015, FP7 GA269672

[5] www.comet-radioecology.org ; COMET– Coordination and implementation of a pan-European instrument for radioecology, 2013-2017, FP7 Euratom Fission, GA604974

human and environmental protection by integrating radioecology. The SRA is being complemented by topical roadmaps[6] that have been initiated by the COMET EC-funded project, with the help and endorsement of the ALLIANCE. The strategy underlying roadmap development is driven by the need for improvement of mechanistic understanding across radioecology, one consequence of this being that we can provide fit-for-purpose human and environmental impact/risk assessments in support of the protection of man and the environment for the three exposure situations defined by the ICRP (*i.e.,* planned, existing and emergency). Topical roadmaps are building blocks that will be used to establish the ALLIANCE roadmap for radioecology at the end of 2017. Some of the research areas for radioecology are also relevant for post-emergency management and low-dose effect research and provide a powerful catalyst to further develop collaboration between the platforms of radiation protection (ALLIANCE, NERIS, MELODI, EURADOS and EURAMED[7]).

2. The progress of the radioecology science during the last 10 years; remaining gaps

The progress accomplished during the past decade mainly dealt with improvement of basic knowledge and tools to assess transfers of radioactive substances in the environment and subsequent human and environmental exposure. These improvements serve among others radiological risk estimation of humans and wildlife. Recent EC-funded projects (STAR, COMET) have developed improved and innovative models, moving from empirical models based on transfer factors and concentration ratios to more process-based, dynamic models for quantifying radionuclide transfers to humans and wildlife (*e.g.,* biokinetic, taxonomy-based models, models with regional parameterisation). They also delivered guidance for development and validation of fit-for-purpose models (*e.g.,* marine dynamic transfer models, human food chain models, soil-vegetation-atmosphere transfer models, forest models). The complex issue of the influence of multiple stressors in radiological risk assessment was also significantly advanced, especially in the context of NORM contaminated sites. Another step forward has been to advance the integration of human and environmental protection frameworks with the development of a combined screening model for both human and nonhuman biota (CROMERICA tool). However, progress is still needed to gain fundamental knowledge and the validated tools and methods one of the outcome being to perform realistic, integrated and graded impact and risk assessments for humans and wildlife, across all ecosystems and exposure scenarios.

Although significant advances have been made since the Chernobyl and Fukushima accidents in predictive modelling to improve exposure estimates, large uncertainties remain, highlighting the need to take into account more realistically key physical, chemical and biological processes in transfer and exposure models. The priority is to develop and validate process-based, dynamic

[6] The topical roadmaps consider the following areas: 1) atmospheric transfer processes, 2) marine radioecology, 3) human food-chain modelling, 4) environmental issues associated to Naturally-Occurring Radioactive Materials (NORM), 5) inter- and intra-species radiation sensitivity and transgenerational effects.

[7] MELODI: Multidisciplinary European Low Dose Initiative, http://www.melodi-online.eu; EURADOS: European Dosimetry Group, http://www.eurados.org; NERIS: European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery, http://www.eu-neris.net ; EURAMED – for medical applications – in progress - http://www.eibir.org/scientific-activities/joint-initiatives/european-alliance-for-medical-radiation-protection-research-euramed/ ; Social Sciences and Humanities in Ionising Radiation Research – platform under development

models that combine physical dispersion, biological and physico-chemical processes in an integrated approach. Improving the predictive capability of these integrated models by validation through comparison of predictions with observed data, alongside filling knowledge gaps on biogeochemical processes, is key to answer research questions on the global biogeochemical cycling of radionuclides in the environment and to reduce uncertainty in human and wildlife exposure estimates. How the fact that environmental transfers and subsequent exposure of humans and wildlife vary spatially and temporally (*e.g.,* with climate, soil type, human practices) is a key issue whatever the source term. Regarding post-accidental issues and communication with stakeholders, these ALLIANCE priorities are clearly shared with NERIS. These research needs largely relate to the radioecology SRA Challenge one (through model development and provision of data for parameterising and validating these models) and to SRA Challenge three (through the application of models in the integration of protection frameworks for humans and the environment for radionuclides and non-radioactive pollutants).

Biological effects of chronic exposure to ionising radiation are still a major concern for both human and environmental radiation protection. Recently, mechanistic models based on the stress-induced disturbance of metabolism in organisms exposed to ionising radiation have proved to provide insight on the causes of the effects observed and also represent tools towards more robust ecological protection benchmarks. COMET proved the relevance of using epigenetic markers in non-human species and started to delineate genetic *vs.* epigenetic causes of transgenerational effects of chronic exposure to ionising radiation. The exploration of omics responses of organisms exposed to ionising radiation have also been highlighted as a useful approach to unravel the basic mechanisms of the biological response to ionising radiation. This approach could be useful to help us understand how co-contaminants/stressors might influence the radiosensitivity of organisms. At present, the system of radiation protection needs more knowledge to be able to confidently address the wide biodiversity and also biological responses to ionising radiation especially in environmentally-relevant multiple stressors contexts. Exploration of intra- and inter-species causes of variation in radiosensitivity and of the mechanisms of multi- or trans-generational effects remains a priority topic to improve the basic knowledge and also to contribute to the validation of biomarkers as early warning tools. These needs, answering Challenge two of the radioecology SRA, are synergistic to those of MELODI research. The needs are challenging, as to meet them we need to establish processes that link radiation-induced effects from the molecular level to population, community or ecosystem levels, for a wide diversity of taxa and in the presence of co-stressors.

Finally, integrated and graded management approaches, and appropriate tools for their implementation over the spectrum of possible exposure scenarios, including scenarios of rehabilitation of impacted areas, are also drivers for radioecological research in the coming decades. This need is partially addressed by the two 3-year projects selected during the first call of CONCERT: (i) CONFIDENCE[8] largely shared with NERIS and EURADOS, which addresses some of the existing gaps in several areas of emergency management and long-term rehabilitation

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(*e.g.,* human food chain modelling; social, ethical and communication aspects related to uncertainties; combination of simulation and environmental monitoring). It concentrates on the early and transition phases of an emergency, but considers also longer-term decisions made during these phases; (ii) TERRITORIES[9] largely shared with NERIS and MELODI, that will produce novel guidance documents for medium to long-term dose assessment, risk management, and remediation for NORM sites on one hand and for radioactively contaminated sites as the consequence of a nuclear accident on the other hand, with harmonisation as far as possible of the consideration of uncertainties and stakeholder involvement in the decision making process

Even though very significant progress has been made during the last decade, with more expected through the ongoing projects from CONCERT first call (results from CONCERT second call unknown at the moment), research in radioecology needs additional resources and efforts since its drivers, such as policy changes, scientific advances and knowledge gaps, radiological risk perception by the public, and a growing awareness of interconnections between human and ecosystem health, require complex and multidisciplinary scientific questions to be answered.

3. Research priorities

On the basis of (i) our previous SRA statements (2015, 2016), (ii) discussions within the ALLIANCE SRA WG and with the topical roadmap leaders and their associated WGs, (iii) the advances from EC-funded projects as described in section 2, our priorities are kept unchanged as follows.

Two priorities with impact expected mainly in terms of reduced uncertainty in exposure and dose assessment and increased human and wildlife radiation protection:

- Environmental availability and impact of radionuclides in terrestrial, freshwater, estuarine, brackish and marine ecosystems (including human and non-human foodwebs) and their interactions with atmosphere, incorporating physical, chemical and/or biological processes. Validated process-based model with robust parameterisation, characterisation of variability and uncertainty, and guidance to obtain fit-for-purpose models which can satisfy the goals of fundamental research;
- Development of models/tools, and datasets for their calibration and validation and guidance to select and evaluate the effectiveness of different remediation strategies in long-lasting exposure situations (*e.g.*, nuclear accidents, NORM/TeNORM) ;

Two priorities with impact expected mainly in terms of reduced uncertainty in effect assessment and increased wildlife radiation protection:

- Biomarkers of exposure and effects in living organisms as operational outcomes of a mechanistic understanding of intra- and inter-species variation of radiosensitivity under

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chronic low dose exposure situations, with a focus on the added value for both human and non-human radiological protection;

- Multiple stressors and modulation of radiation effects in living organisms;

The 4 priorities were not ranked since the outcomes from the recently started projects (selected under CONCERT first call (CONFIDENCE, TERRITORIES)) and from CONCERT second call (decision expected during summer 2017) are not known at the present time. The ALLIANCE SRA/roadmap working group has planned a meeting in autumn 2017 to identify and prioritise new drivers and associated topics for research in radioecology by interacting with an external advisory stakeholder board.

Annex 1. Detailed description of the ALLIANCE research priorities.

Priority title	**Environmental availability and impact of radionuclides in terrestrial, freshwater, estuarine, brackish and marine ecosystems (including human and non-human foodwebs) and their interactions with atmosphere, incorporating physical, chemical and/or biological processes. Validated process-based model with robust parameterisation, characterisation of variability and uncertainty, and guidance to obtain fit-for-purpose models which can satisfy the goals of fundamental research**
Priority description	A key goal of radioecology is to understand at the fundamental level and to predict the transfers of radionuclides and consequent exposure of humans and wildlife. More specifically, this is needed for improved knowledge in a wide range of sources and release scenarios, exposure situations and assessment contexts in continental environments, including interactions at the level of the total environment (atmosphere, hydrosphere, lithosphere, biosphere, and anthroposphere). Although considerable advances have been made since the Chernobyl accident in predictive modelling, the Fukushima accident in Japan has highlighted the need of improved transfer and exposure models. The new models should represent the behaviour of the radionuclides in a more realistic way, ideally considering the different levels of organisation present in the environment. The key physical, chemical and biological processes that govern radionuclide transfers, and how transfers and exposure of humans and wildlife vary spatially, temporally and with the source term, should also be taken into account. Research should contribute at the fundamental level to an improved process-based understanding of radionuclide transport and transfers in various radioactively contaminated areas and eventually into the human food chain. Major physical and biogeochemical processes should be identified, conceptualised and mathematically translated into models (from empirical to mechanistic, depending on the requirement) taking into account spatial heterogeneity and temporal variability of the environment under study. One of the expected outcomes is to provide guidance for selecting the level of refinement for models according to the targeted uncertainty. Another is to obtain calibrated and validated models which are fit for purpose.
European relevance	This topic is highly relevant for European radioecology in view of substantial advances in improving process-based understanding of radioecology in Europe, which needs to be supported by adequate funding, allowing European scientists to be leaders in the field. This topic has synergies with MELODI, NERIS and EURADOS, since dose assessment is a key step in the radiological impact/risk characterisation.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	This topic is multidisciplinary because it connects radioecology, radiation protection, dosimetry, ecotoxicology, physics and biogeochemistry. The topic has links with European research platforms: -ALLIANCE (Sep 2013): p.14-22; Challenge 1; research lines: 3.1.2.1; 3.1.2.2.; 3.1.2.3; and 3.1.2.4; p.32, Challenge 3, research line 3.3.2.1. - NERIS (April 2014): p. 12: key topic 1.6; p. 13: key topic 2.1; p. 16: key topic 3.4; p. 18: key topic 5.1; p.23: cross cutting issues. -EURADOS (May 2014): p.6: vision 3 and 5.
Impact: decreased uncertainty	A deeper scientific understanding at the fundamental research level of the environmental processes involved in the transport and transfer of radionuclides will reduce uncertainties and hence robustly support decision making in various exposure situations. The knowledge gained will allow providing guidance for selecting the level of refinement for models according to the targeted uncertainty.
Impact: increased radiation protection	The topic will contribute to improve the radiation protection system, since it will allow to accurately predict exposure to humans and wildlife in planned, existing and emergency exposure situations, within continental and marine ecosystems that may interact between each other and with atmosphere.
Impact: increased quality and reliability	Uncertainties and lack of predictive power in risk assessments are major contributors to the public's reduced credibility of radiological sciences. Therefore, the acquisition of new scientific knowledge to reduce the uncertainties of the dose assessments, allowing more robust predictions and improved human and wildlife impact/risk assessments, will improve credibility with stakeholders.
Feasibility	There is a strong European radioecology research base with access to modelling, international databases, long-term collaborations with international organisations and first-class facilities.

