This project has received funding from the Euratom research and training programme 2014-2018 under grant agreement No 662287.

EJP-CONCERT

European Joint Programme for the Integration of Radiation Protection Research

H2020 – 662287

D2.5 Long-term RTD roadmaps from MELODI, ALLIANCE, NERIS and EURADOS

Lead Author: Sisko Salomaa (UEF)

With contributions from:

MELODI SRA working group	Michaela Kreuzer (BfS) and Simon Bouffler (PHE);
ALLIANCE SRA-Roadmap Working Group	Jacqueline Garnier-Laplace (IRSN), Hildegarde Vandenhove (SCK-CEN), Almudena Real (CIEMAT), C. Adam-Guillermin (IRSN); T. Arnold (HZDR); N. Beresford (NERC-CEH); C. Duffa (IRSN); N. Horemans (SCK•CEN); O. Masson (IRSN); S. Sachs (HZDR); J. Tschiersch (HMGU), Nathalie Impens, (SCK•CEN)
NERIS RTD Committee	T. Schneider (CEPN), W. Raskob (KIT), J. Camps (SCK-CEN), S. Andronopoulos (NCSR Demokritos), T. Duranova (VUJE), E. Gallego (UPM), F. Gering (BfS), O. Isnard (IRSN), M. Maître (CEPN), C. Murith (FOPH), D. Oughton (NMBU/CERAD), K. Andersson (DTU), J. Bohunova (VUJE), M-C. Cantone (UMIL), S. Charron (IRSN), P. Croüail (CEPN), C. Turcanu (SCK-CEN), M. Montero (CIEMAT), M. Muikku (STUK), A. Bexon (PHE), A. Liland (NRPA),
EURADOS Working Group	Roger Harrison (Newcastle University, Joao Alves (IST), Isabelle Clairand (IRSN), Phil Gilvin (PHE), Željka Knežević (RBI),Weibo Li (HMGU), Maria Antonia Lopez (CIEMAT), Rick Tanner (ISGlobal), Isabelle Thierry-Chef (ISGlobal), Arturo Vargas (UPC), Clemens Woda (HMGU)

Reviewer(s): CONCERT coordination team

Work package / Task	**WP2**	**Tasks 2.1, 2.2, 2.3, 2.4**
Deliverable nature:	**Report**	
Dissemination level: (Confidentiality)	**Public**	
Contractual delivery date:	**31 May 2017 (Month 24) , postponed→ new due date end Nov 2017 (Month 30)**	
Actual delivery date:	**end Nov 2017 (Month 30)**	
Version:	**2 (resubmission 16.01.2018)**	
Total number of pages:	**60**	
Keywords:	**low dose risk, radioecology, nuclear emergencies, dosimetry**	
Approved by the coordinator:	**05 December 2017 (16012018)**	
Submitted to EC by the coordinator:	**05 December 2017 (resubmission 16012018)**	

Contents

Abstract 4

1. Developing the long-term RTD roadmaps 5

2. MELODI roadmap activities 7

3. The long-term roadmap for research on radioecology (ALLIANCE) 11

4. The long-term roadmap for research on nuclear and radiological emergency response and recovery (NERIS) 16

5. Development of EURADOS Roadmaps 20

ANNEX 1: ELEMENTS OF THE ALLIANCE ROADMAP 22

SWOT ANALYSIS 22

SCHEME OF EACH TOPICAL ROADMAP ACTIVITIES ACROSS THE 2015-2030 TIMELINE 23

ANNEX 2. NERIS ROADMAP 26

Annex 3: Current status of EURADOS roadmapping. Examples for Visions and Challenges. 55

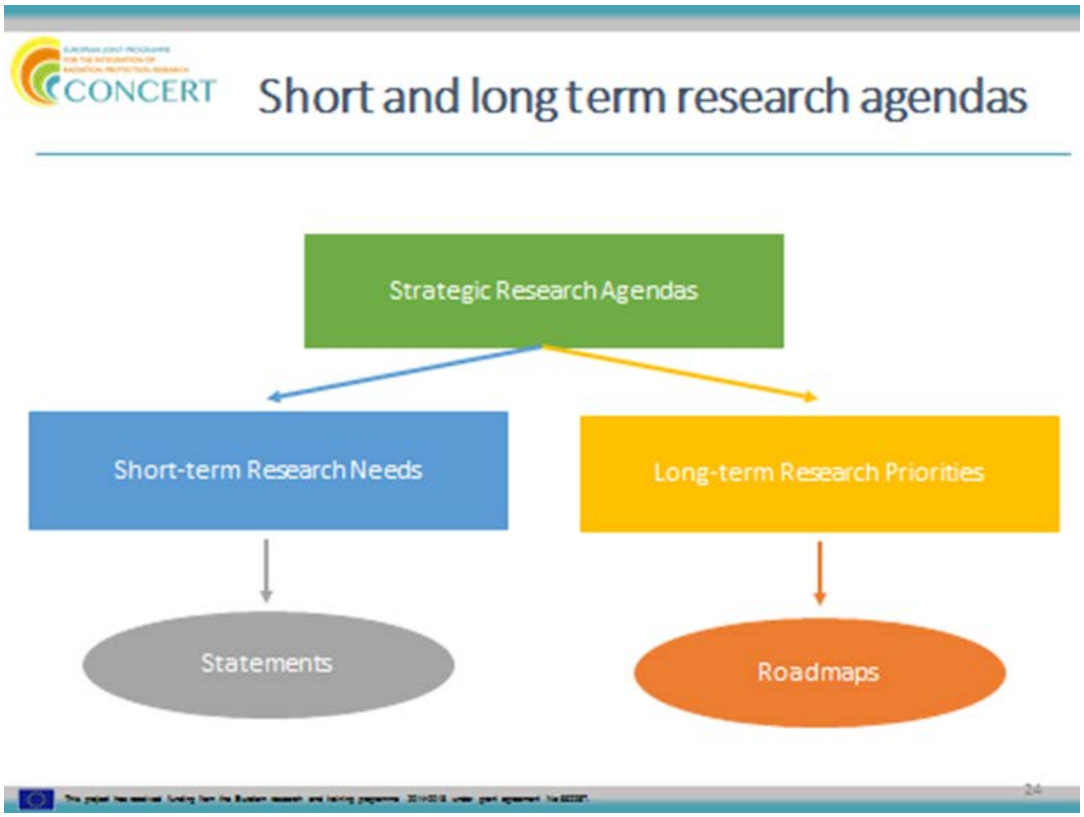
Abstract

This document describes the roadmaps of MELODI, ALLIANCE, NERIS and EURADOS that are based on the long-term research priorities of the Strategic Research Agendas of the individual platforms. In parallel, a Joint Roadmap for Radiation Protection Research is being elaborated. Whereas the individual Roadmaps focus on one of the radiation protection research disciplines and are science-driven, originating from the Strategic Research Agendas, the joint roadmap integrates the research needs that stem from potential exposure scenarios affecting humans and the environment. It is the intention to regularly update the joint and individual roadmaps beyond CONCERT, as these documents are intended as guides to plan radiation protection research over the next decades. Within this time frame, the roadmaps should take into account research progress and updated societal needs.

1. Developing the long-term RTD roadmaps

By 2017, the European radiation protection research platforms MELODI, ALLIANCE, NERIS and EURADOS have prepared the Strategic Research Agendas (SRAs) for their field of research. They have also established processes for the updating of the SRAs and providing annual SRA Statements that describe the current (short-term) research priorities. This work is carried out by SRA Working Groups or the RTD Committees of the platforms.

The next step in joint programming is to consider in more detail the long-term roadmap for research, taking into account the timeframe, progress in science, feasibility of approaches and resources needed for accomplishing the long-term goals.



A Joint roadmap meeting was held in Oxford 2016, discussing the strategy towards the joint roadmap, the joint roadmap definition, and some first ideas on stakeholder involvement. While the societal context (potential exposure scenarios) is central for the joint roadmap, it was evident that the platforms also need more detailed implementation plans for the specific scientific questions in their fields. A brainstorming meeting on the platforms individual roadmaps took place in Budapest 9 March 2017. The objective of the Budapest meeting was to create a common understanding on what is meant by a roadmap and to compare different approaches applied within the European research community. A roadmap generally refers to a goal-oriented implementation plan, describing steps to be taken in long-term. Common examples are technology roadmaps (e.g. Fusion). Another example is maturity roadmapping, describing development sequences (e.g. PDCA, Plan-Do-Check-Act). The roadmap can also be in a societal context, for example a plan for peace or solving a conflict. Examples of European research roadmaps were also explored. The roadmaps addressing a particular research field are typically based on an existing SRA or research priorities, whereas policy-oriented roadmaps (like open access to research publications or research data) describe policy actions to be taken to reach the goal. Roadmaps for development of research infrastructures (RI) typically have both scientific and policy

aims such as long-term development of all RI, improvements to the access to and collaborative use of RI and shoring up the funding base of RI.

In the radiation protection research context, previous experience in roadmapping (HLEG, DoReMi, EURAMET) was explored. It was concluded that each platform should use for the individual roadmaps the approach that serves best the needs of the specific research field. Alongside the development of individual platform roadmaps based on the scientific goals of specific fields, work on a joint radiation protection research roadmap has also been initiated in CONCERT WP3. The joint roadmap has a societal viewpoint, addressing exposure scenarios and their challenges for research. The first steps towards the development of the joint roadmap will be published also by end of November 2017 (Deliverable 3.4). A first version of the joint roadmap is expected in 2019, after consultation of stakeholders such as representatives from industrial, academic, medical and public bodies and the research community, and after alignment of the joint and individual roadmaps towards a consistent ensemble

The SRA Working Groups of the platform have worked on the individual roadmaps. Various approaches were taken by the platforms. MELODI identified six key lines for future research and evaluated the feasibility and impact of potential approaches at very low (0-10 mGy), low (10-100 mGy) and moderate (100-1000 mGy) dose levels. ALLIANCE, has developed short-term (5 years) roadmaps for a limited number of research topics, identified as priorities for the radioecology research community, as building blocks for the radioecology global roadmap. NERIS worked on exposure scenarios related to nuclear emergencies and radiological terrorist acts and addressed their three main challenges areas and related key topics. EURADOS chose the EURAMET model as a tool to visualize their five visions and related challenges.

2. MELODI roadmap activities

MELODI (http://www.melodi-online.eu/index.html) was established in 2010 following a recommendation from the High Level and Expert Group on European low dose risk research (http://www.hleg.de/). The HLEG report (http://www.hleg.de/fr.pdf) itself provided initial roadmaps relating to the proposed overarching strategy and the key areas for future work identified:

- The shape of dose-response for cancer;
- Tissue sensitivities for cancer induction;
- Individual variability in cancer risk;
- The effects of radiation quality (type);
- Risks from internal radiation exposure;
- Risks of, and dose response relationships for, non-cancer diseases and hereditary effects.

MELODI has since its inception developed and published a Strategic Research Agenda (SRA, see http://www.melodi-online.eu/sra.html) that has been revised and updated on an annual basis (for early versions of the MELODI SRA, see http://www.melodi-online.eu/m_docs_sra.html). The SRA aims to provide a framework to guide research activities and help the development of research proposals that have the overall goal to improve the scientific basis for radiation protection. Additionally annual statements (http://www.melodi-online.eu/m_docs_statement.html) have been prepared that provide more specific advice on the priority issues in a given year, taking into consideration the SRA and ongoing research activities.

Further development of the MELODI roadmap has been an area of active work and consideration for some time, and in 2016 a substantial draft roadmap was produced. The approach taken was to carry out a feasibility and impact assessment for each of the topic areas identified in the SRA. The main uncertainties identified in the SRA relating to radiation health risk evaluation are:

- the magnitude of cancer risk at low and protracted doses below 100 mSv,
- the magnitude of non-cancer effects below 500 mSv,
- the variation in disease risk between individuals in the population.

Within these broad areas the MELODI SRA defines six key areas for further research:

- To explore the shape of the dose-response relationship for radiation-induced health effects (*Shape*)
- To understand the potential impact of individual susceptibility on radiation-induced health effects (*Susceptibility*)
- To identify, develop and validate biomarkers for exposure, early and late effects for cancer or/and non-cancer diseases (*Biomarkers*)
- To explore and define the role of epigenetic modifications in radiation-induced health effects (*Epigenetics*)
- To explore the roles of specific target cells for radiation-induced late developing health effects (*Target cells*)
- To understand the health effects of inhomogeneous dose distributions, radiation quality and internal emitters (*Inhomogeneity*)

The priorities were evaluated with respect to feasibility and impact in three different time periods (<5, 5-10 and 10+ years) and three different dose ranges. Feasibility was defined as the availability of relevant methods and techniques, and capacity within Europe to do the work. Impact was defined as the likelihood that results on the topic will inform judgements in the radiation protection system, and

specifically the scientific evidence underpinning radiation protection, in this time period. The dose range categories were defined as an external exposure of 0-10 mGy (very low), 10-100 mGy (low) and 100+ mGy (moderate) with respect to the first five topics and as an effective dose of 0-10 mSv (very low), 10-100 mSv (low) and 100+ mSv (moderate) for the topic 'dose inhomogeneity' . The final feasibility and impact score is defined as the feasibility score multiplied by the impact score (range: 1 to 9).

Results of the scoring of the feasibility and impact with a specific focus on cancer that was carried out by individual members of the MELODI SRA working group followed by discussion in the entire SRA WG to reach a consensus score are shown in the table below. The short-term time scale is considered as less than 5 year, medium-term as 5-10 years and long-term as 10 or more years.

Evaluation	**Feasibility**			**Impact**			**Score**		
Time scale	**Short-term**	**Mid-term**	**Long-term**	**Short-term**	**Mid-term**	**Long-term**	**Short-term**	**Mid-term**	**Long-term**
100 – 1000 mGy									
Shape	3	3	3	2	2	2	6	6	6
Epigenetics	3	3	3	2	2	1	6	6	3
Biomarkers	2	3	3	2	2	2	4	6	6
Target cells	2	3	3	2	2	2	4	6	6
Susceptibility	3	3	3	3	3	2	6	9	6
Inhomogeneity	2	3	3	2	3	2	4	9	6
10 – 100 mGy									
Shape	1	2	3	3	3	3	3	6	9
Epigenetics	2	3	3	3	3	2	6	9	6
Biomarkers	2	2	3	2	3	2	4	6	6
Target cells	1	2	3	2	2	3	2	4	9
Susceptibility	2	2	3	3	3	3	6	6	9
Inhomogeneity	2	2	3	3	3	3	6	6	9
0-10 mGy									
Shape	1	1	2	3	3	3	3	3	6
Epigenetics	1	2	3	3	3	3	3	6	9
Biomarkers	1	2	2	2	2	2	2	4	4
Target cells	1	2	3	3	3	3	3	6	9
Susceptibility	1	2	3	3	3	3	3	6	9
Inhomogeneity	1	1	2	3	3	3	3	3	6

Time Scale	short-Term: < 5 years, Mid-Term: 5 -10 years, Long-term: 10 or more years
Feasibility	(1= low, 2=medium, 3 =high)
Impact	(1= low, 2=medium, 3 =high)
SCORE	Feasibility Score times Impact Score (range 1 to 9)

The results have also been plotted to provide a better visual representation of anticipated trends with time. In short-term, research to understand the potential impact of individual susceptibility on radiation-induced health effects was considered most likely to yield useful information on radiation risks, but only if conducted after moderate exposures (above 100 mGy). By time, it is expected that useful information can be obtained at lower exposure levels, in particular for epigenetic effects, target cells, inhomogeneous dose distributions and shape of dose response.