Priority title	**Development of models/tools, and datasets for their calibration and validation and guidance to select and evaluate the effectiveness of different remediation strategies in long-lasting exposure situations (*e.g.*, nuclear accidents, NORM/TeNORM)**
Priority description	Management approaches in emergency and existing exposure situations can range widely in complexity. Although significant knowledge exists for a wide range of exposure situations, it tends to be fragmentary rather than forming an integrated strategy capable of dealing with complex, dynamically changing conditions. The need for integrated and graded management approaches and the appropriate tools to implement them over the entire spectrum of possible exposure scenarios, and thus ensuring that socio-economic facets are taken into account in the rehabilitation of the impacted areas, are primary drivers for radioecological research in the coming decades. The events at Fukushima after the NPP accident exemplify these problems and the existing deficiencies. There is a need for sound, fundamental and progressive science to yield maximum benefits from these efforts. Research is needed to guide the development/selection of models and assessment tools for medium to long-term predictions. There is a parallel need to generate and make available field data for their validation. Appropriate models (from empirical to process-based) should be developed to help compare radiological effects from various remediation measures, including those reducing radionuclide transfers into the food chain and/or those improving ecosystem services. For relevant radionuclides, models need to be applied to design remediation strategies to the major components of the ecosystems. Regarding more specifically post-accident exposure situations, the research to be done ought to complement the OPERRA-2014 HARMONE, CONFIDENCE and TERRITORIES (CONCERT 1st Call on going project), Regarding NORM/TeNORM sites research is needed to give answers to the specific requirements of the EURATOM Basic Safety Standards (BSS); this is only partially tackled in TERRITORIES.
European relevance	This topic has synergies with NERIS and EURADOS, in the establishment of priorities for pre-accident recovery preparedness, and expand beyond by dealing with medium- to long-term transfer processes and by tackling remediation issues. The topic is relevant to implement the requirements from the EURATOM BSS in relation to NORM/TeNORM. The priority is designed up-front to address specific BSS requirements for long-lasting exposure situations / remediation strategies in complement to TERRITORIES.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	Multidisciplinarity is assured through topical links between radioecology, radiation protection/dosimetry, ecotoxicology, physics and biogeochemistry. -ALLIANCE (Sept 2013): p. 30-37- challenge 3- research lines 3.3.2.1 to 3.3.2.6; p.14-22: challenge 1- research lines 3.1.2.1 to 3.1.2.4. -NERIS (Apr 2014): p. 12: key topic 1.6; p. 16: key topic 3.4; p. 19: key topic 5.7; p.23: cross cutting issues -EURADOS (May 2014): p.6: vision 3 and 5.
Impact: decreased uncertainty	Scarcity of data is one of the major sources of uncertainty. The databases developed will contribute to the reduction of uncertainties in the impact/risk characterization in long-term radiological assessments, making remediation strategies more credible and robust, and offering the possibilities of comparing a range of strategies. The use of calibrated and validated models will also contribute to reduce uncertainties.
Impact: increased radiation protection	The predictions obtained in the assessment models are often key constituents in decisions made about emergency response, waste management, environmental remediation, and mitigation. The availability of more accurate validated models will increase the confidence in the radiological impact/risk assessment process, and therefore will contribute to the improvement of the radiation protection system through robust evaluation of the best remediation strategies to minimise exposures to the public and the environment.
Impact: increased quality and reliability	The use of validated models will improve the predictive accuracy and precision of the radiological impact assessments, with a greater confidence in the results. Moreover, justification of nuclear industry activities is increased if robust remediation approaches exist and are well evaluated before things go wrong.
Feasibility	The expertise and technological resources needed exist and are well consolidated at the European level to make this research highly feasible.

Priority title	**Biomarkers of exposure and effects in living organisms, as operational outcomes of a mechanistic understanding of intra- and inter-species variation of radiosensitivity under chronic low dose exposure situations, with a focus on the added value for both human and non-human radiological protection**
Priority description	The issue of biological effects of low doses of ionising radiation is still of major concern for both human and environmental radiation protection, as highlighted after the Fukushima accident, especially with the aim of quantifying (and reducing if needed) the magnitude of risk to individuals (human and endangered species) and populations (human and biota) health at low doses/dose rates. We need urgently to complement the system of radiation protection to be able to face the wide biodiversity and biological responses to radiation (from molecules to ecosystems) in a credible and robust way. A key for success is to explore intra- and inter-species causes of radiosensitivity variation. This requires reliable quantification of radiosensitivity *in vitro* and ideally also *in vivo*. This will help to screen out candidates for biomarkers to be used as early warning tools after *ad hoc* validation. Research is required to contribute to the identification of the primary mechanisms of radiation induced effects at the molecular level and their propagation up to the individual level, including consequences for physiological functions (*e.g.*, reproduction). This will be evidenced by evaluating suitable biomarkers of exposure and biomarkers of effects. A comparative and "lab-field-modelling"-combined approach for a number of exposure conditions and/or a number of species will enhance the understanding of the toxicity profiles as a response to exposure conditions. Dose-response relationships will be established making the best use of "omics" analytical methods, possibly combined with the use of a system biology approach, to provide evidence of linkage between metabolic pathways and associated biomarkers of effects. Research could expand to the use of genetic and epigenetic changes as biomarkers by implementing innovative approaches to test changes in the genome (*e.g.*, mutation rates and types) and the epigenome (*e.g.* epigenetic tags) through generations.
European relevance	This topic, synergistic with MELODI, was highly scored in the OPERRA e-survey. It presents a high potential for multidisciplinarity beyond the radiological protection community since it highlights similarities that radioecology has with ecotoxicology, stress ecology and human radiation biology. The topic is indirectly relevant to NERIS in that biomarkers potentially also useful in health surveillance, are looked for. The research is also relevant to EURADOS as accurate dosimetry is a prerequisite for any robust dose-response relationships. Impact on risk communication is expected by providing answers to burning questions emerging from public perception of the consequences of the Fukushima and the Chernobyl accidents. Outcomes will support emerging policy in the field of radioprotection of the environment, mentioned in the EURATOM Basic Safety Standards.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	This topic will complement human and environmental radiation protection frameworks in a consistent way and will contribute to an improved and efficient integration of both protection frameworks. -MELODI (Aug 2015): p.12-17: chapter 4.2, 4.3. -ALLIANCE (Sept 2013): p.23-30: challenge 2 – research lines 3.2.2.1, 3.2.2.2; 3.2.2.4; p.33: challenge 3-research line 3.3.2.2. -NERIS (Apr 2014): p.18: key topic 5.1; p.20: key topic 5.8; p.23: cross cutting issues. -EURADOS (May 2014): p.7-13: vision 1 topics 1, 2, 3; p.22-25: vision 3 topic 1
Impact: decreased uncertainty	This research should provide the basis for the development of biologically-based extrapolation models which are the key to tackle the wide species diversity and would be useful for risk assessors by helping reducing uncertainty in predictions of effects (and ultimately risk).
Impact: increased radiation protection	Identification of such biomarkers will be relevant to humans or non-human species radiation protection. Acquired knowledge will highlight and feed the various extrapolations needed when assessing radiological risk to humans or non-human species, and will provide robustness in effects predictions and decision making.
Impact: increased quality and reliability	By encouraging openness to other disciplines and innovative hypothesis-driven approach to understand underlying mechanisms, this research topic will contribute to increasing acceptability of the radiation protection system and aid in risk prediction, management and communication.
Feasibility	A wide range of methods and approaches exists to make this research highly feasible, along with effect database (*e.g.*, FREDERICA).

Priority title	**Multiple stressors and modulation of radiation effects in living organisms**
Priority description	Exposure to multiple stressors may directly or indirectly modulate radiation effects in living organisms. Even though studying a contaminant in isolation is necessary to understand the underlying mechanisms resulting in the observed effects, this does not allow to predict potential interactions among the many stressors to which organisms are actually exposed and the resulting effects. Interactions can reduce overall damage or augment single stressor effects. Hence, the presence of co-stressors may alter the level at which organisms are likely to show radiation effects. From a risk point of view, knowing how co-contaminants/stressors might influence the radiosensitivity of organisms is therefore a pressing need. Research is required to contribute to the mechanistic understanding of how radiation effects in living organisms are modulated in the context of multiple stressors. Emphasis is on environmentally relevant combinations of stressors that interact such that synergistic effects are likely to occur with exposure to radiation or radionuclides. The occurrence of synergisms will have to be investigated at realistic radiation levels and realistic concentrations/conditions of other stressors. Given the multitude of potential stressors and combinations that exists in real exposure conditions, the approach to prioritise hypotheses, select stressor combinations and conditions is quintessential. Projects should be directed to the mechanistic understanding of the site where interactions occur: at the level of exposure, where interactions can take place in various processes (*e.g,*. uptake, internal distribution of the radionuclides), or at the level of effect (where interactions could be observed at the primary site(s) of disturbance or in regulation and signal transduction of the response of the organism following exposure). Dynamic and biology-based methods and approaches (*e.g.*, DEBtox, gene expression pathways) could contribute to mechanistic understanding. Multiple stressor research will benefit from field based studies and the evaluation of the results in a risk assessment context. The question of the robustness of screening values in a multiple stressor context should be considered.
European relevance	This multidisciplinary complex topic can build on the achievements of the STAR Network of Excellence and was selected as a high importance synergistic topic by ALLIANCE, MELODI and EURADOS. The research on this topic will help reduce uncertainties by taking into account environmentally relevant exposure conditions. The research is relevant to EURADOS as accurate dosimetry is a prerequisite for any robust dose-response relationships. Impact in communication to the public is expected by improving the capability of demonstrating the impact of ionising radiation in comparison to other environmental stressors.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	This topic will support chemical and radiological environmental protection frameworks in a consistent way and will improve consistency for any environmental impact assessment. This research is highly multidisciplinary in nature and will benefit from interacting with ecotoxicology and biochemistry. -MELODI (Aug 2015): p.17: synergistic topic 1. -ALLIANCE (Sept 2013): p.27: challenge 2 – research line 3.2.2.3; p.34: challenge 3-research line 3.3.2.3. -NERIS (Apr 2014): p. 16: key topic 3.6; p.23: cross cutting issues.-EURADOS (May 2014):): p.7-13: vision 1 topics 1, 2, 3; p.22-25: vision 3 topic 1
Impact: decreased uncertainty	This research will complete the scientific foundation for fully integrating environmental and human protection frameworks under one generalised system (*i.e*. consistent between radiation and chemicals on one hand and human and environment on the other hand), which would be of much interest to regulators, industry and the public.
Impact: increased radiation protection	This research will demonstrate if radiation protection standards are robust and protective enough. Will provide robustness to any risk assessment, associated decisions and communication.
Impact: increased quality and reliability	Gaining knowledge on low dose effects under realistic exposure conditions and explaining clearly important and relevant results obtained to the public are needed to give people the power of informed choice and of making decisions knowing the level of risks associated to their living conditions for them and the future generations. Being able to clearly demonstrate the role of ionising radiation in comparison to any other environmental stressor is a must for being successful.
Feasibility	This research needs to implement an innovative approach and as such, is risky.

Annex 2. Overview of recently finished and started EU projects in research areas closely related to the ALLIANCE SRA.

COMET project (Coordination and iMplementation of a pan-European instrument for radioecology)

The EC FP7 COMET was funded to strengthen the pan-European research initiative on the radiological impact on man and the environment by facilitating the integration of the Research and Development activities in radioecology. COMET contributed to the realisation of the ambitions of the European Radioecology ALLIANCE by working on joint programming and implementation, building upon the foundations laid in this respect by the FP7 STAR NoE and the European Radioecological ALLIANCE (ALLIANCE).

An important research contribution within COMET was improving models for risk assessment and for emergency and post-accident situations. This focused on improving parametrisation of key processes controlling the transfer of radionuclides, with a specific emphasis on dynamic and mechanistic modelling approaches. The research was initially conducted within topical working groups on marine transfer modelling, forest radioecology, human food chain, NORM, wildlife transfer modelling and on particle behaviour. After an open call under the umbrella of OPERRA, these groups were complemented by two projects, FRAME (The impact of recent releases from the Fukushima nucleaR Accident on the Marine Environment) and RATE (RAdioactive particle Transformation procEsses), in which additional investigations on the mechanisms for radionuclide transfer in the Fukushima marine environment and on particle behaviour, respectively, further reduced the uncertainties associated with key transfer processes.

COMET dealt also with epigenetic changes and their possible role in adaptation and transgenerational effects by increasing understanding of the effects of chronic low-dose radiation and the possible contribution of epigenetic mechanisms to long-term and trans/multi-generational effects. It performed laboratory controlled exposure experiments to test hypotheses on the role of epigenetic changes in the alteration of physiological functions on laboratory models and field studies on autochthonous species to investigate epigenetic changes in wildlife within contaminated areas. Lastly, COMET promoted the exchange of knowledge and expertise by disseminating COMET activities, facilitating discussion of topical radioecological issues between researchers and users and developing training packages to maintain and enhance professional competence.

OPERRA-project HARMONE (Harmonising Modelling Strategies of European Decision Support Systems for Nuclear Emergencies)

The HARMONE project started December 1, 2015 and aims to reduce scientific, methodological and operational gaps identified in the strategic research agendas of the four European Platforms in the area of radiation protection and issued as TOPIC 2 of the OPERRA-2014 Call: “Spatial and temporal environmental modelling and human dose assessment after a nuclear accident”. This includes the following work activities

- Development of a knowledge data base and guidance that allows, according to the first event description, to propose a first management strategy to reduce doses and highlights potential issues for the dose assessment.
- Refinement of simulation models for all exposure pathways to obtain a better assessment of the total dose. This would include also a methodology for the regionalisation of the model to have assessments on all relevant scales.
- Development of guidelines for dose monitoring to back-up the first two steps and facilitate the refinement of the simulations.

In this respect, the HARMONE project addresses the following areas and topics of the NERIS SRA and the ALLIANCE SRA

- Aquatic modelling (NERIS key topic 2; ALLIANCE Challenge 1)
  - Test of runoff models and identify gaps therein
- Improvement of existing Decision Support Systems (NERIS key topic 3; ALLIANCE Challenge 3)
  - Support the customisation of the food chain and dose models to European conditions
  - Refinement of simulation models, e.g. introduce snow in the ADM, snow melting in ERMIN
- Data mining, information gathering and providing information to stakeholders and mass media (NERIS key topic 4; ; ALLIANCE Challenge 3)
  - Knowledge data base for the later phase scenarios
- Improving the decision making process (NERIS key topic 5; ; ALLIANCE Challenge 3)
  - Development of generic guidance on countermeasure strategies
  - Some ideas on monitoring strategies for model support

HARMONE is limited in resources and therefore will not result in new developments but more in the refinement of existing ones.

CONCERT CALL 1 - CONFIDENCE COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs

The H2020 CONFIDENCE Project aims to address existing gaps in several areas of emergency management and long-term rehabilitation. It concentrates on the early and transition phases of an emergency, but considers also longer-term decisions made during these phases. The work-programme of CONFIDENCE aims to understand and if possible with the given resources to reduce and cope with the uncertainty of meteorological and radiological data and their further propagation in decision support systems, including atmospheric dispersion, dose estimation, foodchain modelling and countermeasure simulations models. Consideration of social, ethical and communication aspects related to uncertainties is also considered. First attempts will be made to combine simulation with monitoring to help gaining a more comprehensive picture of the radiological situation. Decision making principles and methods will be investigated to understand the need for uncertainty handling in the decision making process. A comprehensive education and training programme is linked with the research activities.

CONFIDENCE is partially dealing with the two priorities from ALLIANCE :

-Environmental availability and impact of radionuclides in terrestrial, freshwater, estuarine, brackish and marine ecosystems (including human and non-human foodwebs) and their interactions with atmosphere, incorporating physical, chemical and/or biological processes. Validated process-based model with robust parameterisation, characterisation of variability and uncertainty, and guidance to obtain fit-for-purpose models which can satisfy the goals of fundamental research.

-Development of models/tools, and datasets for their calibration and validation and guidance to select and evaluate the effectiveness of different remediation strategies in long-lasting exposure situations (e.g. nuclear accidents, NORM/TeNORM).

CONCERT CALL 1 - TERRITORIES To Enhance unceRtainties Reduction and stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife In long-lasting radiological Exposure Situations

The TERRITORIES project targets an integrated and graded management of contaminated territories characterised by long-lasting environmental radioactivity, filling in the needs emerged after the recent post-Fukushima experience and the publication of International and European Basic Safety Standards. A graded approach, for assessing doses to humans and wildlife and managing long-lasting exposure situations (where radiation protection is mainly managed as existing situations) is being developed through reducing uncertainties to a level that can be considered fit-for-purpose. The overall outcome will be a first attempt to provide an umbrella framework, that will constitute the basis to produce, and disseminate, novel guidance documents for dose assessment, risk management, and remediation of NORM and radioactively contaminated sites as the consequence of an accident, with due consideration of uncertainties and stakeholder involvement in the decision making process.

TERRITORIES is partially dealing with the two priorities from ALLIANCE

-Environmental availability and impact of radionuclides in terrestrial, freshwater, estuarine, brackish and marine ecosystems (including human and non-human foodwebs) and their interactions with atmosphere, incorporating physical, chemical and/or biological processes. Validated process-based model with robust parameterisation, characterisation of variability and uncertainty, and guidance to obtain fit-for-purpose models which can satisfy the goals of fundamental research.

-Development of models/tools, and datasets for their calibration and validation and guidance to select and evaluate the effectiveness of different remediation strategies in long-lasting exposure situations (e.g. nuclear accidents, NORM/TeNORM).

NERIS statement – May 2017

NERIS is a European platform on preparedness for nuclear and radiological emergency response and recovery, founded in June 2010. 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. 57 institutions are currently members of the NERIS platform from which 26 are supporting organisations.

An integral part of the mission of NERIS is to identify gaps and needs for further research and developments and addressing new and emerging challenges in the field of preparedness for nuclear or radiological emergency response and recovery. The Strategic Research Agenda (SRA) of NERIS, coordinated by the NERIS R&D Committee, identifies these research needs.

In its statement of August 2015, NERIS has identified research priorities which have been used in 2016 as input for defining topics for the second call in CONCERT. The identified research priorities defined in the NERIS SRA statement so far are still considered to be current needs and are repeated in this statement. However, it is also briefly discussed which of the priorities were at least partly tackled in ongoing research.

Research and development in the field of emergency management and recovery at the European level calls for co-operation between authorities, emergency centres, research organisations and the academic community in different countries, as well as interactions with key concerned stakeholders with the goal to enhance adequate and coherent response throughout Europe in case of a nuclear and or a radiological event. To reach this goal, apart from advances in the development of models, research improving the decision-making processes is crucial (NERIS SRA key topic 5). Four out of the six priority subjects proposed here fall within this key topic and include uncertainty handling in emergency response and recovery, robust decision making, countermeasure preparedness strategy and monitoring strategies. This research requires a highly multidisciplinary approach and should include societal and ethical aspects. The identified priority research needs related to advances in modelling are in the domain of atmospheric dispersion modelling and local radio-ecological modelling. Based on the exchange of ideas with other radiation protection platforms (MELODI, ALLIANCE, EURADOS) a link with potential common research priorities was identified.

Within research projects CONFIDENCE and TERRITORIES, funded through CONCERT project, some of the research priorities were considered. However, one has clearly to state that these two projects are a first step in exploring the further research needs and they may end up with a preliminary attempt to propose solutions. CONFIDENCE addresses parts of priority 1 and 2 with uncertainty handling and robust decision making. TERRITORIES focuses on the long-term

management of contaminated territories aiming to explore uncertainty management and stakeholder engagement in such a long lasting situation.

Similarly, other projects listed in Annex 2 have addressed particular research questions of NERIS. However, these topics are wide and the small research projects of the recent years could only answer particular facets of the whole research topic.