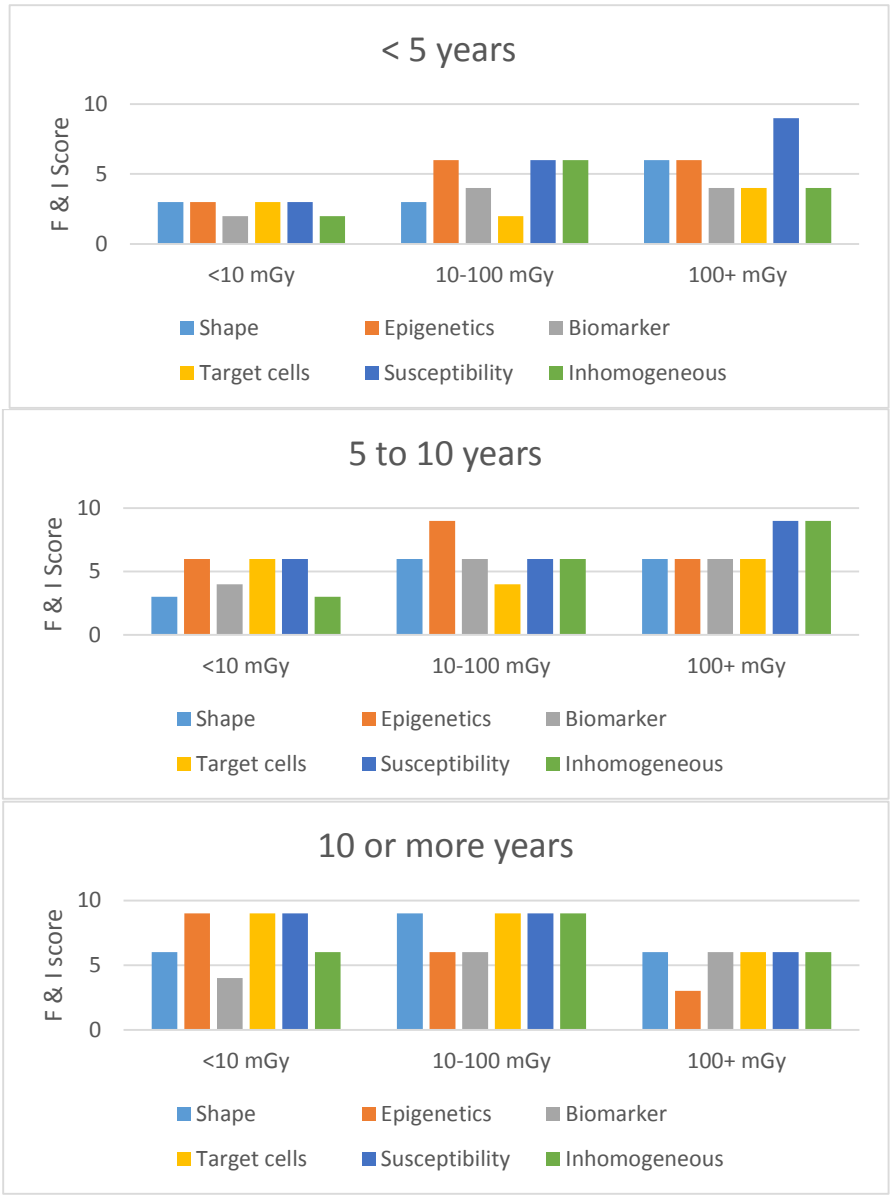


Figure 1: Feasibility and impact score for six MELODI research topics for three different dose ranges (NB where high LET radiation is under consideration dose ranges are in mSv) for the short-term (<5 years) (upper figure), mid-term (10-15 years) (middle figure) and long-term (10+ years) bottom figure.

The feasibility-impact assessment of the six major MELODI topics provides a tool to plan research for the next years for different dose ranges. A separate assessment can be made for different diseases (cancer, circulatory diseases, etc.) if needed. Decisions on priorities for next calls, may additionally take into account, (1) whether specific topics have been recently funded and results are not yet available, and (2) potential synergy with topics of other platforms.

Further work on the MELODI roadmap was suspended pending the development of the joint platforms roadmap in the CONCERT European Joint Programme.

3. The long-term roadmap for research on radioecology (ALLIANCE)

Background elements - In 2009, the European Radioecology Alliance (ALLIANCE: http://www.er-alliance.eu/) was formed as an association open to organisations with interest in supporting radioecological science. Members of the ALLIANCE recognised that their shared radioecological research could be enhanced by efficiently pooling resources among its partner organisations and prioritising group efforts along common themes of mutual interest. To assist in this prioritisation process, a Strategic Research Agenda (SRA) was developed in 2012 within the EC-funded Network of Excellence in radioecology STAR (Strategy for Allied Radioecology), in collaboration with the ALLIANCE (1). The draft SRA was launched to the wider research community for critical review and recommendations through a questionnaire and dedicated workshop. The stakeholders input expressed through more than 100 comments was incorporated into an updated version of the SRA, published in September 2013 (2). The development of the SRA for radioecology has therefore been supported by a large fraction of the radioecological community and by major international organisations (including IUR, UNSCEAR, ICRP, IAEA, NEA). The radioecology SRA highlights 3 Scientific Challenges, with 15 associated research lines, as a strategic vision of what radioecology can achieve in the future via a world-wide prioritization of efforts.

The SRA challenge-related approach and expected outcomes are:
For Challenge 1: To Predict Human and Wildlife Exposure in a Robust Way by Quantifying Key Processes that Influence Radionuclide Transfers and Exposure.

- *Approach*: Improve human and environmental dose and impact assessment by mechanistic/process-based modelling of environmental transfer and exposure in the biosphere.
- *Expected outcome*: Fit-for-purpose environmental models to support human and wildlife impact assessment and risk management.

For Challenge 2: To Determine Ecological Consequences under Realistic Exposure Conditions

- *Approach*: Unravel causes and mechanisms of radiation induced effects in wildlife from molecular to individual levels up to populations.
- *Expected outcome*: Knowing causes of biological effects to detect early damages and to protect populations.

For Challenge 3: To Improve Human and Environmental Protection by Integrating Radioecology

- *Approach*: Improve risk characterisation by better quantification of uncertainty and variability of exposure and effects.
- *Expected outcome*: An integrated approach to enhanced risk characterisation and communication (connecting science, economy & society).

These elements constitute the basis for driving our research activities.

The mechanisms used for elaborating the global roadmap - Under the COMET (COordination and iMplementation of a pan-European instrumenT for radioecology) European project, with the support of the ALLIANCE, a first-phase roadmap and associated implementation plan was developed at the end of 2013 (3).

The first phase radioecology RTD roadmap (5 years) was based on the 3 challenges and associated 15 research lines established within the ALLIANCE SRA. Several key-research activities were identified and discussed within the COMET Steering Committee (Oct 2013) which included representatives of the other radiation protection research platforms (MELODI, NERIS), and was endorsed by the ALLIANCE. The COMET Steering Committee suggested the development of a 5-year research strategy, which

included the dictation of the final criteria used to select key research priorities in radioecology (Table 1). A more realistic roadmap in terms of time and scoping needed to be built and implemented.

Table 1: Final list of criteria for key radioecology research prioritization.

Broad Area	Specific criterion	Comments
Impact	*Substantial enhancement of knowledge*	Required to give confidence to stakeholders and provide an improved capability giving greater confidence in decision making.
	Addresses major unresolved issues relevant to radiological protection	Ensures that the overall enhancement of knowledge is directed to the specific requirements of the radiological protection community.
	Practical applicability	Results can be used directly or readily adapted for use by legislators, regulators, operators and other interested parties
	Public relevance	Seen to be addressing issues of public interest or concern.
Achievability	*Realistic on a five-year timescale*	Or at least feasible to undertake in stages, so that well-defined interim goals can be achieved and demonstrated within five years.
	Sufficient guaranteed capacity	Sufficient internal resources within the ALLIANCE to deliver a useful product even in the absence of external funding.
	Adequate basis in current knowledge and experience	Builds on existing knowledge and makes use of experience and facilities that are available within the research community.
	Appropriate level of risk of failure	Suitable balance between high risk and low risk components, i.e. there is a need to ensure that some useful outcome is delivered, but this should not stifle the need to undertake speculative work that could lead to a high return if it is successful.
Relevance & public perception	*High relevance for protection of humans*	Implies a focus on the radionuclides and pathways that contribute most to doses to humans in a variety of assessment contexts.
	High relevance for the protection of wildlife	Includes consideration of biodiversity, ecosystem performance and health, sustainability and protection of endangered species. Again, implies a focus on key radionuclides and pathways in a variety of assessment contexts.
	Relevant to research initiatives in areas outside radioecology	These research initiatives include studies on the effects of low doses, developments in emergency planning and preparedness and dosimetry.
	Addresses major unresolved issues relevant to radiological protection	Duplicates the corresponding item under impact, so could be deleted in one or the other instance.
	Important and relevant	Are the results to be obtained of importance from a public perspective (irrespective of their significance for radiological protection? Are results of relevance to an issue of great public interest. Will results be of direct relevance to members of the public in enhancing their understanding of a given situation and informing their decision making.
	Convincing	Has provision been made to demonstrate why a member of the public should place credence in the results to be obtained, e.g. by explaining the background to the work in appropriate language and showing how it fits within a broader body of scientific knowledge?
Good science	*Logical development*	Builds on existing understanding and addresses a generally recognised deficiency in that understanding (e.g. due to lack of data or an appropriate conceptual model of the processes and mechanisms of relevance).
	Hypothesis driven	The research should be targeted to support or refute one or more hypotheses of importance for understanding the issue being considered.
	Innovative	In so far as innovation enhances our ability to answer the key questions posed by the research topic.

The ALLIANCE organised a workshop (April 2014) to identify the on-going research activities and present fields of excellence of each ALLIANCE member. Alongside with research activities funded by EC under STAR and COMET, this constituted the basic information to identify groups of interest per challenge/research line of the SRA. ALLIANCE members were asked at that meeting to show their interests and expertise in the priority research areas identified in COMET D2.1 and D3.1 (3, 4). ALLIANCE members were also asked for additional research lines for which common interest could be expected. Known international activities were also considered.

It was decided to develop short-term (5 years) roadmaps for a limited number of research topics identified as priorities for the radioecology community (5). The topical roadmaps included:

- Marine radioecology.
- Human food chain modelling.
- Naturally Occurring Radioactive Materials (NORM) Radioecology.
- Transgenerational effects and species radiosensitivity.
- Atmospheric dispersion and transfer processes.

The topical roadmaps were started in COMET and continue through the ALLIANCE. Each of them expresses a clear view on the 5-y work plan associated to the specific priority topic, and defines concrete and achievable activities (6). The ALLIANCE Working Group "SRA-Roadmap" will evaluate and revise annually the topical roadmaps, and determine if new topics need to be addressed.

The participants in the ALLIANCE SRA-Roadmap Working Group, coordinated by J. Garnier-Laplace (IRSN, France), are: C. Adam-Guillermin (IRSN, France); T. Arnold (HZDR, Germany); N. Beresford (NERC-CEH, UK); C. Duffa (IRSN, France); N. Horemans (SCK•CEN, Belgium); O. Masson (IRSN, France); C. Berthomieu (CEA, France); L.Currivan (EPA, Ireland); P. Krajewsky (CLOR, Poland); F. Legarda (UPV-EHU, Spain); B. Michalik (GIG, Poland); M. J. Madruga (IST, Portugal); M.Merroun (UGR, Spain); M. Muikku (STUK, Finland); J. Popi (NRPA, Norway); A. Real (CIEMAT, Spain); S. Sachs (HZDR, Germany); B. Salbu (NMBU, Norway); M.Steiner (BfS, Germany); J. Tschiersch (HMGU, Germany); H. Vandenhove (SCK•CEN, Belgium); M. Vidal (UB, Spain).

In April 2017, the ALLIANCE organized the workshop "*Radioecology prepares its future in the European landscape: Topical roadmaps, Update of the strategic research agenda, for ALLIANCE and the CONCERT umbrella*". The objectives of the workshop were, among others, to discuss the future of the existing ALLIANCE topical roadmap WGs, and to prepare the elements of the ALLIANCE global roadmap due end of November 2017 under CONCERT WP2. In addition to the ALLIANCE members, a representative of the COMET Steering Committee, and three observers from Japan participated in the workshop. It was suggested that the topical roadmaps should be evaluated by stakeholders as input to / to better guide the future needs and activities.

Thus, in September 2017 the ALLIANCE organised an External Stakeholders Advisory Board Meeting, to perform an external evaluation and review of the topical roadmaps that are under implementation and the global roadmap on Radioecology to be produced within CONCERT WP2.

The following External Stakeholder Advisory Board (ESAB) members participated in the meeting: Geert Biermans (Federal Agentschap voor Nucleaire Controle, Belgium); Philippe Ciffroy (Électricité de France, France); David Copplestone (University of Stirling, UK); Ted Lazo Nuclear Energy Agency (NEA/OECD); Susan Molyneux-Hodgson (University of Exeter, UK).

The main comments of the ESAB to the topical roadmaps were:

- Include a "state of the art" description for each topical roadmap, describing current knowledge and identifying gaps in each topic.
- In order to articulate a "mechanism" by which the scientific knowledge can be efficiently transferred to regulators, industry, etc., each topical roadmap should include specific examples on how they can solve problems, demonstrating their usefulness.
- There is a need to define short-term (5 years) "useful deliverables" in each topical roadmap, in addition to long-term outputs. Key priorities in each topical roadmap need to be stated.
- To homogenise the structure of the five topical roadmaps, it was suggested to perform a SWOT analysis (Strengths, Weaknesses, Opportunities, and Threats), which could help to identify the major research needs (Annex 1 illustrates the content of such SWOT analysis).
- The roadmaps are the "tools" to implement the Strategic Research Agenda (SRA) in radioecology. This has to be made evident in the documents. Linking the roadmaps with the SRA (where within the SRA the topical roadmaps fit), and with the ongoing projects in the field, will show the progress that has been made in a specific topic, which will be very valuable for the funding agencies.

The building blocks of the global roadmap - Each topical roadmap has scheduled its research activities across the 2015-2030 timeline and the Technology Readiness Level of each major research activity (adapted from TRL scales - from "basic research" to "ready to use"), giving visibility on what to go on and what to stop, on how to make use of infrastructures/observatory sites, etc. Activities are justified with drivers (Improve RP) and target/goals (Annex 1).

For ALLIANCE, the topical roadmaps are primary elements to develop the radioecology global roadmap.

The **global roadmap for radioecology** aims to be a global picture of the main achievements planned for the next 15-30 years. It will help in giving visibility to priority research to be implemented consistently with stakeholders' needs and request for associated external funds (7). In addition, it will ensure that the topical Roadmaps are translated effectively into funded research programmes, with funding at national and international levels.