It has also to be noticed, that in the frame of developing the NERIS roadmap, the NERIS community felt that there is a need to update the SRA rephrasing some research topics in light of the societal challenges identified. This process started with a meeting of the R&D Committee with the NERIS Board members at the European Radiation Protection Week meeting in Oxford in October 2016, continued with a R&D Committee meeting in Brussels, in January 2017 and the meeting of all NERIS members in Lisbon at the General Assembly and NERIS Workshop in May 2017. The process was also framed with a meeting together with representatives of the emerging Social Science and Humanities platform in Brussels in October 2016. The update of the SRA will rephrase the three main challenges and the 10 key topics and a final version of the new SRA is expected by end of this year connected with the NERIS roadmap. However, this refinement does not affect the current ranking of the research priorities identified so far.

A short description of the current ranked research priorities identified by NERIS are given below. A more detailed description can be found in annex 1. In annex 2 also a short summary is given of the main European research projects finished and started in the past year in areas closely related to the NERIS SRA

1. **Assessment of and communication of uncertainties**. Investigation of data uncertainties (model or monitoring results) and how they can be communicated, e.g. in model results and in Decision Support Systems (DSS) to help decision-makers to understand the radiological situation. This includes also work on model sensitivity, validity of model results and inter-comparisons of models and measurements.
2. **Robust decision-making.** Structuring the decision processes and the protective strategies at national, regional and local levels with the help of formal decision aid tools, such as multi-criteria analysis and on the basis of feedback from stakeholder processes. Development of guidance on the use of DSS in the various phases of an event based on feedback from stakeholder processes and from Fukushima experience in emergency response and recovery.
3. **Countermeasure strategy preparedness.** Development of sustainable preparedness strategy at Local, National and European levels based on the analysis of countermeasures for relevant accident scenarios. Ensuring that parameters governing the radiological consequences can be identified in time to enable optimized remediation.
4. **Atmospheric dispersion modelling.** To make more reliable forecasts of atmospheric dispersion, including data assimilation and improved inverse modelling (to determine source term and/or source location) in different environments (e.g. urban areas) and/or at different spatial scales (near range to global scale)

5. **Local radio-ecological models.** Development and integration in general DSS of local radio-ecological models interlinked with monitoring information and the more global and food chain dose models. Investigate the capability of such models to be operated by local stakeholders as farmers or local communities. Link with ALLIANCE.
6. **Monitoring strategies.** Optimised use of monitoring resources, including mobile units and trans-border issues. Integration of new monitoring technologies (e.g. drones). Development of processes and tools for integrating the monitoring results from experts and lay people into a common operational picture (monitoring crowdsourcing). Information fusion (radiological and non-radiological). Link with EURADOS but focus on strategy and integration, less on the improvement or development of new measurement methods/techniques.

Annex 1. Detailed description of the NERIS research priorities.

Priority 1	**Assessment of and communication on uncertainties**
Priority description	Important advances have been made in the last decades in the development of models and monitoring methods for evaluating the impact of nuclear/radiological events or to assist in the recovery phase after such an accident. Examples are the validation of food chain and hydrological models, validation of the RODOS model for the Hanford scenario, use of models & monitoring methods in the aftermath of the Fukushima accident. However, uncertainty in these assessments has never been addressed in detail. Both, uncertainty arising from limited information, especially in the early phase of an accident, as well as inherent model or monitoring uncertainties have to be addressed. The research needs identified are: The investigation of data uncertainties on model or monitoring results and how to propagate uncertainty through simulation models; How to communicate uncertainty to decision-makers. Key research questions are: Identify the need of decision makers: how to include uncertain information from simulation and modelling in their decision making process; Define the level of uncertainty for the key simulation areas of a DSS; How to include/visualise uncertainty in the results of simulations & measurements and how to propagate them between simulations (e.g. source term – dispersion – dose assessment)? Is there a methodology for uncertainty handling and sensitivity analysis applicable for all? How to communicate uncertainty – legal, social and ethical aspects.
European relevance	The topic is part of the NERIS Strategic Research Agenda (Key Topic 5, sub-topic 5.1). Especially in European context, in which accidents have a high probability to have cross border consequences, having better insight in the uncertainty of evaluations based on models or monitoring and how to communicate and visualize these uncertainties is of key importance to come to common European decisions on protective actions and for the harmonization of intervention levels across Europe.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	Uncertainty handling is crucial in all aspects of radiation protection and of importance in several disciplines: apart from assessments in nuclear emergency response and recovery it is of importance e.g. in radio-ecological modelling (ALLIANCE), dosimetry (EURADOS) and studying dose-effect relationships (MELODI).
Impact: decreased uncertainty	Better understanding and quantification of the sources of uncertainty will result in efforts to reduce the main sources of uncertainty
Impact: increased radiation protection	Taking into account the uncertainty of model calculations and monitoring results makes it possible to take better scientifically sound decisions.
Impact: increased acceptability	One of the main challenges of communication of uncertainties is to improve the decision making processes (DMP).
Feasibility	The propagation of the uncertainty between simulations is a scientific challenge. However, model developers are the key scientists to address this topic.
Other justifications	The topic has a high scientific relevance because by identification of the uncertainties new research priorities will be identified. In addition, it has a very societal relevance by addressing uncertainties to improve DMP and favour the communication with the public.

Priority 2	**Robust decision-making**
Priority description	Further developments in decision-making are currently required to clearly address i) the structure of the different levels of decision making and the needs of different tools and ii) how to make best use of existing Decision Support Systems (DSS). The work proposed entails: Structuring the decision processes and the protective strategies at national, regional and local levels with the help of formal decision aiding tools, such as multi-criteria analysis and on the basis of feedback from stakeholder processes. Development of guidance on the use of DSS in the various phases of an event based on feedback from stakeholder processes and from Fukushima experience in emergency response and recovery. The work proposed will investigate: how are DSS used today and if this complies with their existing structure and robustness; the potential added value of using formal decision aiding tools in the decision making process; the adequacy of decision support tools at different levels of decision making, including all possible stakeholder groups; stakeholder involvement in the preparedness phase: the use of predefined strategies in emergency and recovery management and inclusion of social resources (crowd sourcing, stakeholder participation,…) in the Decision Making Processes (DMP).
European relevance	The topic is part of the NERIS Strategic Research Agenda (Key Topic 5, sub-topic 5.3). Moreover, the work proposed will help in evaluating whether pre-defined protective strategies are sufficient to manage the early phase of an emergency and if yes, how to define and use them in an emergency. It is thus relevant to the implementation of the BSS, namely recommendations regarding emergency planning and recovery strategies. Finally, the work is grounded on strong stakeholder involvement and will entail establishing legal, social and ethical guidelines; it will thus require input from social sciences and humanities and contribution from stakeholder engagement processes in Europe.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	The topic is highly relevant at European level, since it will lead to the identification of criteria for the “optimal” use of European DSS and the development of additional guidance material to support their usage. The topic is related to the priorities described in the SRA of European platforms: - NERIS: Key Topic 5, sub-topic 5.3 -ALLIANCE: Challenge 3
Impact: decreased uncertainty	By helping to develop appropriate tools to support the decision making process at the various levels, the topic will contribute to decreased uncertainty concerning the efficiency of the protection and thus to the health effects for people in emergency and recovery situations.
Impact: increased radiation protection	By contributing to an improved decision making process on protective actions in case of a nuclear or radiological accident, it will contribute to better protection of workers, people living in affected area and the general public in emergency and recovery situations.
Impact: increased acceptability	A better structured and more efficient decision-making process will bring increased transparency and grounds for justification of protective actions in case of an emergency and recovery situations. It will thus also contribute to increased social participation in the DMP and thus improve efficiency of protection and favour reassurance.

Feasibility	The scientific/technological competences needed for this topic are available in Europe.
Other justifications	The topic has a high societal relevance since it aims at a better protection of the population in case of a nuclear or radiological situation.
Priority 3	**Countermeasure strategy preparedness**
Priority description	Several European projects in past Framework Programmes have addressed the multiple dimensions (radiological effectiveness, technical feasibility, stakeholder involvement, economic impact, legal issues, etc.) of management options for agricultural and urban areas in the aftermath of a nuclear accident (FARMING, SAGE, EURANOS, NERIS TP, PREPARE . The accident in Fukushima highlighted however, the need for further work in the area of emergency and recovery preparedness and response as regards the development of countermeasure and recovery strategies, by: Drawing the lessons on the applicability, efficiency and sustainability of countermeasures strategies from the emergency and recovery responses following the Fukushima accident Improving the adequacy of existing decision making processes and tools at national/regional/local levels to favour the preparedness of efficient countermeasure strategies Achieving sustainable engagement of local stakeholders in emergency and recovery preparedness and response The work proposed under this topic entails: The development of sustainable preparedness strategy at Local, National and European levels, based on the analysis of countermeasures for relevant accident scenarios and recovery strategies. Ensuring that parameters governing the radiological consequences can be identified in time to enable optimized remediation. Ensuring that countermeasures preserve territorial resilience
European relevance	The topic is part of the NERIS Strategic Research Agenda (Key Topic 5, sub-topic 5.7). Inputs from social sciences and humanities are required concerning the social and ethical dimensions of countermeasure strategies.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	The accidents in Chernobyl and Fukushima demonstrated that consequences of nuclear accidents exceed by far national boundaries and could last over several decades. The topic proposed will contribute to improved preparedness and response to nuclear and radiological emergency and recovery situations. It is highly relevant at European level, since it entails the development of sustainable preparedness strategies at both local and European level. It is also essential to draw the lessons from the long term management of the consequences of the Fukushima accident. The topic is related to the priorities described in the SRA of European platforms: NERIS: Key Topic 5, sub-topic 5.7 & ALLIANCE: Challenge 1
Impact: decreased uncertainty	Optimized remediation contributes to decreasing uncertainty concerning the effects on people and the environment in emergency and recovery situations and to improve the stakeholder engagement in the strategies.
Impact: increased radiation protection	By developing sustainable countermeasure and recovery strategies and that ensuring that parameters governing the radiological consequences are

	identified in time to enable optimized remediation, the topic contributes to increased protection of the population in emergency and recovery situations.
Impact: increased acceptability	Stakeholder involvement at different levels of preparedness and response will reinforce the efficiency of decisions taken in case of an emergency and recovery situations and will lead to increased acceptability of countermeasures strategies. It will also increase the capability of resilience in case of an accident.
Feasibility	The scientific / technological competences needed for this topic are available in Europe.
Other justifications	The topic has a high societal relevance since it aims at a better protection of the population in case of a nuclear or radiological situation. It will also allow drawing on the lessons from the management of the consequences of the Fukushima accident.
Priority 4	Atmospheric dispersion modelling
Priority description	Atmospheric dispersion models are the key tools to study the impact of atmospheric releases of radioactive material to humans and the environment. Although a long history exists in the development of atmospheric dispersion models and recent improvements such as worldwide applicability of the JRODOS system (FP7 project NERIS-TP), the use of higher spatial and temporal resolution meteorological data (FP7 project PREPARE) and source term estimation based on monitoring has been achieved, several improvements are still required. Important steps can still be made to improve reliable forecasts of atmospheric dispersion, including data assimilation and inverse modelling to determine source term and/or source location. Especially in specific environments e.g. urban areas and specific ranges (e.g. the near-range) room for improvement is possible. Specifically highly interesting research questions are: Model improvements responding to the needs of decision makers in specific areas: e.g., near-range, urban areas, confined spaces Inverse modelling and data assimilation techniques related to dispersion modelling from near-range to global scales Multi-scale modelling: how to integrate model calculations from local to global scale to allow coordinated use of ADM Better understanding of the complex interplay between time-varying release characteristics and meteorological conditions (E.g. use of ensembles, impact of precipitation, …) Statistical analysis and graphical representation of multiple model simulations (using different source terms and meteorological analyses), including use of below-threshold data (null measurements) Model validation, robust uncertainty handling and visualization in ADM
European relevance	The topic is part of the NERIS Strategic Research Agenda (Key Topic 1). Improved and validated modelling tools will help harmonization of emergency countermeasures across Europe.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	Atmospheric dispersion modelling is of particular interest, apart from assessing the impact of emergency exposures, in the impact analysis of routine emissions in planned exposures (planned exposure situations, …).
Impact: decreased uncertainty	Improved and validated models will reduce the uncertainty in the output generated by the models and in all further assessments of the radiological evaluation and improve advice to the decision makers.