The ESAB made the following comments on the global radioecology roadmap, during the September 2017 meeting:

- The SRA must guide the development of the global roadmap. The SRA described the "state of the art" in radioecology.
- It was suggested to make a SWOT analysis of the 3 SRA challenges, as a first step to develop the global roadmap.
- Important to consider the needs (what is needed and what is not needed) when establishing the priorities in the roadmap.
- A roadmap should be an iterative process.

Following the ESAB advices, ALLIANCE is implementing at present the SWOT analysis that will help to articulate topical roadmaps and potential missing elements outcoming from a gaps analysis under preparation, into a second version of the global roadmap. The latter will establish a time line for all the justified research priorities, taking into account the European funding opportunities (on going EJP CONCERT (2015-2020), Euratom WP 2018, WP 2019-2020, FP9). Additionally, the second version of the ALLIANCE global roadmap will make use of two scenarios with societal concerns that were developed in the frame of the CONCERT WP3 activities:

- Biological and ecological effects of low dose/low dose rate exposure of living organisms;
- Integration and harmonisation of environmental exposure assessment for ionising radiation and other stressors.

References

1. STAR D2.1. Draft Strategic Research Agenda. April 2012.
2. Strategic Research Agenda for Radioecology: A Second Version with Stakeholder Input. September 2013
3. COMET D2.1. Towards a first phase Radioecology Alliance RTD roadmap and implementation plan as input for the preparation of the Competitive Call organised in collaboration with OPERRA. October 2013
4. COMET D3.1. Detailed plan for the COMET WP3 Initial Research Activity – list of research projects and goals, participants and timing. October 2013.
5. Garnier-Laplace J., Vandenhove H., Beresford N., Muikku M., Real A. 2017. COMET strongly supported the development and implementation of medium-term topical research roadmaps consistent with the ALLIANCE Strategic Research Agenda. *J. Radiol. Prot.* https://doi.org/10.1088/1361-6498/aa9c0a
6. European Radioecology ALLIANCE website - http://www.er-alliance.org/media-centre/publications/radioecology-roadmap/
7. Muikku M., Beresford N., Garnier-Laplace J., Real A., Sirkka L., Thorne M.C., Vandenhove H. and Willrodt C. 2017. Sustainability and integration of radioecology – position paper. *J. Radiol. Prot.* https://doi.org/10.1088/1361-6498/aa9c0b

4. The long-term roadmap for research on nuclear and radiological emergency response and recovery (NERIS)

T. Schneider[1], W. Raskob[3], J. Camps[4], S. Andronopoulos[5], T. Duranova[6], E. Gallego[7], F. Gering[8], O. Isnard[9], M. Maître[2], C. Murith[10], D. Oughton[11], K. Andersson[15], J. Bohunova[6], M-C. Cantone[12], S. Charron[9], P. Croüail[2], C. Turcanu[4], M. Monteiro[13], M. Muikku[14], A. Bexon[16], A. Liland[17].

[1] Chair of NERIS - Nuclear Evaluation Protection Centre - CEPN, 28 rue de la Redoute, 92260 Fontenay-aux-Roses, France - e-mail: thierry.schneider@cepn.asso.fr
[2] CEPN, France
[3] KIT, Germany
[4] SCK-CEN Mol, Blegium;
[5] NCSR Demokritos, Greece;
[6] VUJE, Slovak Republic;
[7] UPM, Spain;
[8] BfS, Germany;
[9] IRSN, France;
[10] FOPH, Switzerland;
[11] NMBU/CERAD, Norway;
[12] UMIL, Italy ;
[13] CIEMAT, Spain ;
[14] STUK, Finland;
[15] DTU, Denmark;
[16] PHE, UK;
[17] NRPA, Norway.

In September 2017, NERIS has adopted its first roadmap for further research development in emergency and recovery management. This document has been developed by the R&D Committee and the Management Board of NERIS with consultation of all NERIS members. The current version was finally discussed at an open workshop in September 2017.

To define this first Roadmap, NERIS members relied on the last developments and the preliminary lessons learned following the management of the Fukushima accident, as well as on two scenarios with societal concern that were developed in the frame of the CONCERT WP3 activities:

- Facing the consequences of a nuclear or radiological major accident or incident: how to optimize society's preparedness, and short term/long term response?
- Facing the threat of a radiological terrorist act: How to minimize consequences?

In a second step, the research activities defined within the Strategic Research Agenda (SRA) of NERIS from 2017 were also taken into account.

SOME LESSONS FROM FUKUSHIMA

The management of the consequences of the Fukushima accident highlighted the importance of providing a good transparency of the decision-making processes at the local, regional and national levels. It also pointed out the key role of the access to environmental monitoring at local, national and international levels, meaning that measurements have to be available and as much as possible understandable by the different stakeholders as well as that there is a need to provide access to individual devices for performing measurements at the local levels. Although it was already identified in the long-term management of the Chernobyl accident, the availability of new devices has proven the need for developing new monitoring approaches even in the early phase of the accident.

Furthermore, although large developments have been achieved following the Chernobyl accident to improve the assessment and management of the consequences of the accident and to identify the efficiency of countermeasures and countermeasures strategies, it occurs that significant uncertainties still exist and have to be addressed to improve the assessment and management of the different phases of the accident.

The extensive exchange of information through the social media just after the Fukushima accident has created a new situation implying for the experts in radiation protection to reorganise the process of dissemination of information. This new situation creates a challenge for producing accessible information to a large public and to organise the moderation of forum of exchange allowing people to give their opinion on a series of situations at stake during the different phases of the accident.

The Fukushima accident has clearly emphasized the role of stakeholders in both emergency and recovery situations. For improving the efficiency and the sustainability of the protective actions, engaging stakeholders in the decision-making processes and empowering them to contribute to the assessment of the situation have been acknowledged as crucial although quite demanding for the experts who have therefore to learn how to dialogue with the local stakeholders. In addition, the need to further consider societal, ethical and economic aspects in emergency and recovery management has been pointed out. It also emphasizes the usefulness of reinforcing Education & Training for various actors.

Main challenges identified in the NERIS roadmap

For elaborating its roadmap, NERIS discussed the challenges and the research activities to identify research priorities and endpoints/visions over a longer period. To structure the research work, activities have been split into three time intervals:

0 – 5 years (related to CONCERT topics)

6 – 10 years (any new research program)

> 10 years (focus on research and operational needs)

Based on lessons learnt from Fukushima, the scenarios and the SRA, research needs identified covered emergency and recovery issues. Furthermore, the three main challenges identified in the SRA became the key challenges of the NERIS roadmap:

1. Challenges in radiological impact assessment during all phases of nuclear and radiological events
2. Challenges in countermeasures and countermeasure strategies in emergency & recovery, decision support and disaster informatics
3. Challenges in setting-up a trans-disciplinary and inclusive framework for preparedness for emergency response and recovery

For each of the challenges, Key topics and subtopics– as introduced in the SRA – were defined and populated with research needs for the three time intervals: up to five years, 6 – 10 years and beyond

10 years. For the better structuring, a research "vision" has been defined for each subtopic within a particular Key topic for each of the challenges. That vision can be seen as our goal for that research area. The challenges, together with the identified key topics and subtopics, are given below:

1. **Challenges in radiological impact assessment during all phases of nuclear and radiological events**

Improvement of modelling

- Applicable in all environments (urban, agricultural, forests, etc.) world-wide, including uncertainties
- Improved foodchain models
- Models for assessing the exposure of the public, of emergency workers and helpers

Improvement of monitoring

- New devices, techniques and guidelines for monitoring in Europe being harmonised
- Optimise all potential emergency scenarios

Development of data assimilation

- Improved capabilities to estimate source locations and source terms
- Improved capabilities to assess the radiological situation
- Combined tools for improved decision making using Big Data capabilities within Decision Support Systems

2. **Challenges in countermeasures and countermeasure strategies in emergency & recovery, decision support and disaster informatics**

Better knowledge on countermeasures and countermeasures strategies

- Further analysis of the efficiency of available countermeasures and countermeasures strategies for the different phases of an accident
- Development of methodological framework for the implementation and lifting of countermeasures

Improvement of formal decision support

- Integration of the new methodological development on decision making process into decision support tools
- Further development on the management of uncertainties in decision making

New development in disaster informatics

- Further development of analytical platform
- Development of knowledge databases
- New generation of DSS and integration of virtual and augmented reality

3. Challenges in setting-up a trans-disciplinary and inclusive framework for preparedness for emergency response and recovery

Further development of emergency and recovery framework

- Integration of reference levels and operational levels
- Better addressing transition and long-term phases into the framework,
- Further development on the management of contaminated goods (food and non-food)

Elaboration of strategies for stakeholder engagement, involvement and public participation

- Analysis and guideline for stakeholder and public engagement processes
- Guideline for integrating citizen science in radiological risk governance
- Better addressing communication issues including social media

Development of an integrated emergency management including non-radiological aspects

- Improving health surveillance programme
- Better addressing socio-economic and ethical aspects in decision making processes
- Guideline for the development of radiological protection culture

Better addressing uncertainties and managing incomplete information

- Guidance framework and advanced tools to better identify, address and communicate uncertainties
- Guidance on the role of social media
- Development of education and training

The current NERIS roadmap is developed in the accompanying word document, which further details visions associated with each key research topics as well as the division of research needs for the three time intervals: up to five years, 6 – 10 years and beyond 10 years. It is anticipated that this first version of the NERIS Roadmap will change in the following years by taking into account new comments and proposals from the NERIS Community.

The full NERIS Roadmap (Version November 20, 2017) is provided in Annex 2.

5. Development of EURADOS Roadmaps

Roger Harrison[1], Joao Alves[2], Isabelle Clairand[3], Phil Gilvin[4], Željka Knežević[5],Weibo Li[6], Maria Antonia Lopez[7], Rick Tanner[4], Isabelle Thierry-Chef[8], Arturo Vargas[9], Clemens Woda[6]

[1]Faculty of Medical Sciences, Newcastle University, Newcastle, United Kingdom
[2]Instituto Superior Técnico (IST), CTN, Portugal
[3]Institute for Radiological Protection and Nuclear Safety (IRSN), France
[4]Public Health England (PHE), Chilton, Didcot, United Kingdom
[5]Ruđer Bošković Institute (RBI), Zagreb, Croatia
[6]Helmholtz Centre Munich, Institute of Radiation Protection (HMGU), Neuherberg, Germany
[7]Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas (CIEMAT), Madrid, Spain
[8]Barcelona Institute for Global Health, Barcelona, Spain
[9]Universitat Politècnica de Catalunya (UPC), Barcelona, Spain

Following the publication of the EURADOS Strategic Research Agenda (SRA) (1,2[1]), the EURADOS Council has proceeded with the generation of associated roadmaps by a group consisting of the authors listed above, coordinated by Roger Harrison. The EURADOS SRA is composed of five Visions. Each Vision is made up of several Challenges which are further described in terms of research lines. The Visions and Challenges, together with the lead authors for the development of roadmaps for each Vision, are given below:

Vision 1: Towards updated fundamental dose concepts and quantities

(Rick Tanner)

Challenges:

(i) To improve understanding of spatial correlations of radiation interaction events
(ii) To establish correlations between track structure and radiation damage
(iii) To improve understanding of radiation-induced effects from internal emitters
(iv) To update operational quantities for external exposure

Vision 2: Towards improved radiation risk estimates deduced from epidemiological cohorts

(Isabelle Thierry-Chef)

Challenges:

(i) To improve exposure pathways not yet considered or validated
(ii) To improve retrospective dosimetry for exposure pathways already considered

[1] References

1. Visions for Radiation Dosimetry over the Next Two Decades – Strategic Research Agenda of the European Radiation Dosimetry Group. EURADOS Report 2014-01
W. Rühm, E. Fantuzzi, R. Harrison, H. Schuhmacher, F. Vanhavere, J. Alves, J.F. Bottollier-Depois, P. Fattibene, Ž. Knežević, M.A. Lopez, S. Mayer, S. Miljanić, S. Neumaier, P. Olko, H. Stadtmann, R. Tanner, C. Woda. ISSN 2226-8057. ISBN 978-3-943701-06-7

2. W. Rühm, E. Fantuzzi, R. Harrison, H. Schuhmacher, F. Vanhavere, J. Alves, J. F. Bottollier Depois, P. Fattibene, Ž. Knežević, M. A. Lopez, S. Mayer, S. Miljanić, S. Neumaier, P. Olko, H. Stadtmann, R. Tanner, and C. Woda. EURADOS Strategic Research Agenda: Vision for Dosimetry of Ionising Radiation. Radiat Prot Dosimetry. 2015 1-12

Vision 3: Towards an efficient dose assessment for radiological emergencies

(Maria Antonia Lopez, Clemens Woda)

Challenges:

(i) To identify and characterize new markers of exposure
(ii) To develop strategies and methods to increase measurement capacity
(iii) To quantify doses after accidental internal contamination

Vision 4: Towards integrated personalized dosimetry in medical applications

(Roger Harrison, Weibo Li, Željka Knežević)

Challenges:

(i) To improve out-of-field dosimetry for photon and particle therapy
(ii) To improve dosimetry in modern external beam radiotherapy
(iii) To develop microdosimetric models for imaging and radiotherap
(iv) To optimize dose and risk estimations in interventional radiology
(v) To establish reliable patient dosimetry in CT examinations

Vision 5: Towards improved radiation protection of workers and the public

(Maria Antonia Lopez, Isabelle Clairand, Arturo Vargas)

Challenges:

(i) To implement new biokinetic models for intake of radionuclides
(ii) To develop calibration procedures for partial body counters
(iii) To develop accurate and on-line personal dosimetry for workers
(iv) To improve neutron dosimetry techniques
(v) To include nuclide-specific information in dose rate measurements in the environment

There are two other important parts of the EURADOS mission for which roadmaps have also been developed: (i) **Training and education actions** (Joao Alves) and (ii) **Harmonisation of dosimetric practices in Europe** (Phil Gilvin).

Roadmaps may take several forms and after consideration of some examples given by Sisko Salomaa (CONCERT meeting, Budapest, 9 March 2017), it was decided to adopt a format similar to that of EURAMET, rather than that used by the High Level and Expert Group (HLEG). This was because the EURAMET format and the EURADOS SRA consider only scientific objectives as a function of time, rather than include additional resource implications. This format is also amenable to the schematic display of the key research lines.

In the EURADOS roadmaps, three levels of activity are identified:

(i) *Drivers*. These are the fundamental reasons for the Visions or Challenges
(ii) *Targets.* These are the main scientific objectives for the Challenges
(iii) *Experimental & computational realisation*. These are the more specific research lines for the targets as discussed in the EURADOS SRA.

The current status of roadmap development is shown in Annex 3, which gives roadmaps for most Visions and Challenges. It is anticipated that some refinements and changes will be made following the next review of the EURADOS SRA. These roadmaps will form the basis of a general EURADOS roadmap which takes into account further factors necessary for accomplishing the long-term goals.