Impact: increased radiation protection	Improved and validated models for different ranges and environments will contribute to better protection strategies and increase in this way radiation protection.
Impact: increased acceptability	More confidence in model calculations will result in more confidence in protection strategies and increase the acceptability of advised countermeasures.
Feasibility	Atmospheric dispersion modelling is a key research theme within the emergency and NERIS community for many years. Improvements are linked to the access to better meteorological data, increasing computer power and the continuous development of dispersion and transport methodologies (e.g. Computational Fluid Dynamics)
Other justifications	The continuous improvements in meteorological forecasts and calculation methods allow the improvement of dispersion models for specific ranges and environments. Also very specific situations require new , more advanced modelling techniques.

Priority 5	Local radio-ecological models
Priority description	Past and on-going European projects (FUTURAE, EURANOS, NERIS TP, COMET, PREPARE) have contributed to the development and integration in Decision Support Systems (DSS) of models for the estimation of the radiological spatial-temporal situation in different environments (terrestrial and aquatic) and the impact on the population. Such models have been applied for remediation purposes in both emergency and recovery situations. Furthermore, generic regionalisation has been done for different European climatic regions of the radiological parameters and other socio-economic factors. However, there is a need to: ▪ Develop / adapt the radioecological models used in DSS for the preparedness and management of the emergency and recovery to the complex local specificity. ▪ Apply the radioecological models to establish feasible and efficient site-specific remediation and monitoring strategies. ▪ Improve the operability and the understanding of the dose assessment and countermeasures models by potential users, including non-expert stakeholders The work proposed under this topic entails: • Development and integration in general DSS of local radio-ecological models interlinked with monitoring information and more global and food chain dose models. • Estimation of the efficiency and spatial-temporal evolution of the protective /remediation actions in relation to site-specific characteristics • Investigation of the capability of locally customised models to be operated by local stakeholders such as farmers or local communities especially for the recovery situation. • Identification/classification of vulnerable areas in European environments with the implication on stakeholders
European relevance	The topic is highly relevant at European level since it involves further developments of European DSS, such that they can be used at local level in order to allow enhanced preparedness and optimised response. The topic is part of the NERIS Strategic Research Agenda (Key Topic 5, sub-topic 5.6).

	Inputs from social sciences and humanities are required concerning stakeholder involvement at the local level.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	The topic proposed will contribute to improved preparedness and response to nuclear and radiological emergency and recovery situations. The topic is related to the priorities described in the SRA of European platforms: NERIS: Key Topic 5, sub-topic 5.6 & ALLIANCE: Challenge 1 and Challenge 3.
Impact: decreased uncertainty	Adaptation of generic models to the specificity of the local areas affected by a nuclear or radiological accident will lead to an improvement in the estimation of radiological transfer and impact on the population. This in turns leads to decreased uncertainty in the estimation concerning the effects on people and the environment in emergency and recovery situations.
Impact: increased radiation protection	The topic will contribute to optimised decision-support and thus to increased protection of the population in emergency and recovery situations.
Impact: increased acceptability	Empowering local stakeholder and communities with tools adapted to the specificity of the local context will contribute to increased preparedness and higher efficiency and acceptability of countermeasures strategies.
Feasibility	The scientific / technological competences needed for this topic are available in Europe.
Other justifications	The topic has a high societal relevance since it aims at a better protection of the population and the environment in case of a nuclear or radiological situation.
Priority 6	**Monitoring Strategies**
Priority description	Decisions in the aftermath of or recovery from a nuclear or radiological accident are largely based on monitoring efforts. Although most countries have installed monitoring capacity for nuclear and radiological accidents, important challenges still exist, such as: - The optimization of the monitoring strategy in function of the decision support; - The integration of different monitoring techniques in one strategy, including new technologies (drones, measurement by the public, …). Research questions are: • How to optimize the measurement strategy taking into account radiological, societal and ethical factors in case of a nuclear accident, especially addressing accidents with cross border impact; • Evaluation of new technologies and how they can be integrated in nuclear emergency and long term monitoring: e.g., drones, smartphone apps, …; • How to integrate and support monitoring by the public; • How can monitoring be linked with nuclear emergency and recovery reference levels (e.g. related to contaminated goods); • How can monitoring (strategies) be linked with advanced modelling (source term calculations); • How to combine monitoring data, including non-radiological data (data fusion); • How does monitoring uncertainty impact decision support and how to visualize monitoring uncertainty; • How to use monitoring efficiently in optimization of recovery countermeasures; • What are the specific differences needed in monitoring in the different phases of an accident.
European relevance	The topic is part of the NERIS Strategic Research Agenda (Key Topic 5, subtopic 5.9). Currently all European countries have developed their own

	monitoring capacity. A sound scientific basis, taking into account local differences, for developing a robust monitoring methodology, considering technical as well as societal factors is missing.
Multidisciplinarity; Reference to the strategic research agendas (SRA)	Apart from NERIS, monitoring is strongly linked to research related to the European platform for dosimetry (EURADOS). However, it should be noted that this topic doesn't focus on the development or optimization of new measurement techniques, but addresses the integration of existing and new technologies in a robust monitoring strategy to support decision making. The set-up of monitoring strategies should also include stakeholder involvement.
Impact: decreased uncertainty	A robust monitoring strategy will allow a much faster assessment of the situation. It will also improve the efficiency of countermeasures.
Impact: increased radiation protection	This topic aims at optimizing monitoring strategies, which should result in acquiring a clear picture of the radiological situation in a limited timeframe. In this way better and faster protective actions can be taken.
Impact: increased acceptability	A clear, stable picture of the radiological situation will enhance trust in decisions related to protective actions and consequently increase acceptability of countermeasures. In addition capabilities will be developed for stakeholders.
Feasibility	The main challenges is to connect monitoring experts with radiological emergency and recovery experts (advisors to the decision makers) and integrate societal/ethical aspects.
Other justifications	The Fukushima accident demonstrated that the involvement of the public in measurements is essential. Research in this context should be the basis for any preparedness actions in this respect.

Annex 2. Overview of recently finished and started EU projects in research areas closely related to the NERIS SRA.

FP7-project Prepare (Innovative integrative tools and platforms to be prepared for radiological emergencies and post-accident response in Europe)

The European research project PREPARE ended in January 2016 and brought together 46 partners from Europe and Japan. The objective was to close gaps identified after the Fukushima accident. With respect to the NERIS SRA work was conducted in the following areas of Key topics of the SRA, however, it cannot be stated that the work reported in the following bullet points is completed. It is more an indication that work has been performed and it has to be analysed to which extent further research is needed.

- Atmospheric modelling (key topic 1)
    - First prototype of inverse source term estimation modules (released quantities, isotopic composition, height) through data assimilation of near or far field measurements
    - Improvements in the speed of calculation allowing to use them for long lasting releases
    - Improved deposition modelling of particles with spectrum of different sizes and densities
- Aquatic modelling (key topic 2)
    - Improved models for coastal areas
    - Improved run-off modelling, however still very limited
- Data mining, information gathering and providing information to stakeholders and mass media (key topic 4)
    - Analytical Platform for data exchange
    - Knowledge data base – so far limited to the early phase, but work in HARMONE will deal with the later phase
    - Trustworthiness of information
- Stakeholder engagement and dialogue (key topic 6)
    - Contaminated goods
- Social media/networking technology (key topic 7)
    - Public behaviour
    - How the public obtains information
    - Factors important for trust

PREPARE has not addressed the key topics 3 and 5, even if results from topics 1 and 2 were integrated in the DSSs ARGOS and JRODOS, however, the individual objectives of these two topics were not addressed. For topic 7 the work provides an initial view and cannot be regarded as completed.

Operra-project CATHyMara (Child and Adult Thyroid Monitoring after Reactor Accident)

The Cathymara project aims at setting-up guidance for monitoring the internal contamination in the case of a large scale nuclear accident, with a focus on the measurement of I-131 content in the thyroid, especially for children and includes:

- Evaluation of existing response capabilities for thyroid monitoring in Europe in case of a large scale accident;
- Harmonization of measurement practices and establishment of a robust protocol in case of the need to monitor children;
- Setting-up the basis for a sustainable network of responders, including trained but non-specialized operators;
- Studying to what extent the total committed effective dose (internal dose) can be evaluated from I-131 measurements and the development of emergency oriented dose assessments methods;
- Developing the optimal monitoring strategy, including guidelines and recommendations.

In this respect, the CATHyMara project mainly touches upon the following topics and areas in the NERIS SRA:

- Improving the decision-making processes (key topic 5), more specifically Health surveillance (subtopic 5.8), Monitoring (subtopic 5.9) and Assessment and communication of uncertainties (subtopic 5.1)

but only with a well-defined and limited focus. In addition also elements of the following NERIS SRA topics are partly addressed:

- Stakeholder engagement and dialogue (key topic 6), more specifically Defining stakeholders and framing problems (subtopic 6.1)

Operra-project HARMONE (Harmonising Modelling Strategies of European Decision Support Systems for Nuclear Emergencies)

The HARMONE project started December 1, 2015 and aims to reduce scientific, methodological and operational gaps identified in the strategic research agendas of the four European Platforms in the area of radiation protection and issued as TOPIC 2 of the OPERRA-2014 Call: “Spatial and temporal environmental modelling and human dose assessment after a nuclear accident”. This includes the following work activities

- Development of a knowledge data base and guidance that allows, according to the first event description, to propose a first management strategy to reduce doses and highlights potential issues for the dose assessment.
- Refinement of simulation models for all exposure pathways to obtain a better assessment of the total dose. This would include also a methodology for the regionalisation of the model to have assessments on all relevant scales.
- Development of guidelines for dose monitoring to back-up the first two steps and facilitate the refinement of the simulations.