Roger Harrison on behalf of EURADOS Council 26/11/2017

ANNEX 1: ELEMENTS OF THE ALLIANCE ROADMAP

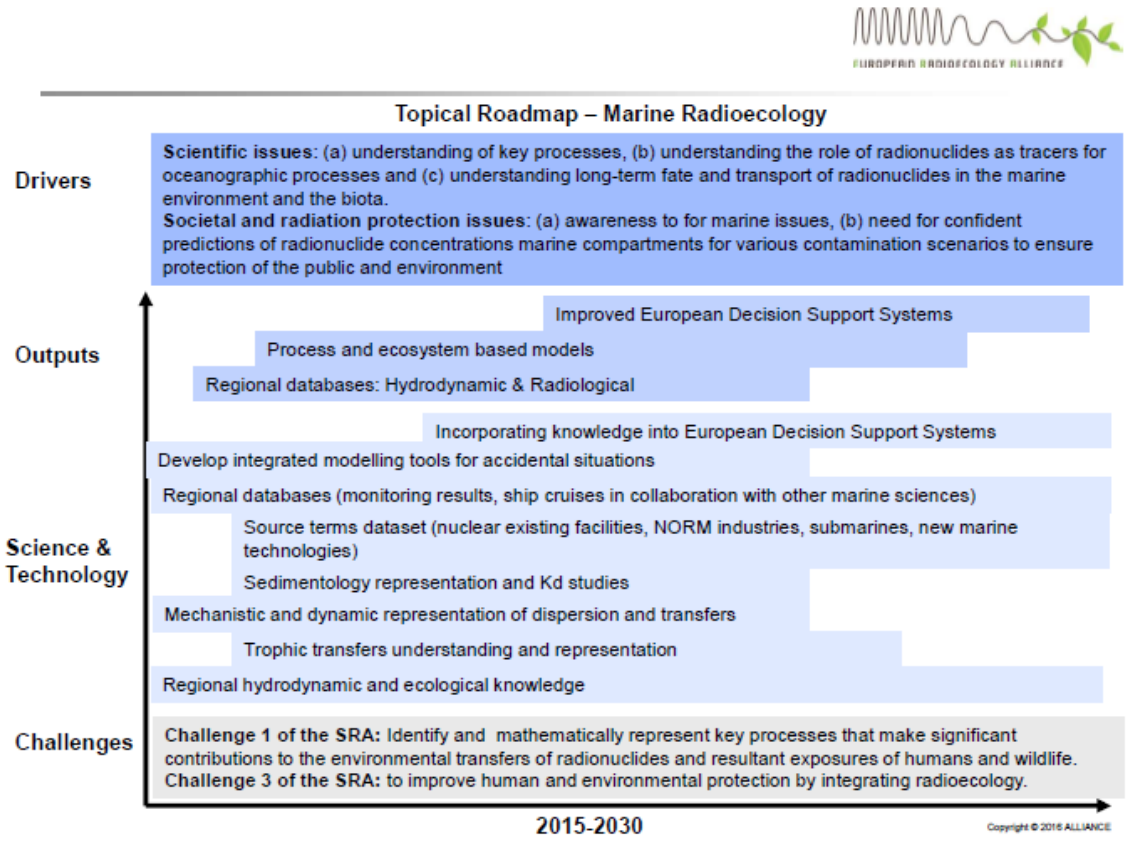
SWOT ANALYSIS

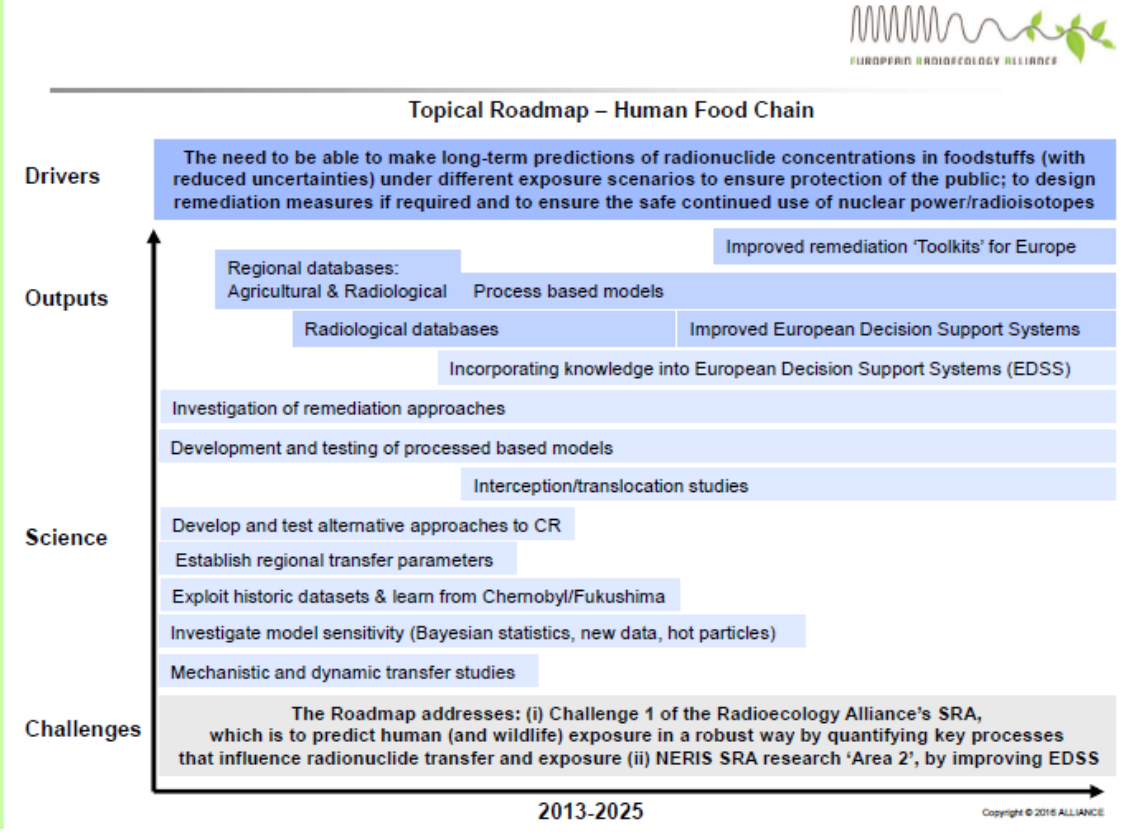
Meaning of the SWOT terms, taking as an example the atmospheric radionuclides in transfer processes roadmap:

- Strengths: What are we able to do? We can model atmospheric dispersion of radionuclides.
- Weaknesses: What are we not able to do? Ex. Now we can't model deposition in snow.
- Opportunities: If science could help to answer these gaps; interaction with other disciplines that will allow to solve the problems; learn from chemicals if they have solved a similar problem, etc.
- Threats: An accident in winter in Siberia; public perception; politicians.

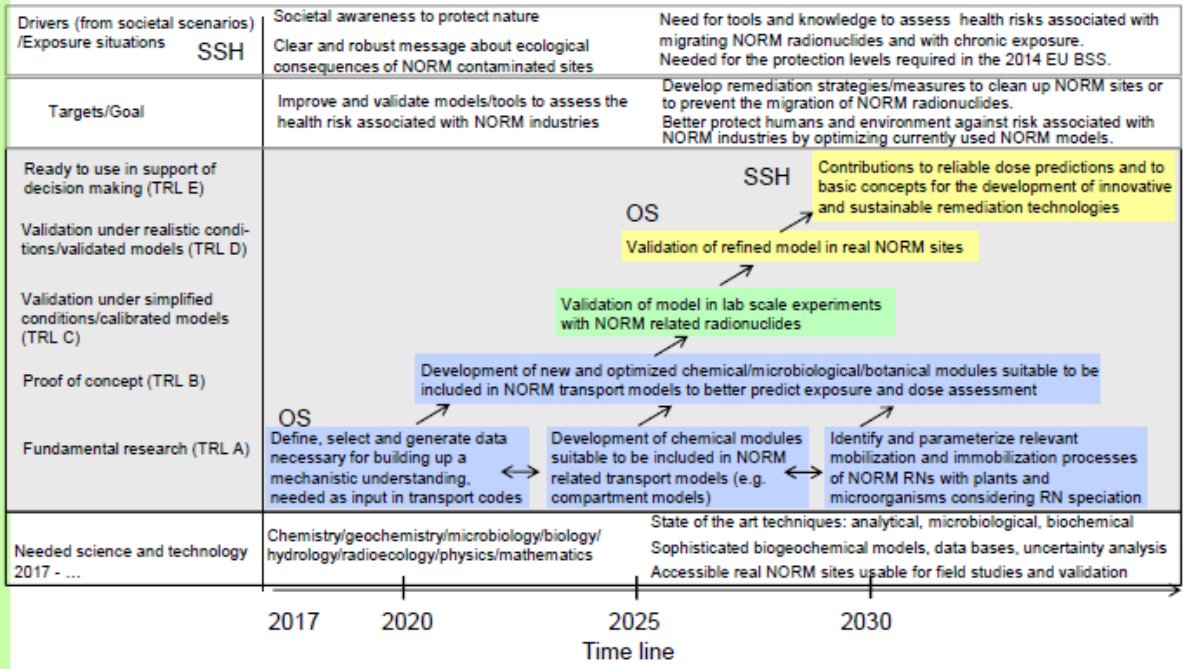
Strengths **What do we have? Models/tool/people** E.G. *Generally well established dispersion models in terrestrial environments*	**Weaknesses** **We are not able to model / to measure / to understand…..** E.G. *We do not know long-term accumulation of RN in estuaries*
Opportunities **Scientific new opportunity we weren't able to do this before but now we can because of advances** **Could science help to fill the gap** E.G. *Advances in molecular biology may help elucidate the mechanisms at the basis of effects shown at individual/population level.*	**Threats** **If we do nothing, what are the consequences?** **What is great for decision making?** E.G. *If accident in winter with deposition on snow, and if we do not know to model dispersion after deposition on snow, this may result in some unknown accumulation and hence be a treat to some local groups* E.G. *We do not know long-term accumulation of RN in estuaries -> breeding ground for wildlife with potential impact+ potential impact on man via food chain*

SCHEME OF EACH TOPICAL ROADMAP ACTIVITIES ACROSS THE 2015-2030 TIMELINE

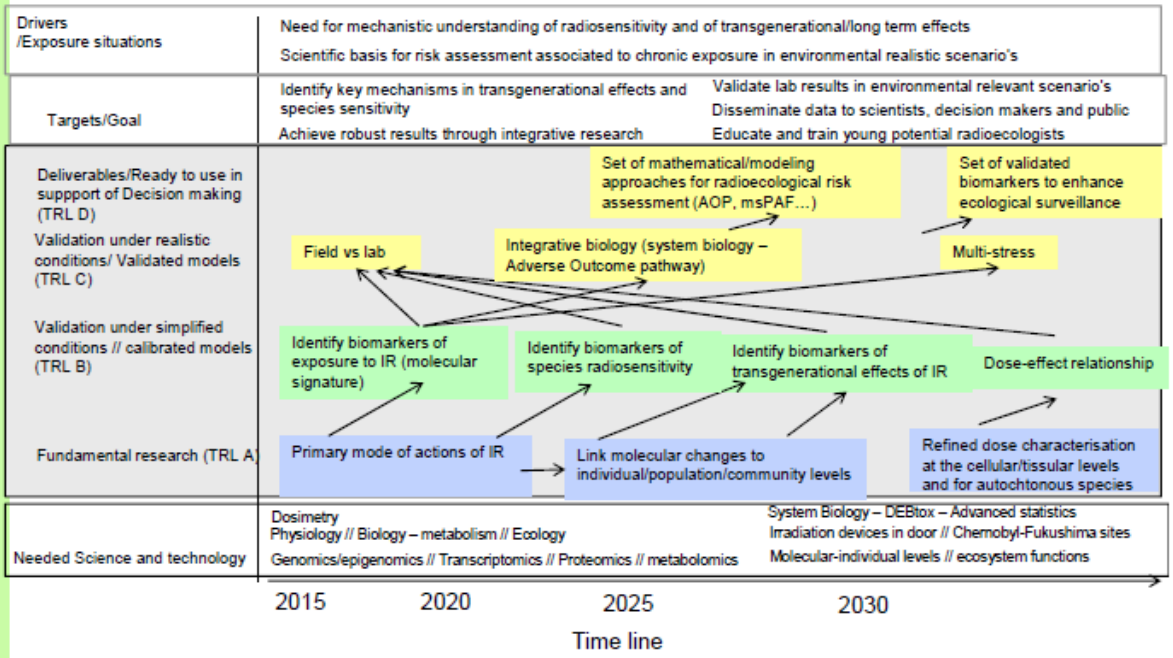


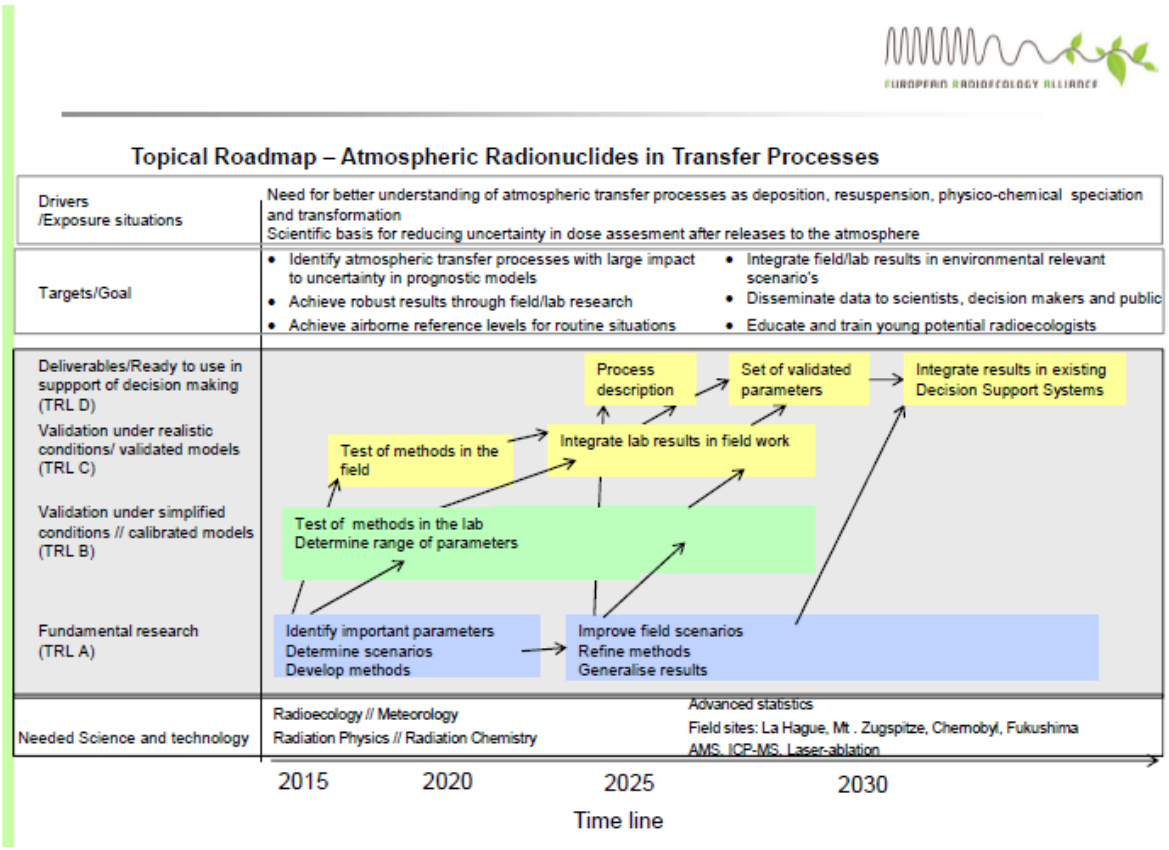


Topical Roadmap - NORM Radioecology



Topical Roadmap - Transgenerational Effects and Species Radiosensitivity




Topical Roadmap – Atmospheric Radionuclides in Transfer Processes
Drivers /Exposure situations
Need for better understanding of atmospheric transfer processes as deposition, resuspension, physico-chemical speciation and transformation
Scientific basis for reducing uncertainty in dose assesment after releases to the atmosphere
Targets/Goal
Identify atmospheric transfer processes with large impact to uncertainty in prognostic models
Achieve robust results through field/lab research
Achieve airborne reference levels for routine situations
Integrate field/lab results in environmental relevant scenario's
Disseminate data to scientists, decision makers and public
Educate and train young potential radioecologists
Deliverables/Ready to use in suppport of decision making (TRL D)
Validation under realistic conditions/ validated models (TRL C)
Validation under simplified conditions // calibrated models (TRL B)
Fundamental research (TRL A)
Process description
Set of validated parameters
Integrate results in existing Decision Support Systems
Test of methods in the field
Integrate lab results in field work
Test of methods in the lab
Determine range of parameters
Identify important parameters
Determine scenarios
Develop methods
Improve field scenarios
Refine methods
Generalise results
Needed Science and technology
Radioecology // Meteorology
Radiation Physics // Radiation Chemistry
Advanced statistics
Field sites: La Hague, Mt . Zugspitze, Chernobyl, Fukushima
AMS, ICP-MS, Laser-ablation
2015
2020
2025
2030
Time line

ANNEX 2. NERIS ROADMAP

NERIS ROADMAP

Version November 20, 2017

Introduction

As part of the CONCERT WP2 activities, it is expected to develop a roadmap for NERIS. This roadmap has also to be considered for the elaboration of a common roadmap of the 5 research platforms involved in CONCERT.

For this purpose, the initial work was the development of the two scenarios with societal concern related to NERIS issues:

Facing the consequences of a nuclear or radiological major accident or incident: how to optimize society's preparedness, and short term/long term response?
Facing the threat of a radiological terrorist act: How to minimize consequences?
These scenarios allow to identify research priorities, in line with the on-going update of the SRA. The aim of the roadmap is to develop research endpoints for three time periods:

- 0 – 5 years (related to CONCERT topics)
- 6 – 10 years (any new research program)
- 10 years (is there a combination of research and operational needs)

The identification of the research needs has to cover emergency and recovery issues. The following definitions are provided to clarify the goals of each situation.

Emergency situation

The IAEA has defined (IAEA Safety Standards) the main goals of nuclear and radiological emergency response:

- to regain control of the situation;
- to prevent or mitigate consequences at the scene;
- to prevent the occurrence of deterministic health effects (tissue reactions) in workers and the public;
- to render first aid and manage the treatment of radiation injuries;
- to prevent, to the extent practicable, the occurrence of stochastic health effects in the population;
- to prevent, to the extent practicable, the occurrence of adverse non-radiological effects on individuals and among the population;
- to protect, to the extent practicable, the environment and property;
- to prepare, to the extent practicable, for the resumption of normal social and economic activity.

Recovery situation

According to ICRP, the main goals for the recovery situations are defined hereafter:

The management of an existing exposure situation, corresponding to recovery, following a nuclear accident relies on the implementation of an integrated and complex rehabilitation programme that considers numerous dimensions.
The radiological protection part of this programme is characterised by strategies that include actions implemented by:

- The authorities at national and local level
- As well as self-help protective actions taken by the affected population either under their own initiative or within a framework provided and supported by the authorities.

Based on this, 3 major challenge Areas are defined in the updated NERIS SRA:

1. Challenges in radiological impact assessment during all phases of nuclear and radiological events
2. Challenges in countermeasures and countermeasure strategies in emergency & recovery, decision support and disaster informatics
3. Challenges in setting-up a trans-disciplinary and inclusive framework for preparedness for emergency response and recovery

For each of the challenges, Key topics and subtopics– as introduced in the SRA - are defined and will be populated with research needs for three time intervals: up to five years, 6 – 10 years and beyond 10 years. The last category was chosen as the Roadmap aims to define long-term research needs and thus a time frame longer than 10 years has to be discussed.

For the better structure of research “Vision” has been defined for each subtopic within the particular Key topic for each of the challenges that can be seen as our goal for that research area.

Roadmap NERIS Challenge Area 1

Challenges in radiological impact assessment during all phases of nuclear and radiological events

Key topic 1: Improved Modelling

- Atmospheric transport and dispersion modelling (ATM/ADM)
- Hydrological modelling
- Dose models
- Environmental models

Key topic 2: Improved Monitoring

- Monitoring techniques and strategies
- Data collection and sharing
- Optimisation

Key topic 3: Data assimilation

- Improved source term estimation
- Improved impact assessment
- Big Data, Data fusion

Challenges and achievement in	Vision
Radiological impact assessment during all phases of nuclear and radiological events	
Key topic 1: Improved Modelling	
Atmospheric transport and dispersion modelling (ATM/ADM)	ATM/ADM modelling suite that is tested and validated, applicable in all environments (urban, agricultural, forests, etc.) world-wide, including uncertainties
Hydrological modelling	A hydrological model suite that is applicable to inland and coastal areas in Europe, that has improved food chain models and that is closely linked to atmospheric and hydrological boundary conditions worldwide
Dose models	A suite of models for assessing the exposure of the public, of emergency workers and helpers during all phases of the event and based on all available data; including dynamic behaviour of the exposed population
Environmental models	A suite of radioecological models that is fit for purpose in emergency management at all levels including inhabited areas

Key topic 2: Improved Monitoring	
Monitoring techniques and strategies	New devices, techniques and guidelines for monitoring in Europe being harmonised for cross-border application and monitoring information supplied by professionals, NGOs and lay people; Harmonised monitoring strategies for Europe for all phases and for all types of radiological and nuclear events
Data collection & sharing	Comprehensive data base of radiological data for model validation and open for wider use.
Optimisation	Optimise all potential emergency scenarios based on monitors and modelling capabilities
Key topic 3: Data assimilation	
Improved source term estimation	Improved capabilities to estimate source locations and source terms with ATM/ADM as defined in Key Topic 1 and advanced data assimilation
Improved impact assessment	Improved capabilities to assess the radiological situation In all phases of an accident or incident (e.g. medical follow-up or other long-term actions)
Big Data, Data fusion	Combined tools for improved decision making using Big Data capabilities within Decision Support Systems in connection to Challenge Area 2

Key topic 1: Improved Modelling (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Atmospheric transport and dispersion modelling ATM/ADM **VISION**: ATM/ADM modelling suite that is tested and validated, applicable in all environments (urban, agricultural, forests, etc.) world-wide, including uncertainties	• Investigate fluid dynamics modelling and its applicability to nuclear emergency management • Improve models and tools for urban and confined areas • Better quantification of uncertainties from all origins in the ATM/ADM models including operational application of ensemble approaches for uncertainty assessment in ATM/ADM models in collaboration with meteorological services	• Quantification / assessment of ATM/ADM uncertainties applying big data and improved mathematical techniques for complex mathematical approaches	• CFD models and ensemble modelling combined with advanced methods for inverse modelling (in connection to key topic 3) • Non-conventional emissions (explosions, aerosol sprays, fires, etc.)
Hydrological modelling **VISION**: A hydrological model suite that is applicable to inland and coastal areas in Europe, that has improved food chain models and that is closely linked to atmospheric and hydrological boundary conditions worldwide *In close collaboration with ALLIANCE*	• Improvement in marine food web modelling • Urban run-off models • Urban water supply models • Improvement of local coastal models	• Development of mechanism to adapt hydrological models to local conditions • Better approaches for surface runoff • Combination of all components of aquatic modelling into one comprehensive modelling suite • Development of test procedures for such a complete model suite to discuss uncertainties	• Subdivision of dispersion and radiological part (as in atmospheric dispersion). • Link to global hydrological models, improved run-off models • Comprehensive aquatic model suite fit for emergency management and validated with reduced uncertainty

Dose models **VISION:** A suite of models for assessing the exposure of the public, of emergency workers and helpers during all phases of the event and based on all available data; including dynamic behaviour of the exposed population	• Dose assessment (including reconstruction of doses) based on all available environmental monitoring data • Individual dose assessment considering the real behaviour of the population and the efficacy of protective actions and remedial measures in reducing doses • Improved assessment of thyroid doses, their uncertainties, in particular among those exposed in utero, when newly born and in infancy, based on an analysis of thyroid measurement data and internal dose reconstruction • Implementation of shielding factors for new house types characteristic of modern urban areas, with new construction materials (e.g. much glass), and material factor dependence *In close collaboration with EURADOS*	• Dose assessment combining input from environmental monitoring and individual monitoring (e.g. personal dosimeters, thyroid monitoring, whole body counting, bio-dosimetry) • During the long term and recovery phases, the assessment and reconstruction of doses of the affected individuals addresses: i) the needs of individuals and society, including communication about the exposure situations; ii) development and possible adaptation of appropriate health surveillance programs and associated social care [from SHAMISEN] • Develop practical guidance to populations who wish to make their own measurements, recommending reliable equipment and resources (e.g., apps, social media, information centres) [from SHAMISEN]	• (Highly) individual dose assessment

Environmental models **VISION**: A suite of radioecological models that is fit for purpose in emergency management at all levels including inhabited areas *In close collaboration with ALLIANCE*	• Improved database for radioecological models • Identify regional parameters and values characterising the radionuclide behaviour and the transfer soil-to-plant and raw- to-product in poorly studied environments (Mediterranean climate, arctic and sub-arctic, complex systems as agro-pastoral, forestry,..) • Consider appropriate uncertainty estimation in the model – propagation of uncertainties in environmental model chains • Implementation of shielding dose rate factors for new house types characteristic of modern urban areas, with new construction materials (e.g. much glass), and material factor dependence	• Development of a local model for assessing individual farms • Incorporating the behaviour of hot particles in radio ecological models • Investigate multiple stressors together with ALLIANCE	• Linking of local and global models for better decision making

Key topic 2: Improved Monitoring (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Monitoring techniques and strategies **VISION**: New devices, techniques and guidelines for monitoring in Europe being harmonised for cross-border application and monitoring information supplied by professionals, NGOs and lay people; Harmonised monitoring strategies for Europe for all phases and for all types of radiological and nuclear events	• Development of low cost monitors for nuclide specific information for wider use • Improve reliability of low cost monitors for lay people • Investigate the capabilities of drones as part of a strategy • Improve existing monitoring techniques such as whole body, thyroid, lung counting – together with EURADOS • Improved concept combining modelling and monitoring approaches • Investigation of techniques for measurement/characterisation of radionuclides that can not be measured by dose rate or gamma emission • Methods for local determination of environmental parameters governing radionuclide migration	• Improve monitoring capabilities based on the investigation on drones and cheap nuclide specific monitors • Integrate monitoring from lay people into strategies and decision tools • Investigate the capabilities of autonomous moving monitors, such as drones as part of a strategy	• Optimise monitoring techniques and develop European wide guidelines for monitoring and the integration of monitoring data of all kind into decision support systems (e.g. dose impact assessment, source term reconstruction, OILs) • Develop methods and guidance for harmonisation in Europe

Data collection and sharing **VISION**: Comprehensive data base of radiological data for model validation and open for wider use.	• Data collection for model validation & development, based on historical and new data • Good radiation background information and variability of background • Overview of / guidance on which data should be collected for recovery operations to be considered • Optimised use of new meteorological instruments with evaluation of application to improve modelling (Lidar's)	• Data collection for model validation & development, based on historical and new data • Robust system for collecting and sharing data campaigns	• Data collection for model validation & development, based on historical and new data
Optimisation **VISION**: Optimise all potential emergency scenarios based on monitors and modelling capabilities	• Reach back for analysing radiation measurements from intervention teams • Development of methods and tools that allows to optimise the placement of monitoring stations (both fixed early warning networks and mobile systems) • Investigate the interlink with dispersion modelling capabilities to optimise your monitoring network	• Further optimization of monitoring resources • Enhance the linkage between monitoring (mobile and stationary) and simulations in air and water to optimise monitors and possibly also monitoring strategies	• Develop procedures and optimisations methods based on scenarios for different emergencies

Key topic 3: Data assimilation (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Improved source term estimation **VISION**: Improved capabilities to estimate source locations and source terms with ATM/ADM as defined in Key Topic 1 and advanced data assimilation	• Rapid analytical tools for estimation of unknown source locations and source terms using data assimilation and inverse methods • Advanced source term estimation methods combined with methods for assessing the plant status and it's future development • Link with plant status experts (NUGENIA)	• First combined ensemble dispersion modelling with data assimilation and inverse methods • Source term (location and strength) estimation in urban areas	• Combined ensemble dispersion modelling and data assimilation methods operational for DSS
Improved impact assessments **VISION**: Improved capabilities to assess the radiological situation In all phases of an accident or incident (e.g. medical follow-up or other long-term actions)	• Combine modelling and monitoring for a better radiological consequence assessment (considering uncertainty as explicit parameter)	• Refine the assimilation approach to better estimate the dose of individual people for dose reconstruction and medical treatment	• How to combine bio-dosimetric approaches with others in an emergency situation for to make individual impact assessments for large groups of people
Big Data, Data fusion **VISION**: Combined tools for improved decision making using Big Data capabilities within Decision Support Systems in connection to Challenge Area 2	• Development computational structures (e.g., platforms, aggregators) that would allow storing, processing and combining large volumes of heterogeneous and of different origins data	• Develop test procedures to optimise the processing of large information • Improve the structure and content to be applicable for decision making under high uncertainty	• Combine Big Data platforms with Decision Support Systems

Roadmap NERIS Challenge Area 2

Challenges in countermeasures and countermeasure strategies in emergency and recovery, decision support and disaster informatics

Key topic 4: Countermeasures & countermeasure strategies

- Countermeasures/management options
- Implementation of countermeasures, lifting of countermeasures, transition from emergency to existing exposure situation

Key topic 5: Formal decision support

- Decision making methods and tools
- Decisions under high uncertainty

Key topic 6: Disaster informatics

- Analytical platform
- Knowledge databases
- New generation Decision Support Systems (DSS)
- Virtual and augmented reality

Challenges and achievement in	Vision
Challenges in countermeasures and countermeasure strategies in emergency and recovery, decision support and disaster informatics	
Key topic 4: Countermeasures & countermeasure strategies	
Countermeasures/management options	Improved understanding of countermeasures to better build and implement countermeasure strategies (preparedness, response, recovery)
Implementation of countermeasures, lifting of countermeasures, transition from emergency to existing exposure situation	Methodological framework for the implementation and lifting of countermeasures based on monitoring (e.g. Operational Intervention Levels), modelling (Decision Support Systems) and guidance on optimisation supporting ICRP recommendations (including stakeholder interaction, see challenge 3)
Key topic 5: Formal decision support	
Decision making methods and tools	Formalised methods and tools that structure and improve the decision making process in all phases of an accident /incident
Decisions under high uncertainty	Formalised methods that support robust decision making under high uncertainties