In this respect, the HARMONE project addresses the following areas and topics of the NERIS SRA

- Aquatic modelling (key topic 2)
  - Test of runoff models and identify gaps therein
- Improvement of existing Decision Support Systems (key topic 3)
  - Support the customisation of the food chain and dose models to European conditions
  - Refinement of simulation models, e.g. introduce snow in the ADM, snow melting in ERMIN
- Data mining, information gathering and providing information to stakeholders and mass media (key topic 4)
  - Knowledge data base for the later phase scenarios
- Improving the decision making process (key topic 5)
  - Development of generic guidance on countermeasure strategies
  - Some ideas on monitoring strategies for model support

HARMONE is limited in resources and therefore will not result in new developments but more in the refinement of existing ones.

Operra-project SHAMISEN (Nuclear energy situations – Improvement of medical health surveillance)

The aim of the project is to build upon the experience and feedback from Chernobyl, Fukushima and other emergency situations to develop recommendations for health surveillance and medical follow-up of affected populations for:

1. Dose assessment in support of emergency response, clinical decision-making in the aftermath of a radiation accident, and long-term follow-up of exposed populations;
2. Improvement of living conditions of affected populations, responding to their needs, and engaging them in surveillance programmes without generating unnecessary anxiety; and
3. Improvement of population estimates of radiation-induced risk both for radiation protection and for communication with affected populations, if and where feasible.

Work is organised in five complementary subtasks (ST): ST1 focuses on learning from radiation accidents; ST2 looks at the needs of populations by way of case-studies; ST3 will develop recommendations for health surveillance aimed at improving living conditions of affected populations and knowledge on health effects; ST4 focuses on cross-cutting issues (stakeholder engagement, ethics, and economics of health surveillance); and ST5 is dedicated to efficient project management.

In this respect, the SHAMISEN project mainly touches the following topics and areas in the NERIS SRA:

- Improving the decision-making processes (key topic 5), essentially Health surveillance (subtopic 5.8), but also partly Monitoring (subtopic 5.9).

Due to the duration of the project, the guidance to be produced will partly cover the topic. In addition also elements of the following NERIS SRA topics are partly addressed:

- Stakeholder engagement and dialogue (key topic 6), including ethical considerations.

CONFIDENCE COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs

The H2020 CONFIDENCE Project aims to address existing gaps in several areas of emergency management and long-term rehabilitation. It concentrates on the early and transition phases of an emergency, but considers also longer-term decisions made during these phases. The work-programme of CONFIDENCE aims to understand and if possible with the given resources to reduce and cope with the uncertainty of meteorological and radiological data and their further propagation in decision support systems, including atmospheric dispersion, dose estimation, foodchain modelling and countermeasure simulations models. Consideration of social, ethical and communication aspects related to uncertainties is also considered. First attempts will be made to combine simulation with monitoring to help gaining a more comprehensive picture of the radiological situation. Decision making principles and methods will be investigated to understand the need for uncertainty handling in the decision making process. A comprehensive education and training programme is linked with the research activities.

In this respect, CONFIDENCE addressed partly priority 1 on the assessment of and communication on uncertainties and priority 2 on robust decision making. However, it has to be stated that this is a first attempt and it is not expected that the project answers all aspects. In contrary, it is expected that more issues will be raised than answered and research needs further defined/refined.

TERRITORIES To Enhance unceRtainties Reduction and stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife In long-lasting radiological Exposure Situations

The TERRITORIES project targets an integrated and graded management of contaminated territories characterised by long-lasting environmental radioactivity, filling in the needs emerged after the recent post-Fukushima experience and the publication of International and European Basic Safety Standards. A graded approach, for assessing doses to humans and wildlife and managing long-lasting exposure situations (where radiation protection is mainly managed as existing situations), will be developed through reducing uncertainties to a level that can be considered fit-for-purpose. The overall outcome will be a first attempt to provide an umbrella framework, that will constitute the basis to produce, and disseminate, novel guidance documents for dose assessment, risk management, and remediation of NORM and radioactively contaminated sites as the consequence of an accident, with due consideration of uncertainties and stakeholder involvement in the decision making process.

In this respect, TERRITORIES addressed the long term aspects of priority 3 on countermeasures strategy preparedness

Third EURADOS SRA Statement – June 28, 2017

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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 (see below). In early 2016, a condensed version of the EURADOS SRA appeared in the printed version of *Radiation Protection Dosimetry* (Radiat. Prot. Dosim. 168, 223-234, 2016).

Actions related to SRA development

Stakeholder involvement

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. The purpose of the workshop was to ask relevant stakeholders of EURADOS to provide their view on the current version of the EURADOS SRA. Emphasis was placed on international organizations expected to be interested in an improved dosimetry of ionizing radiation.

Altogether, 23 international organizations accepted the EURADOS invitation and provided their view on the EURADOS SRA. These organizations are listed in Annex A (listed in alphabetical order). Annex B shows the workshop agenda.

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 organizations. In their presentations, the stakeholders were asked to briefly (about 10 minutes each) 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?

At the end of the Workshop, members of the EURADOS Council (P Olko, Poland; Ž Knežević, Croatia) prepared and presented a short summary of the comments provided by the participants. The discussions revealed that the format of the Workshop including about 10 minutes presentations given by the invited organizations was efficient and well received. The need was emphasized that different societies should closely collaborate on the future topics of interest, becasuse there is overlapping in topics between different organisations.

A summary of the workshop was published recently as EURADOS Report 2017/02. This report is free for download from the EURADOS website (see below). In the meantime, a EURADOS task group has been formed who is currently evaluating the outcome of the workshop in more detail. Based on the outcome of the analysis, this task group will then update the EURADOS SRA.

References:

http://www.eurados.org/-/media/Files/Eurados/documents/EURADOS_Report_2014_01.pdf

http://www.eurados.org/-/media/Files/Eurados/documents/EURADOSReport2017_02.pdf

Organisation of the EURADOS Winterschool on "Internal Dosimetry for Radiation Protection and Medicine"

At its meeting in July 2016 in Munich, Germany, the EURADOS Council decided to organize a one-day Winterschool during the EURADOS Annual Meeting in Karlsruhe, Germany, in February 2017. The topic of the Winterschool, "Internal Dosimetry for Radiation Protection and Medicine" was chosen in relation to Vision 4 of the EURADOS SRA ("Towards integrated personalized dosimetry in medical applications"), and to strengthen the contacts to the medical associations, and in particular to EANM (European Association of Nuclear Medicine). The programme of the Winterschool is shown in Annex C: most of the presentations given at the Workshop can be downloaded for free from the EURADOS website:

http://www.eurados.org/en/Events/Winter_schools.

Priorization of SRA challenges

As already mentioned, the current version of the EURADOS SRA includes five visions. Each of these visions includes a number of so-called challenges described in more details by the required research lines. The challenges were ranked according to a survey among the EURADOS Voting Members and EURADOS Council Members as follows:

1 To quantify correlations between track structure and radiation damage
2 To improve neutron dosimetry techniques
3 To quantify doses after accidental internal contamination

4 To develop accurate and on-line personal dosimetry for workers
5 To improve out-of-field dosimetry for photon and particle therapy
6 To improve dosimetry in modern external beam radiotherapy
7 To optimize dose estimations in interventional radiology
8 To rapidly identify individuals with highest doses
9 To establish reliable patient dosimetry in CT examinations
10 To update operational quantities for external exposure
11 To improve understanding of dosimetry and biokinetics of internal emitters
12 To improve understanding of spatial correlations of radiation interaction events
13 To explore exposure pathways not yet considered or validated
14 To improve retrospective dosimetry for exposure pathways already considered
15 To improve internal microdosimetry in radiotherapy and medical imaging
16 To handle a large number of dosimetric samples in a short time
17 To include nuclide-specific information in environmental monitoring
18 To improve, validate and implement new biokinetic models

Based on this ranking and in cooperation with the other platforms, for the first CONCERT Call challenges 1 and 3 were chosen. For the second CONCERT Call challenges 2 and 4 were chosen.

At the present stage it is too early to judge whether and how the successful proposals of the first Call will contribute towards the identified challenges 1 and 3. Furthermore it is currently not known which proposals of the second Call will be funded. It is obvious, however, that a combination of challenges 2, 5 and 6 will require a high priority in the future. These first 6 challenges are described in more detail below.

Detailed description of the EURADOS research priorities.

Priority 1	**To quantify correlations between track structure and radiation damage**
Priority description	• The correlation between track structure and radiation damage must be established in a quantitative way. For this, cells need to be exposed to single particle tracks keeping the geometrical relation between the particle track and the exposed cell. In these experiments, the required radiobiological assays must be improved in terms of statistical power, useable cell types, etc.. The physical characteristics of the track structures involved should be explored by using nano-dosimeters with multi-scale measurement capabilities or by employing track structure simulation codes that have been benchmarked with nano-dosimetric measurements. Statistical cross-analysis should then identify correlations between the yield of a particular biological endpoint and nano-dosimetric quantities characterizing the particle tracks. A variety of human cell types of different differentiation and coming from donors of different age and sex should be investigated.

Priority 2	**To improve neutron dosimetry techniques**
Priority description	Neutrons are intentionally used or incidentally created in various scientific and technical applications, and they can dominate the total dose received. Neutron dosimetry is still challenging as neutrons are present in mixed-fields and are indirectly ionizing particles. Their energy range may cover up to 12 orders of magnitude, they show a wide range of incidence angles, and their conversion coefficients from fluence to dose varies by a factor of 50 over the entire energy range. Some neutron fields represent new challenges, for example due to strongly pulsed radiation and/or high energy ranges, and proper reference fields are needed. The characterization of workplace fields is complex and requires sophisticated procedures. Better and easier-to-use methods are needed allowing the uncertainty of results to be evaluated. The detection threshold of neutron personal dosimeters and their energy and angular dependence remain the main deficiencies of neutron personal dosimetry compared with that for photons.