Key topic 6: Disaster Informatics	
Analytical platform	Establish the analytical platform as part of the emergency management toolbox
Knowledge databases	Knowledge databases becoming operational allowing to support decision making in all phases of an accident/incident
New generation Decision Support Systems (DSS)	New generation Decision Support Systems for integrated decision making (tactical, operational, strategic)
Virtual and augmented reality	Suite of new training facilities for first responders, decision makers and other stakeholders that can be used for preparedness and testing

Key topic 4: Countermeasures and Countermeasure strategies (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Countermeasures and countermeasure strategies **VISION:** Improved understanding of countermeasures to better build and implement countermeasure strategies (preparedness, response, recovery)	• Investigate the need for improvement of European handbooks (footnote) • If needed improve European handbooks • Investigate enhancing the new guidance handbook developed under the HARMONE project as part of OPERRA (footnote) • Review and investigate if new protective actions and strategies for remediation and restoration can be derived from the Fukushima experience (also other new countermeasures for other surfaces, such as glass, and for a range of 'new' radionuclides) • Investigate the uncertainties in the spatio-temporal behaviour and response to countermeasures • Generation of information sheets for countermeasures implementers (including 'self-help' volunteers)	• Development of electronic versions that are linked to knowledge databases and Big Data structures • Improve concepts and parameters of existing countermeasure models such as ERMIN and AGRICP implemented in JRODOS and ARGOS • Improve user-friendliness of tools • Develop a better estimation of factors that characterise countermeasures and countermeasure strategies (effectiveness, costs, non-radiological effects, …) as function of environment, region and affected population • Consider countermeasures strategies for other incidents than large scale nuclear accidents	• Development of intelligent wizards that propose optimised countermeasures / countermeasure strategies based on available information from a DSS

Implementation of countermeasures, lifting of countermeasures, transition from emergency to existing exposure situation **VISION**: Methodological framework for the implementation and lifting of countermeasures based on monitoring (e.g. Operational Intervention Levels), modelling (Decision Support Systems) and guidance on optimisation supporting ICRP recommendations (including stakeholder interaction, see challenge 3)	• Analyse European, national and local countermeasure strategies, their implementation and lifting conditions • Review the experience in implementing and lifting countermeasures in Fukushima and Chernobyl • Investigate preparedness scenarios for recovery • Develop monitoring strategy to support countermeasure implementation • Develop Operational Intervention levels for the use in the decision making process – review the proposal from IAEA for NPP scenarios and revise, add if necessary • Develop OIL's for non-nuclear scenarios in cooperation with the IAEA • Develop catalogues and check-lists to facilitate timely implementation • Develop means to review the result of the countermeasure strategies selected	• Develop criteria and methods to determine the start and end of countermeasures. Take all relevant factors into account • Start work on the better definition of the transition phase and the methodological and technical needs for preparing the recovery phase • Implement appropriate OILs into Decision Support Systems to be compared with monitoring information and investigate optimisation possibilities for that selection	• Development of the methodological framework

Key topic 5: Formal decision support (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Decision making methods and tools **VISION**: Formalised methods and tools that structure and improve the decision making process in all phases of an accident /incident	• Investigate the added value of multi-criteria analysis for decision support, in particular in pre-planning and the recovery phase • Development of methods and guidelines to address the planning and decision making during the transition phase • Development of structured analysis to look for the preferences and needs of stakeholders and its introduction into the decision making process • Development of training and support material for decision makers	• Develop multi-criteria analysis tools that are fit for purposes • Support the structuring process in decision making • Development of guidance material for "good decision making practice" Development of structured methodologies to define generic scenarios for preparedness and planning taking into account different driving forces (technical, societal, economic, environmental..)	• Review the progress and develop a research program for the way forward
Decisions under high uncertainty **VISION**: Formalised methods that support robust decision making under high uncertainties	• Improve multi-criteria analysis with uncertainty handling • Investigate the importance of uncertainties in the decision making process in all accident/incident phases • Investigate the scenario planning as tool to support the decision making under uncertainty • Develop methods and tools for the local stakeholders to manage daily life under conditions with high uncertainty	• Combination of agent based simulation systems with multi-criteria Analysis for uncertainty handling to better quantify the preferences of all stakeholders • Develop methods and criteria to support when using uncertainties in decision making • Development of training and support material for decision makers	• Investigate more complex decision analysis tools for use under high uncertainty aiming to move towards big data applications

Key topic 6: Disaster informatics (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Analytical platform **VISION**: Establish the analytical platform as part of the emergency management toolbox	• Investigate the usability of the existing analytical platform • Test and improve the existing analytical platform	• Expand the capability of the analytical platform based on findings from exercises and applications	• Investigate combination of the analytical platform with big data approaches
Knowledge databases **VISION**: Knowledge databases becoming operational allowing to support decision making in all phases of an accident/incident	• Extend the knowledge database with more scenarios for all phases of an accident/incident • Develop more focused similarity approaches	• Investigate how big data analysis can be used for the knowledge database • Develop tool or mechanism to collect relevant information from the internet (e.g. Twitter, Facebook and other media) • Usage of all relevant information from whatever sources (e.g. Twitter, Facebook, scenarios)	• Expand knowledge databases and big data functionalities to develop a focal point for decision support. • Investigate if this approach can complement existing DSS
New generation Decision Support Systems (DSS) **VISION**: New generation Decision Support Systems for integrated decision making (tactical, operational, strategic)	• Improve user interfaces of existing Decision Support Systems for the various phases of an accident/incident • Develop new interfaces of DSS's to comply with improved decision making methods • Investigate the need for re-engineered DSS to deal with uncertainty	• If necessary, investigate concepts and advanced informatics approaches to modularise Decision Support Systems for application in different phases including uncertainty handling • Coupling of the existing strategic Decision Support Systems such as ARGOS and RODOS to Command and Control (C2) systems	• Develop new generation of Decision Support Systems based on advanced informatics approach

Virtual and augmented reality **VISION**: Suite of new training facilities for first responders, decision makers and other stakeholders that can be used for preparedness and testing	• Review and investigate the usability of serious gaming and augmented reality in radiation protection research • Development of serious games and augmented reality for preparedness	• Explore the usage of serious gaming and augmented reality for training of the decision making processes • Develop appropriate tools to train decision makers and other stakeholders	• Develop better training tools for responders, decision makers and other stakeholders by combining virtual and augmented reality tools with Decision Support Systems .

Roadmap NERIS Challenge Area 3

Challenges in setting-up a trans-disciplinary and inclusive framework for preparedness for emergency response and recovery

Key topic 7. Emergency response and recovery framework, including reference levels

- Implementation of BSS including reference levels and relation with operational levels
- Longer term management
- Contaminated goods

Key topic 8. Stakeholder engagement, involvement of the public & communication (presentation of and addressing uncertainties)

- Stakeholder engagement processes including the public
- Citizen Science
- Communication

Key topic 9. Integrated emergency management – non-radiological aspects (health surveillance, ethical aspects, economic issues…)

- Health surveillance
- Ethical aspects
- Socio-economic aspects
- Integrated surveillance and monitoring
- Radiological protection culture

Key topic 10. Uncertainty and incomplete information handling (presentation of uncertainties)

- Dealing with uncertainties

Challenges and achievement in	Vision
Setting-up a trans-disciplinary and inclusive framework for preparedness for emergency response and recovery	
Key topic 7: Emergency response and recovery framework, including reference levels	
Implementation and development of BSS including reference levels and relation with operational levels	Harmonised framework to support countries in applying the BSS and key decision criteria such as OILs
Longer term management	Better guidance for long term management of contaminated areas including societal aspects
Contaminated goods	Guidance framework to better manage goods from contaminated areas

Key topic 8: Stakeholder engagement, involvement of the public & communication (presentation of and addressing uncertainties)	
Stakeholder engagement processes including the public	Guidance framework for establishing a successful stakeholder engagement process
Citizen Science	Guidance framework for establishing a successful integration of citizen science in radiological risk governance
Communication	Guidance framework for efficient communication for different exposure contexts, time scales, cultural and socioeconomic contexts
Key topic 9: Integrated emergency management – non-radiological aspects (health surveillance, ethical aspects, economic issues…)	
Health surveillance	Guidance framework for justification and improvement of health surveillance
Ethical aspects	Guidance framework for including ethical aspects in decision making in all phases of an emergency
Socio-economic aspects	Guidance framework for including socio-economic aspects in decision making in all phases of an emergency
Integrated monitoring and surveillance	Guidance framework for an integrated surveillance and monitoring programme articulating health surveillance, environmental monitoring, human dose assessment and food monitoring
Radiological protection culture	Guidance framework for establishing a sustainable Radiation Protection Culture in all relevant areas of radiation protection including means to support education and training as well as supervision
Key topic 10: Uncertainty and incomplete information handling (presentation of uncertainties)	
Dealing with uncertainties	Guidance framework and advanced tools to better identify, address and communicate uncertainties

Key topic 7: Emergency response and recovery framework, including reference levels (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Implementation and development of BSS including reference levels and relation with operational levels **<u>VISION</u>**: Harmonised framework to support countries in applying the BSS and key decision criteria such as OILs	• Review OILs developed under RA2 and refine and adapt according to societal factors • Development of socially and scientifically robust Operational Intervention Levels (OILs) for the transition and longer-term management • Investigate the potential of simulation models to set up a possible reference levels early in the emergency to support decisions such as temporary or permanent relocation • Define success criteria for the application of countermeasures, methodology and tools to better understand actual and future risks and vulnerabilities	• Adapt decision support systems to implement results from the screening in the first period (0-5 years) • Support the operational application of the BSS and OILs with further scientific research • Define success criteria for the application of countermeasures • Incorporate risk-reduction strategies into governance and local decision-making	• Development of scientific based guidance how to best use OILs and intervention levels in the operational application of the BSS • Implement this guidance into decision support systems • Integrate Radiation protection into a broader environmental protection framework

Longer term management **VISION**: Better guidance for long term management of contaminated areas including societal aspects	• Develop long term, sustainable communication models and stakeholder engagement frameworks to improve public health and well-being • Develop criteria for lifting of countermeasures and transition from emergency to existing situations	• Developing guidance documents how to best use policy formulation tools mathematical models and stakeholder engagement framework for a sustainable recovery	• Test the guidance in stakeholder groups and improve mathematical tools and stakeholder engagement framework
Contaminated goods **VISION**: Guidance framework to better manage goods from contaminated areas	• Studies on the implications of trade and use of goods from contaminated territories in the perspective of a sustainable recovery • Development of simulation models that allows the quantification of potential doses from usage of contaminated goods	• Analysis of different management strategies – including health, economic and ethical issues	• Develop management procedures for Europe based on the simulation models

Key topic 8: Stakeholder engagement, involvement of the public & communication (presentation of and addressing uncertainties) (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Stakeholder engagement processes including the public **VISION**: Guidance framework for establishing a successful stakeholder engagement process	• Identifying roles, constraints, responsibilities and cooperation among European/national/regional/local levels in order to improve the Preparedness Plans for each phase of the emergency and post-accident. • Assessment and design of stakeholder participation tools and methodologies for preparedness, emergency and recovery situations. Rules and roles of stakeholders in the engagement process. Motivational factors for, ethics of and link between theory and practice of stakeholder engagement	• Further development of database on experiences of stakeholder engagement in preparedness and response highlighting lessons learned and guidance for best practice, taking into account the national context. • Develop guidance on information and participation of population, increasing effectiveness if multiple source of information may compete or conflict	• Analysis of societal needs for an evaluation of legal instruments and governance frameworks supporting access to information, public participation and access to justice in relation with RP issues. • Preservation of knowledge and experience of local stakeholders' (e.g.; local community, schools, citizens) involvement and participation. Community research and tracing for development of participation culture in relation to different exposure situations

Citizen Science **<u>VISION</u>**: Guidance framework for establishing a successful integration of citizen science in radiological risk governance	• Investigate the potential and pitfalls of citizens involvement in knowledge production and data sharing for radiological risk governance • Determine factors influencing the trust between different actors	• Development of guidance for successful integration of citizen science in radiological risk governance	• Initiate a platform for sustainable application of citizen science in radiological risk governance

Communication **<u>VISION</u>**: Guidance framework for efficient communication for different exposure contexts, time scales, cultural and socioeconomic contexts	• Investigate the conditions and means for pertinent, reliable and trustworthy information to be made available to the public in due time according to its needs in the course of nuclear emergency and post-emergency contexts. • Use and perception of technical information and risk estimates in communication with various publics (lay people, experts, informed civil society). • Development of methods and procedures for analysing the information flow related to social trust including traditional information sources as well as social media and modern IT-based structures	• Development and usage of social media and other information sources in emergency response and recovery: how social media can be used to improve emergency response and better communicate and cooperate with the public • Investigate in detail the impact of social and traditional media on perception of radiological risk and general well-being linked to radiation exposures. This includes the influence of citizen journalism on radiation protection behaviour in different exposure situations and developing models for integrating scientific journalism in radiation protection • Investigate the links between perception of radiological risk and radiation protection behaviour, or individual strategies to cope with perceived risk in relation to radiation exposure	• Development of a framework that considers research from the first decade and develop plans guidance for operators, regulators, decision makers and journalists

Key topic 9: Integrated emergency management – non-radiological aspects (health surveillance, ethical aspects, economic issues…) (for more detailed description of topics and subtopics please refer to the SRA)

Challenges and achievement in	1-5 years	6-10 years	>10 years
Health surveillance **VISION**: Guidance framework for justification and improvement of health surveillance	• Development of procedures for health surveillance including sampling of population and dose reconstruction, the concerns of both institutional decision-makers and populations, and with involvement of stakeholders.	• Investigate in detail socio-psychological and economic aspects of medical and health follow-up after accidental or other exposures. • Investigate the results from the health surveillance program in Fukushima aiming to identify positive or negative components of the program	• Development of necessary guidance documents for better health surveillance approaches
Ethical aspects **VISION**: Guidance framework for including ethical aspects in decision making in all phases (preparedness, emergency and recovery)	• Investigate the ethical aspects of emergency management and recovery, particularly ethical questions of evacuation, and the transition from emergency to existing radiation exposure situations • Investigate the ethical basis and values underpinning risk communication about ionizing radiation exposures	• Investigate the ethical perspective of compensation for damage incurred due to various situations of radiation exposure and differences among countries	• Expand the ethical aspect to all questions of decision making and provide guidance how to deal with it

Socio-economic aspects **VISION**: Guidance framework for including socio-economic aspects in decision making in all phases (preparedness, emergency and recovery)	• Understand how the population reacts and how socio-economic factors can be used by local-national tools to improve the response • Investigate possible compensation schemes and other economic support for the recovery phase	• Development of comprehensive approaches to studying the perception of radiological risk and environmental remediation actions in post-accident and existing exposure situations. • Investigate the perception of radiological risks from low doses of radiation, accounting for cultural differences in routine, emergency and other exposure situations. • Development of guidance for economic supports for the improvement of living conditions of the population	• Investigate in detail the interplay of psychological aspects associated with radioactivity, social environment and radiation protection behaviours • Development of socio-economic valuation and multi-criteria decision aiding methods to formally structure the evaluation and integration of radiological and non-radiological factors for different ionising radiation exposure situations