Priority 3	**To quantify doses after accidental internal contamination**
Priority description	• As for dose assessment after internal contamination, efforts should be made to link internal dosimetry from incorporated radionuclides with biological dosimetry methods. This would require definition of suitable biological end-points, definition of the proper dosimetric quantity to be compared to the biological end-point (e.g. blood dose instead of administered activity), and identification of cases for which sufficient biological dosimetry and bioassay data are available to be used for method validation. These studies could also be performed using radiopharmaceuticals. Specific emergency bioassay methods for in-vitro monitoring of radionuclides such as transuranium isotopes must be developed and validated. For other radionuclides such as radioidodine isotopes, new thyroid phantoms of various sizes should be developed for computational dosimetry. These actions should be complemented by development of counter measures to reduce doses after accidental internal contamination. In particular, for transuranium isotopes, reference biokinetic models under DTPA therapy should be developed to improve the reliability of dose assessments in such cases.
Priority 4	**To develop accurate and on-line personal dosimetry for workers**
Priority description	• To provide on-line personal dosimetry for occupationally exposed workers is challenging, because it requires monitoring of workers in real time for all limiting quantities (including whole body, eye lens, extremities, brain, heart doses). Well-characterized active personal and area dosimeters should be developed for all relevant dosimetric quantities including all relevant radiation fields, especially pulsed fields, with and without shielding, as well as computational tools using advanced tracking technology. Further consideration is needed taking into account their potential for use as official dose record. The inclusion of dosimetry of other potentially radiosensitive organs (brain, heart) might also be needed, dependent on the outcome of biological research on brain and cardiovascular risk.

Priority 5	**To improve out-of-field dosimetry for photon and particle therapy**
Priority description	• Epidemiological studies of second cancers following radiotherapy require a specification of dose to the patient at the site of the subsequent malignancy, making out-of-field dosimetry for photon and particle therapy an important field of dosimetric development, including the development of analytical models for out-of-field dosimetry calculations. Moreover, because additional dose contributions may come from diagnostic procedures, epidemiological studies will require quantification of all sources (therapy and/or imaging), for an estimation of combined risk, which must be harmonized and combined. This could be done by means of computational methods supported by the development of novel small-scale detectors for neutrons and photons that could be used to measure the dose distribution within dedicated phantoms irradiated according to typical radiotherapy treatments and modalities. Special attention must be given to paediatric radiotherapy and hadron radiotherapy where high-energy secondary neutrons are produced. As an ultimate goal of this research, calculation of a complete map of doses for each individual patient would be possible.
Priority 6	**To improve dosimetry in modern external beam radiotherapy**
Priority description	The rapid development in new radiotherapy techniques requires a continuous effort in dosimetry research, not only to develop experimental on-line dosimetry techniques, but also to improve calibration techniques. Indeed, it is important to be able to check if the planned dose distribution to the tumour region is really administered in the treatment.

Annex A: International organizations invited to participate in the "First EURADOS Stakeholder Workshop". *) EUTERP sent apologies but provided written comments on EURADOS SRA after the Workshop

ALLIANCE	European Radioecology Alliance
EANM	European Association of Nuclear Medicine
EFOMP	European Federation of Organisations for Medical Physics
ENISS	European Nuclear Installations Safety Standards Initiative
ESR	European Society of Radiology
ESTRO	European Society for Radiotherapy and Oncology
EURAMET	European Association of National Metrology Institutes
EUTERP *)	European Training and Education in Radiation Protection
HERCA	Heads of the European Radiological Protection Competent Authorities
IAEA	International Atomic Energy Agency
IARC / WHO	International Agency for Research on Cancer
ICRP / C2	International Commission on Radiological Protection / Committee 2 on Dosimetry
ICRP / C3	International Commission on Radiological Protection / Committee 3 on Radiation Protection in Medicine
ICRU	International Commission on Radiation Units & Measurements
ILO	International Labor Organization
IRPA	International Radiation Protection Association
ISO	International Organization for Standardization
ISSDO	International Solid State Dosimetry Organization
MELODI	Multidisciplinary European Low Dose Initiative
NEA	Nuclear Energy Agency
NERIS	European platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery
NUGENIA	Nuclear Generation II and II Association
PTCOG	Article Therapy Co-Operative Group
RENEB	Realizing the European Network of Biodosimetry
SSH	Social Sciences and Humanities

Annex B: Agenda of the "First EURADOS Stakeholder Workshop"

1st EURADOS Stakeholder Meeting for European Research in Dosimetry

Date and time: **30 June 2016, 09:00 to 17:00**
Location: **HMGU, Munich, Germany**

AGENDA (preliminary)

1. Welcome and organizational issues (W Rühm, HMGU) (9:00 – 9:15)
2. The HMGU Department of Radiation Sciences (M. Atkinson, HMGU) (9:15 – 9:30)
3. EURADOS – Strategic Research Agenda (F. Vanhavere (SCK-CEN)) (9:30 – 10:00)
4. CONCERT – European Joint Programming in Radiation Protection Research (N Impens, SCK-CEN) (10:00 – 10:30)

   Coffee Break (10:30 – 11:00)

5. Participants – Research Needs in Dosimetry (~ 10' each) (11:00 – 12:30)

   Lunch (12:30 – 13:15)

6. Participants – Research Needs in Dosimetry (cont'd) (~ 10' each) (13:15 – 14:45)

   Coffee Break (14:45 – 15:15)

7. Participants – Research Needs in Dosimetry (cont'd) (~ 10' each) (15:15 – 16:15)
8. General Discussion (all) (16:15 – 17:00)
9. Final Remarks, Action List and Closure (W. Rühm, HMGU) (17:00)

Annex C: Program of the 10th EURADOS Winter School, March 2nd 2017

09:00	Welcome on behalf of the Scientific Committee	
Session 1:		
09:05	B. Breustedt, Germany	How to assess doses from internal emitters in radiation protection and medicine
09:30	D. Nosske, Germany	ICRP perspective on internal dosimetry– OIR and radiopharmaceuticals
10:00	G. Etherington, UK	Internal dosimetry in occupational radiation protection – The TECHREC project
10:30	Coffee Break	
Session 2:		
11:00	M. Lassmann, Germany	Internal dosimetry in nuclear medicine— status, challenges and perspectives
11:30	M. Bardies, France	The use of alpha-emitting radionuclides in medicine: status, challenges and perspectives
12:00	M. Zankl, Germany	Computational phantoms used in internal dosimetry for radiation protection and medicine
12:20	W. Li, Germany	Micro- and nanodosimetry for internal emitters– changing the scale
12:40	Lunch break	
Session 3:		
13:50	A Giussani, Germany	Uncertainties in internal dosimetry
14:10	E. Davesne, France	Dosimetry for the epidemiology of internal emitters – risk assessment vs. operational radiation protection
14:30	M.A. Lopez, Spain	Internal dosimetry in emergency situations – challenges and recent developments
14:50	D. Bingham, UK	Standardization in internal dosimetry – Recent developments in ISO standards for radiation protection
15:10	Round Table	Research needs in internal dosimetry– updating EURADOS SRA
16:00	End of the Winter School	

Annex to D2.9.

Abstracts of recent and on-going projects funded from OPERRA and CONCERT calls

1. Projects funded in the framework of the OPERRA (Open Project for the European Radiation Research Area) project, Euratom FP7 grant agreement no: 604984. OPERRA ended 31 May 2017.

SOPRANO (Systems Oriented Prediction of Radiation Risk)

A systems radiation biology approach must be adopted to understand the complexities of the biological processes that determine individual sensitivity to low doses of radiation. The ultimate goal of a systems approach will be to develop a model of the cellular radiation response that reflects individual differences in age, gender and genetic constitution. The systems model will be able to incorporate known and newly discovered differences between individuals to personalize risk prediction.

Despite considerable effort to initiate a research programme no concerted European activity in the field of systems radiation biology has emerged. The SOPRANO project is an 18 month activity that will assemble the first interdisciplinary research team in Europe to undertake a systems radiation biology approach. SOPRANO has a pilot study nature for radiation research, as this will be the first project that explores the interfaces between the three key components of systems biology: data generation, bioinformatic analysis and systems modelling.

EURALOC (European epidemiological study on radiation-induced lens opacities for interventional cardiologists)

The proposed research, called EURALOC, focuses on low dose radiation effects on the lens of the eye. Research on formation of lens opacities following radiation exposure has been an area of intense interest recently and is a major target area of the MELODI Strategic Research Agenda. Several issues regarding the relationship between radiation dose, lens opacities and cataract development remain unclear and there is an urgent need for high-quality epidemiological studies at low doses. EURALOC will combine epidemiological, ophthalmological and dosimetric research expertise to address effects of radiation on the lens of the eye and to determine the dose-response relationship at low doses. A well-designed epidemiological study on a European cohort of interventional cardiologists with cutting edge methods for evaluating opacities and eye lens dosimetry is planned. The strengths of our EURALOC consortium is the methodology to guarantee harmonised data collection, the availability of state of the art dosimetry methods and of standardised, central ophthalmological assessments, including non-invasive, quantitative measure of lens transparency developed earlier in the ELDO project. The reduction of the occupational dose limit for the eye lens to 20 mSv per year will have implications for the targeted population in this study and for other health care professionals, as previous studies have shown that this limit can easily be exceeded for medical staff. A clarification of the dose-response relationship for radiation-induced lens opacities will not only provide a scientific basis for the determination of the low-dose threshold for lens opacities, but will also have an impact on the improvement of radiation protection and dose reduction procedures for medical staff in the clinical environment.

DIMITRA (Dentomaxillofacial paediatric imaging: an investigation towards low dose radiation induced risks)

Cone Beam Computed Tomography (CBCT) is an emerging X-ray technology that has found wide applications in dentomaxillofacial imaging. The ability to provide high-resolution 3D images has resulted in a significant increase in the volume of dental radiology procedures. Although CBCT is associated with higher radiation risk to the patient than conventional dental X-ray imaging (intraoral or panoramic), it is considered to be 'low dose' imaging as defined by the High Level Expert Group (HLEG; www.hleg.de) with doses ranging from a few µSv to mSv per examination.

This proposal is set to tackle important issues raised by the HLEG and the MELODI (Multidisciplinary European Low Dose Initiative) platform. In particular, as deduced by the name DIMITRA (Dentomaxillofacial paediatric imaging: an investigation towards low dose radiation induced risks), the project focuses on the uncertainties associated with radiation-induced health risks at low doses in paediatric dentistry and is a multidisciplinary effort to approach the involved risks from different yet interrelated perspectives: radiobiological characterisation, dosimetric quantification, epidemiological surveying and image quality & dose optimization. A unique Monte Carlo (MC) framework will be used to accurately calculate organ doses in dental CBCT imaging, to quantify the radiation induced risk and to feed the radiobiology team with the appropriate data towards the identification, development and validation of biomarkers for radiation induced health effects. Furthermore, it will constitute the basis upon setting up a gender and age related epidemiology study. The balance between image quality and dose levels will be explored aiming at reducing the risk through image quality optimization.

It is expected that DIMITRA`s outcomes and deliverables can be presented to a wider forum via a dissemination meeting, leading to further recommendations and potential future adaptations for the use of CBCT in paediatric dentistry.

CAThyMARA (Child and Adult Thyroid Monitoring After Reactor Accident)

A nuclear power plant accident will cause uncontrolled release of a large amount and complex mixture of radionuclides; however ^{131}I generally makes the largest dose contribution. After the Chernobyl accident, many citizens received thyroid doses exceeding 1 Gy due to radio-iodine intakes and more than 6 000 thyroid cancers (mostly in children) were attributed to radio-iodine intakes. After the Fukushima accident, about 98% of the effective dose received by emergency workers was attributable to radio-iodine intakes (UNSCEAR 2013).