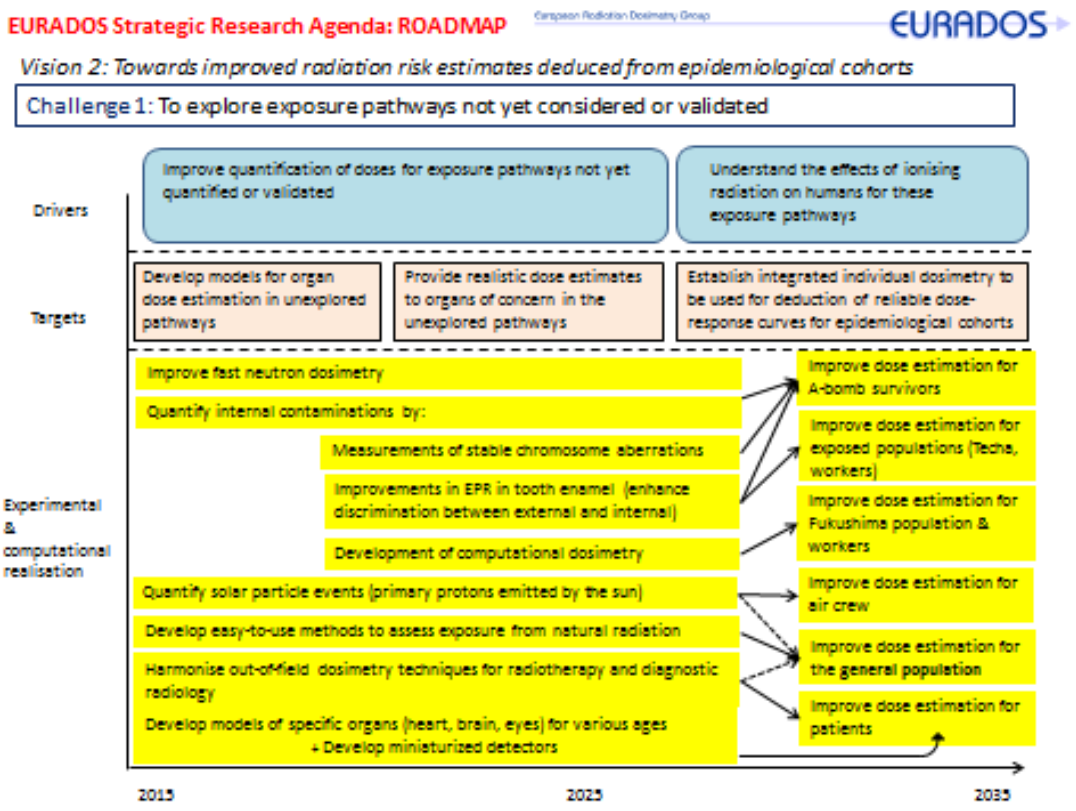
Integrated surveillance and monitoring **VISION**: Guidance framework for establishing a comprehensive surveillance and monitoring system addressing health surveillance, human dose assessment, environmental monitoring and food monitoring in meaningful way for local populations	• Investigate connections between issues of health surveillance, human dose assessment, environmental monitoring and food monitoring from the point of view of institutions and local populations in the emergency and post-emergency phase • Investigate connections between these different dimensions of surveillance, healthcare and the development of radiation protection culture • Investigate possible connections between institutional surveillance and independent initiatives	• Develop guidance on the way to set up comprehensive surveillance and monitoring systems articulating health, body, environment and food surveillance and healthcare, taking into account the potential of citizen-based monitoring	Implement and test guidance on the way to set up comprehensive surveillance and monitoring systems articulating health, body, environment and food surveillance and healthcare, taking into account the potential of citizen-based monitoring

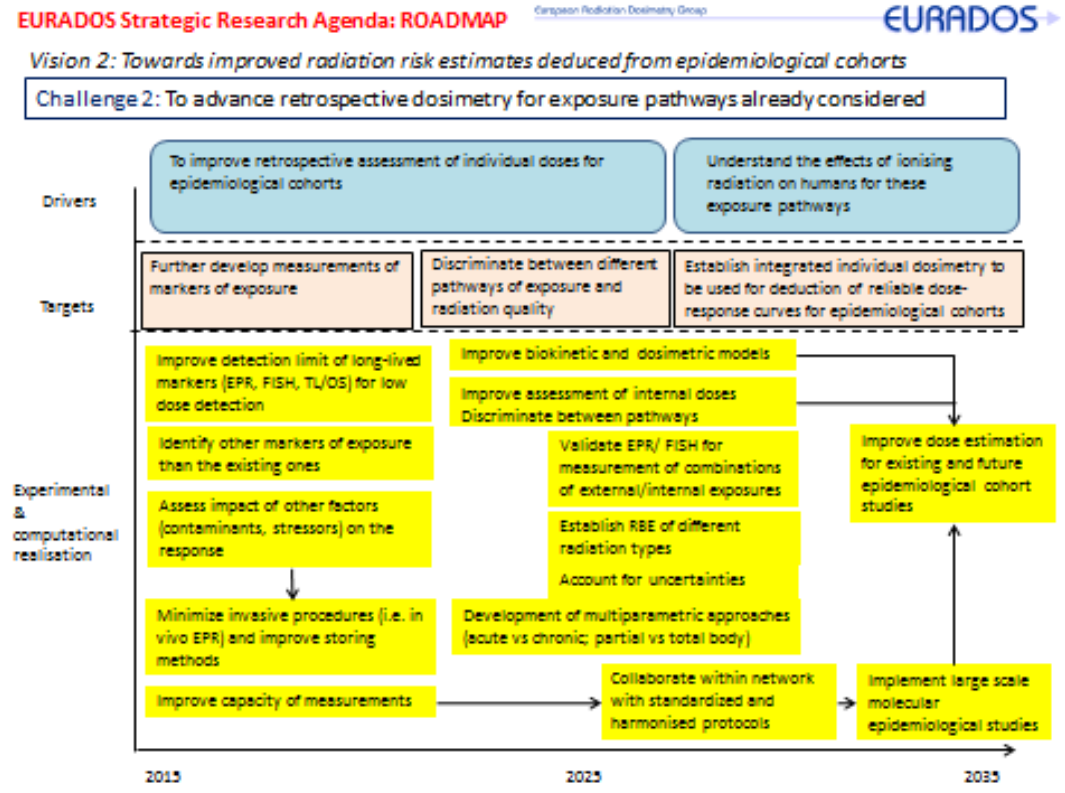
Radiological protection culture **VISION**: Guidance framework for establishing a sustainable Radiological Protection Culture in all relevant areas of radiation protection including means to support education and training as well as supervision	• Investigate the role of Radiation Protection (RP) culture, in particular its contribution to the protection system and the improvement of if it can improve health and well being • Development of tools, methods, processes to build, maintain and transmit RP culture in all aspects of emergency management with due consideration of the needs of stakeholders	• Development of guidance for enhancing RP culture for specific publics (communities around nuclear installations, schools, patients, pregnant women, medical doctors) • Development of appropriate education and training means	• Development of procedures how to use the RP culture in the operational world and develop mechanisms to quantify a successful implementation of RP culture

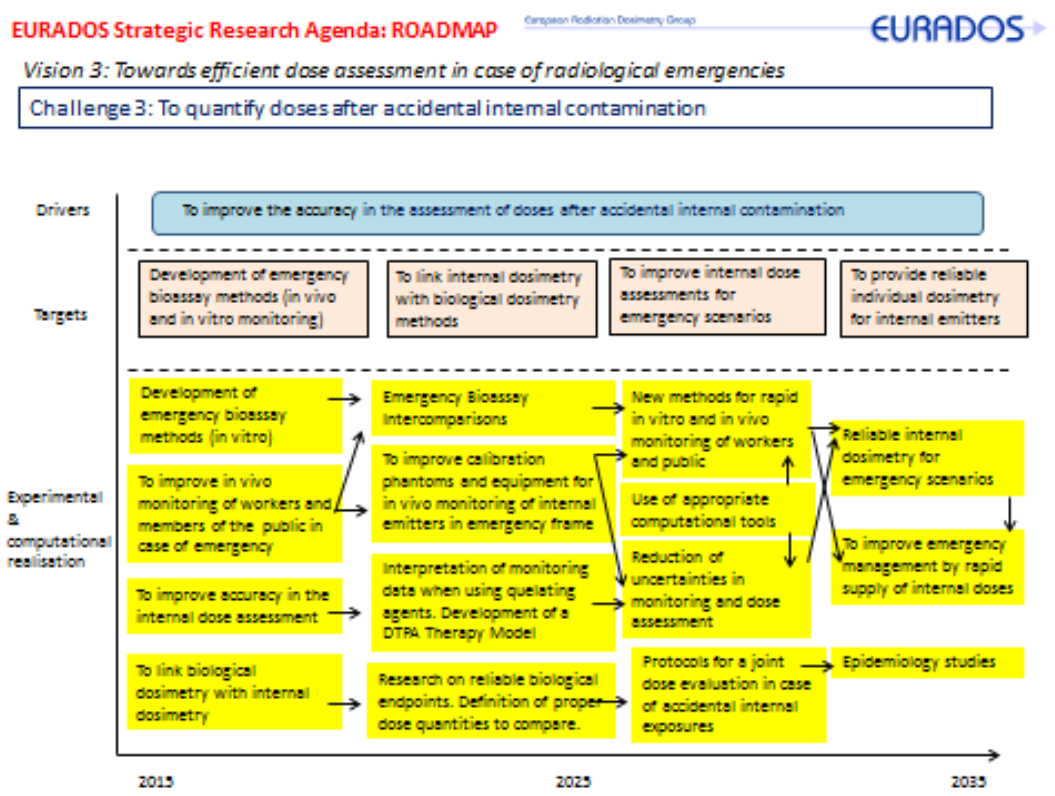
Key topic 10: Uncertainty and incomplete information handling (presentation of uncertainties) (for more detailed description of topics and subtopics please refer to the SRA)

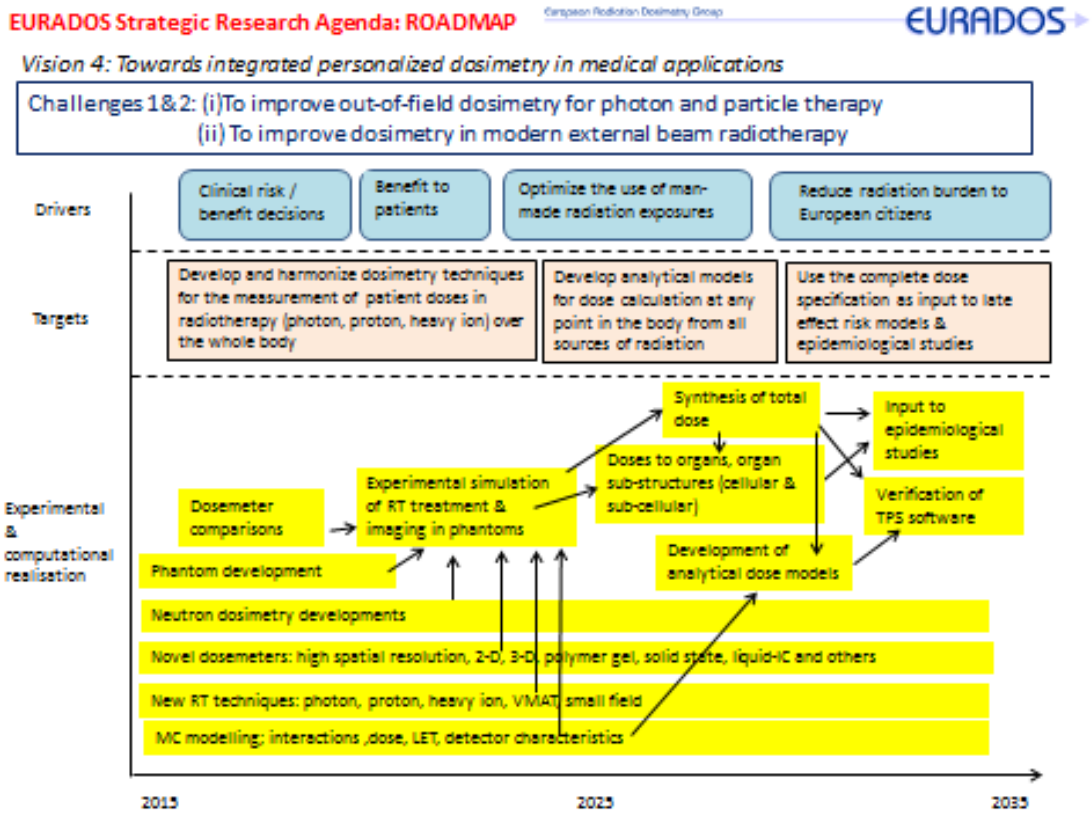
Challenges and achievement in	1-5 years	6-10 years	>10 years
Dealing with uncertainties **VISION**: Guidance framework and advanced tools to better identify, address and communicate uncertainties	• Investigating overall uncertainties and how they can be communicated, e.g.; in model results and in decision support systems to help decision makers to understand the radiological situation. • Investigate media communication about ionizing radiation, in particular low radiation doses and related uncertainties in the field of radiological protection including inter-media agenda setting in different exposure situations. • Investigate how local actors and non-institutional stakeholders make sense of uncertainty in their own decision-making processes and what governance mechanisms can facilitate these processes.	• Identify information that should be considered for decision making in the various phases of an emergency; • Investigate how decisions taken under high uncertainty can be communicated to media and general public • Develop tools and methods for a two-way communication of uncertain information between experts and non-experts • Develop education and training material for decision makers on uncertainty management	• Review the developments from the first decade and develop further needs for improved communication of uncertainties • Investigate to which extent serious gaming can be used in communication of uncertainties

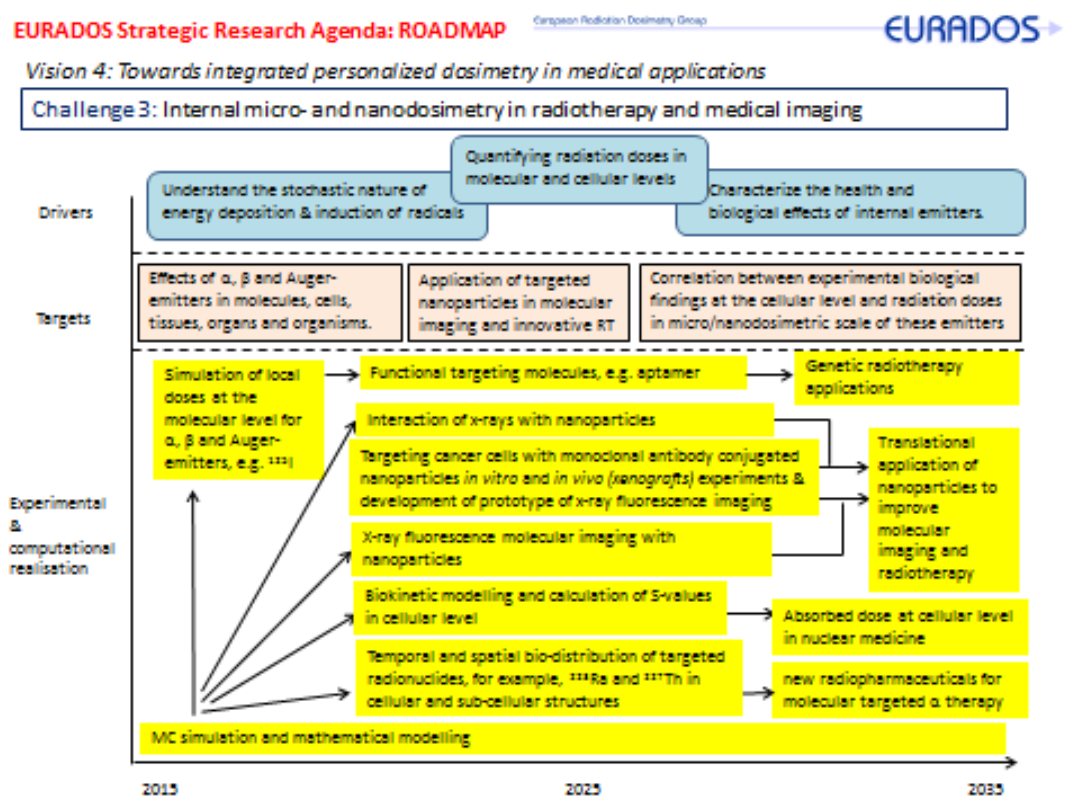
Annex 3: Current status of EURADOS roadmapping. Examples for Visions and Challenges.