Following a large scale nuclear accident, or even a small accidental release, citizens will expect to be individually monitored rather than rely on calculated dose. This project focuses on post-accidental ^{131}I measurement in the thyroid, particularly for *children.*

This project will consider doses resulting from exposures to all significant radionuclides, but focuses on the monitoring strategies and assessment of thyroid doses resulting from intakes of radio-iodine. Monitoring strategies will address monitoring of children and adults, required capabilities and existing gaps. Strategies will also address harmonization of measurements and dose assessment to be done by national authorities, within the European Union and neighbouring countries.

This project relies on a review of existing European means, *on two thyroid measurement inter-comparison circuits, focusing on children*, on Monte-Carlo based device calibrations and on the development of emergency oriented dose assessment methods.

More specifically, the goals of the project are as follows

1. To evaluate the existing response capabilities for thyroid monitoring in Europe in case of large scale nuclear accident, including the potential of citizenship measurements (i.e. measurements made by members of the public).

2. To harmonize measurement practices and establish a robust protocol in case of the need to monitor children.
3. To set-up the basis for a sustainable network of responders including trained but non-specialized operators.
4. To study to what extent total committed effective dose (internal dose) can be evaluated from ^{131}I measurements and develop emergency oriented dose assessment methods.
5. To develop the optimal monitoring strategy and supporting technical guidelines for large scale post-accidental monitoring of internal exposure and dose assessments and to issue recommendations about the needed technical development, international collaboration and the adequacy of existing and needed means.

Identified gaps such as the children case will be solved and other potential gaps will be revealed. The main outcome of the project will be guidelines based on practical experience and on the comparison of existing and required means. They will also benefit from the inputs of the civil society. This project relies on the experience of specialists involved in the EURADOS, NERIS and NKS networks or involved in international organizations such as ICRU or IAEA.

HARMONE (Harmonising modelling strategies of European Decision Support Systems for Nuclear Emergencies)

This proposal aims to reduce scientific, methodological and operational gaps identified in the strategic research agendas of the four European Platforms in the area of radiation protection and issued as TOPIC 2 of the OPERRA-2014 Call: "Spatial and temporal environmental modelling and human dose assessment after a nuclear accident". In particular we intend to provide a system that is able to deal with all possible release scenarios, environmental characteristics and shortcomings on information in the early phase of an emergency. As information in the early phase is uncertain, the application of simulation model might not be satisfactory. Furthermore, in due time, the public requires confidence by monitoring information. Therefore, we intend to develop a three layer approach that can be characterised by the following objectives:

- Development of a knowledge data base and guidance that allows, according to the first event description, to propose a first management strategy to reduce doses and highlights potential issues for the dose assessment.
- Refinement of simulation models for all exposure pathways to get a better assessment of the total dose. This would include also a methodology for the regionalisation of the model to have assessments on all relevant scales.
- Development of guidelines for dose monitoring to back-up the first two steps and facilitates the refinement of the simulations.

SHAMISEN (Nuclear Emergency Situations - Improvement of Medical And Health Surveillance)

Nuclear emergencies, such as those which occurred in Chernobyl and Fukushima, have resulted in large numbers of persons being exposed to ionising radiation. In addition, they have caused major and continuing upheavals in the lives of populations affected by fallout, both directly (emergency and accident recovery workers, evacuees, persons living in areas where dose reduction measures were taken) and indirectly (persons living in less contaminated regions).

Some populations have undeniably sustained health impacts from the radiological consequences of accidents, in particular early emergency workers in Chernobyl who suffered acute radiation syndrome and young people who developed thyroid cancer as a result of fallout from that accident. Many others, however, have suffered serious consequences that were not directly related to the biological effects of radiation, but rather induced by the event itself, the presence of radioactive contamination and consequent emergency and remediation measures taken, and/or uncertainties about radiation levels and

health effects. These include intensive care unit patients and institutionalised elderly persons evacuated after the accident at Fukushima; clean-up workers who developed anxiety, depression, post-traumatic stress disorders and suicide ideation; and evacuees and residents of contaminated areas whose lives were affected by emergency and/or remediation actions taken, and who continue to experience social and economic disturbances resulting from raised levels of radioactivity in the environment.

Strategies for preparedness and surveillance should aim to meet society's needs for accurate information on doses and health effects and provide a system of follow-up that allows affected population both to feel, and to be, well-monitored for radiation and its possible effects. Surveillance programmes raise ethical issues and challenges that need to be addressed, however: though affected populations may consider them beneficial in terms of health monitoring and care, the surveillance can create undue anxiety in populations; conversely, persons whose dose levels do not warrant particular medical surveillance may suffer psychological consequences if not included in the surveillance programme. At present, there are no well-established, comprehensive strategies for preparedness and health surveillance relating to radiation accidents. This highlights the clear need to learn from past experiences and plan measures that engage affected populations in their follow-up, enabling them to better manage their situation.

It is upon this background that we submit this proposal, with the overarching objective of building upon lessons learned from experience with populations affected by Chernobyl, Fukushima and other nuclear emergencies to develop recommendations for medical and health surveillance of populations affected by previous and future radiation accidents.

Recommendations will be made focusing on the following three complementary aspects:

- Dose assessment supporting emergency response, clinical decision-making in the aftermath of a nuclear emergency and long-term follow-up of exposed populations;
- Improvement of living conditions of affected populations, responding to their needs and engaging them in surveillance programmes while avoiding generation of unnecessary anxiety; and
- Improvement of population estimates of radiation-induced risk both for radiation protection and for communication with affected populations, if and where feasible.

2. Projects funded in the framework of the CONCERT European Joint programme (1st call 2016). Ongoing till February 2020.

CONFIDENCE (Coping with uncertainty for the improved modelling and decision making in nuclear emergencies)

The CONFIDENCE Project, funded under the H2020 CONCERT project, will perform research focussed on uncertainties in the area of emergency management and long-term rehabilitation. It concentrates on the early and transition phases of an emergency, but considers also longer-term decisions made during these phases. The project brings together expertise from four European Radiation Protection Research Platforms (NERIS, MELODI, ALLIANCE and EURADOS) and also from Social Sciences and Humanities, such that it can address the scientific challenges associated with model uncertainties and improve radioecological predictions and emergency management (NERIS and ALLIANCE), situation awareness and monitoring strategies (EURADOS), risk estimation in the early phase (MELODI), decision making and strategy development at local and national levels (NERIS) including social and ethical aspects (NERIS and Social Sciences and Humanities).

The work-programme of CONFIDENCE is designed to understand, reduce and cope with the uncertainty of meteorological and radiological data and their further propagation in decision support systems

(including atmospheric dispersion, dose estimation, foodchain modelling and countermeasure simulations models). Consideration of social, ethical and communication aspects related to uncertainties is a key aspect of the project activities. Improvements in modelling and combining simulation with monitoring will help gaining a more comprehensive picture of the radiological situation and will clearly improve decision making under uncertainties. Decision making principles and methods will be investigated, ranging from formal decision aiding techniques to simulation based approaches. These will be demonstrated and tested in stakeholder workshops applying the simulation tools developed within CONFIDENCE. A comprehensive education and training programme is fully integrated with the research activities.

TERRITORIES (To Enhance unceRtainties Reduction and stakeholders Involvement TOwards integrated and graded Risk management of humans and wildlife In long-lasting radiological Exposure Situations)

TERRITORIES targets an integrated and graded management of contaminated territories characterised by long-lasting environmental radioactivity, filling in the needs emerged after the recent post-Fukushima experience and the publication of International and European Basic Safety Standards. A graded approach, for assessing doses to humans and wildlife and managing long-lasting situations (where radiation protection is mainly managed as existing situations), will be achieved through reducing uncertainties to a level that can be considered fit-for-purpose. The integration will be attained by:

- Bridging dose and risk assessments and management of exposure situations involving artificial radionuclides (post-accident) and natural radionuclides (NORM),
- Bridging between environmental, humans and wildlife populations monitoring and modelling,
- Bridging between radiological protection for the members of the public and for wildlife,
- Bridging between experts, decision makers, and the public, while fostering a decision-making process involving all stakeholders.

This project interlinks research in sciences supporting radiation protection (such as radioecology, human or ecological dose and risk assessments, social sciences and humanities, etc.), providing methodological guidance, supported by relevant case studies. The overall outcome is an umbrella framework, that will constitute the basis to produce novel guidance documents for dose assessment, risk management, and remediation of NORM and radioactively contaminated sites as the consequence of an accident, with due consideration of uncertainties and stakeholder involvement in the decision making process. The results will be widely disseminated to the different stakeholders and accompanied by an education and training programme.

Thus, the eleven partners of TERRITORIES will develop a common coherent guidance with a greater understanding of multiple sources of uncertainties along with variabilities in exposure scenarios, making the best use of scientific knowledge to characterize human and wildlife exposure, integrating this knowledge and know-how to reduce uncertainties and finally taking consideration of social, ethical and economic aspects to make decisions.

LDLensRad (Towards a full mechanistic understanding of low dose radiation cataracts)

The lens of the eye is known to be more radiosensitive than previously thought but, despite a substantial reduction in occupational dose limits based on recent epidemiological information and reanalyses, the mechanisms of low dose radiation cataract induction are still unclear. This is an important current public health issue, for instance for medical radiation workers, many of whom will need to amend their working practices despite a clear understanding of the effects of chronic, low dose, ionising radiation exposure.

This multidisciplinary project aims to bring together experts from across Europe to answer a number of key research questions on this topic, including: how does low dose radiation cause cataracts; is there a dose rate effect, and how does genetic background influence cataract development after radiation exposure. The research will also address the issue of ageing in a sensitive subset of mice and whether lens effects can be viewed as global biomarkers of radiosensitivity. The collaborators will work with mouse models supported by cellular studies to investigate the mechanistic chain of events from the initial radiation insult and biological responses through to formation of lens opacities. The biological investigations will be supported by rigorous statistical modelling for hypothesis development. In addition, the partners will explore the potential for a prospective molecular epidemiology programme using human lenses taken from the former Mayak PA workers.

The results of this project will be highly relevant for CONCERT low dose radiation research and radiation protection and the work plan is particularly in line with the MELODI and EURADOS strategic research agendas with additional key implications for medical radiation protection. Concrete outcomes are anticipated to include: definitive information regarding the shape of the dose response curve and thus the risk of radiation cataract at doses < 500 mGy, advancing the debate as to the nature of radiation cataracts as either deterministic tissue reactions or stochastic effects and thus strengthening the evidence base for informed radiation protection; the assessment of lens effects as biomarkers of global radiosensitivity to provide potential new tools for health risk assessment as well as the education and training of a number of earlier career scientists in low dose radiation research.