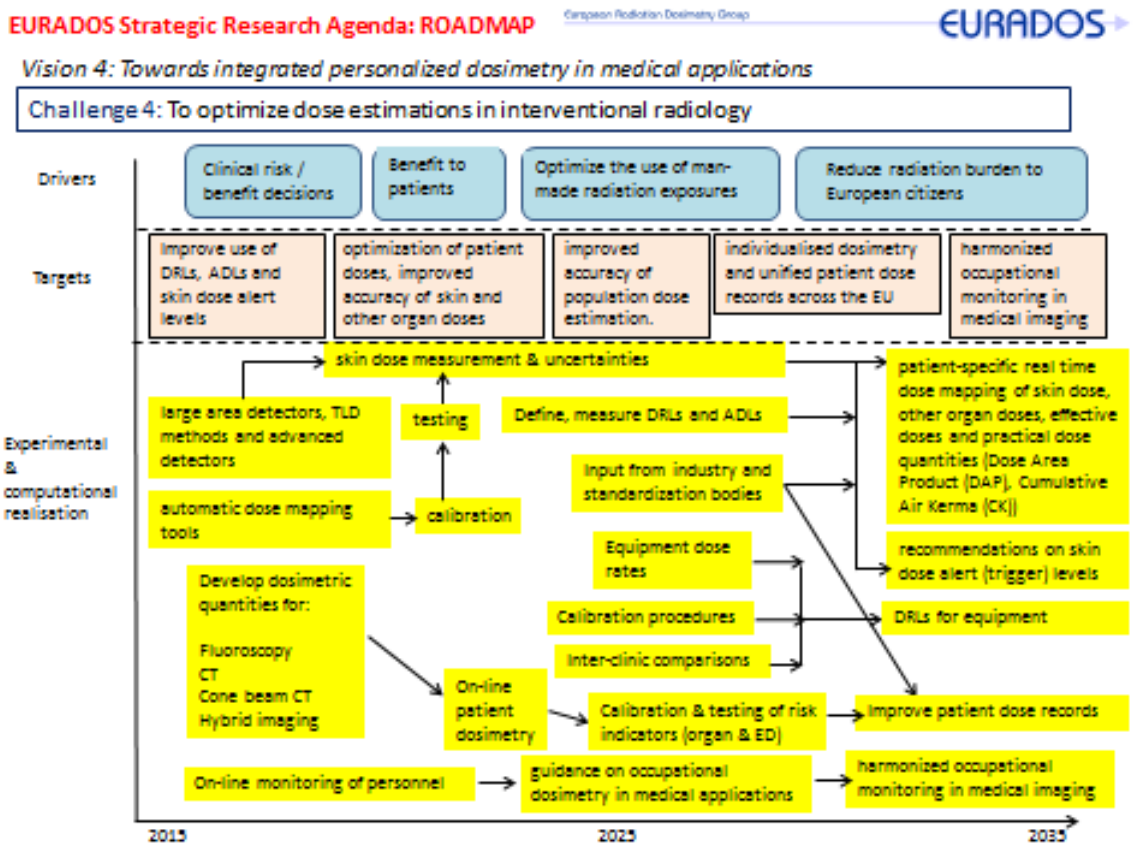


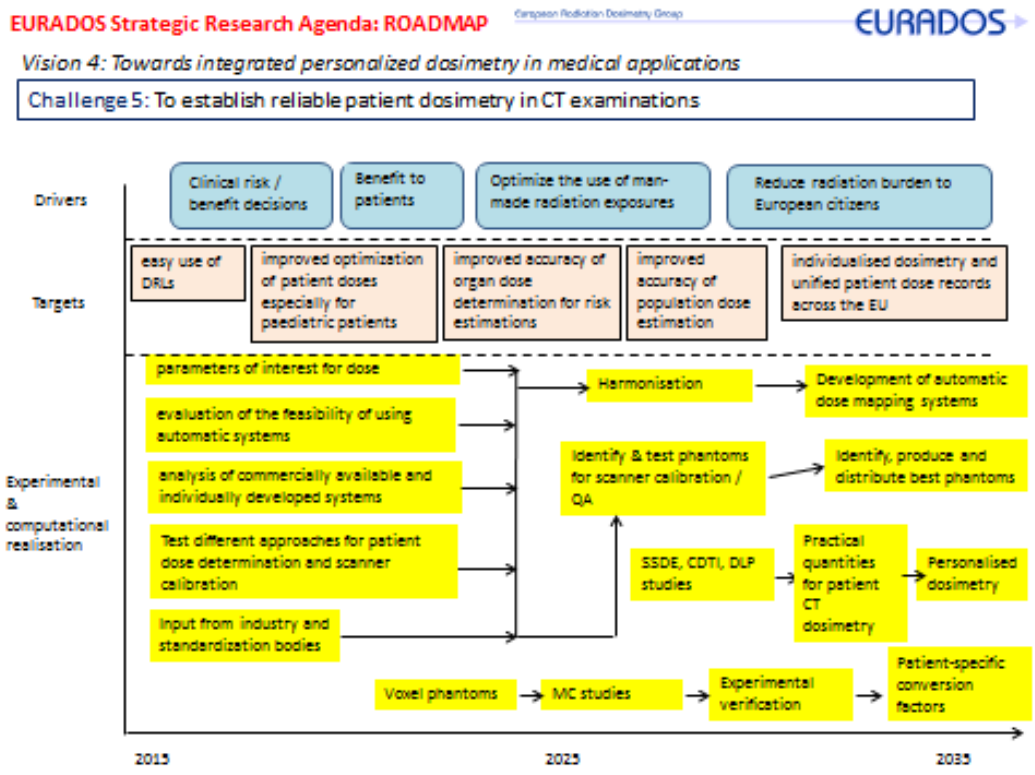


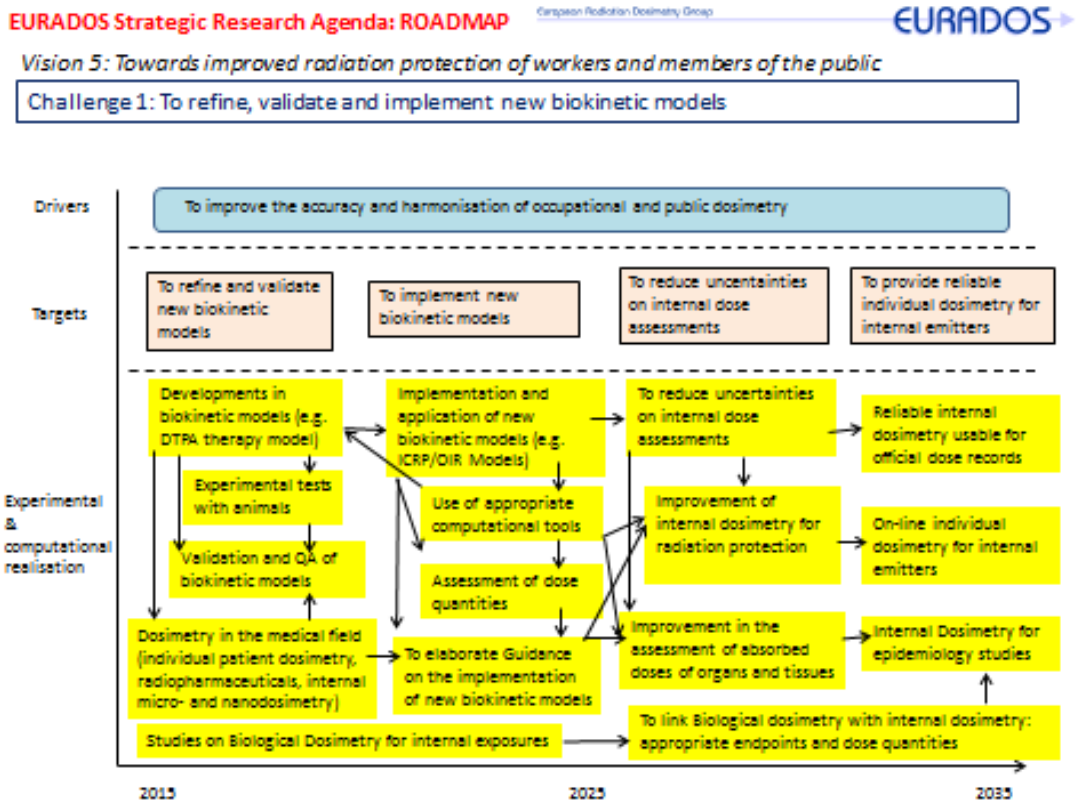

EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 3: Towards efficient dose assessment in case of radiological emergencies
Challenge 3: To quantify doses after accidental internal contamination
Drivers
To improve the accuracy in the assessment of doses after accidental internal contamination
Targets
Development of emergency bioassay methods (in vivo and in vitro monitoring)
To link internal dosimetry with biological dosimetry methods
To improve internal dose assessments for emergency scenarios
To provide reliable individual dosimetry for internal emitters
Experimental & computational realisation
Development of emergency bioassay methods (in vitro)
To improve in vivo monitoring of workers and members of the public in case of emergency
To improve accuracy in the internal dose assessment
To link biological dosimetry with internal dosimetry
Emergency Bioassay intercomparisons
To improve calibration phantoms and equipment for in vivo monitoring of internal emitters in emergency frame
Interpretation of monitoring data when using quelating agents. Development of a DTPA Therapy Model
Research on reliable biological endpoints. Definition of proper dose quantities to compare.
New methods for rapid in vitro and in vivo monitoring of workers and public
Use of appropriate computational tools
Reduction of uncertainties in monitoring and dose assessment
Protocols for a joint dose evaluation in case of accidental internal exposures
Reliable internal dosimetry for emergency scenarios
To improve emergency management by rapid supply of internal doses
Epidemiology studies
2015
2025
2035

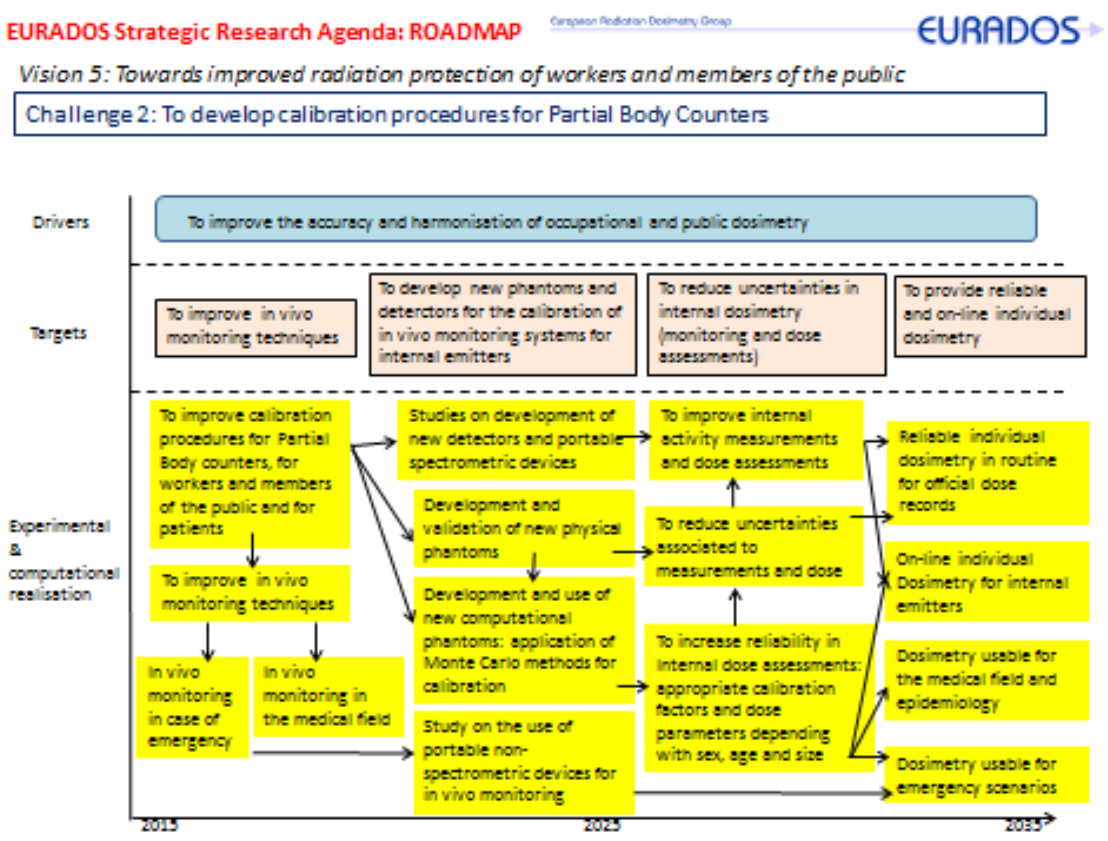

EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 4: Towards integrated personalized dosimetry in medical applications
Challenges 1&2: (i)To improve out-of-field dosimetry for photon and particle therapy
(ii) To improve dosimetry in modern external beam radiotherapy
Drivers
Clinical risk / benefit decisions
Benefit to patients
Optimize the use of man-made radiation exposures
Reduce radiation burden to European citizens
Targets
Develop and harmonize dosimetry techniques for the measurement of patient doses in radiotherapy (photon, proton, heavy ion) over the whole body
Develop analytical models for dose calculation at any point in the body from all sources of radiation
Use the complete dose specification as input to late effect risk models & epidemiological studies
Experimental & computational realisation
Dosemeter comparisons
Phantom development
Experimental simulation of RT treatment & imaging in phantoms
Synthesis of total dose
Doses to organs, organ sub-structures (cellular & sub-cellular)
Development of analytical dose models
Input to epidemiological studies
Verification of TPS software
Neutron dosimetry developments
Novel dosemeters: high spatial resolution, 2-D, 3-D, polymer gel, solid state, liquid-IC and others
New RT techniques: photon, proton, heavy ion, VMAT, small field
MC modelling: interactions ,dose, LET, detector characteristics
2015
2025
2035

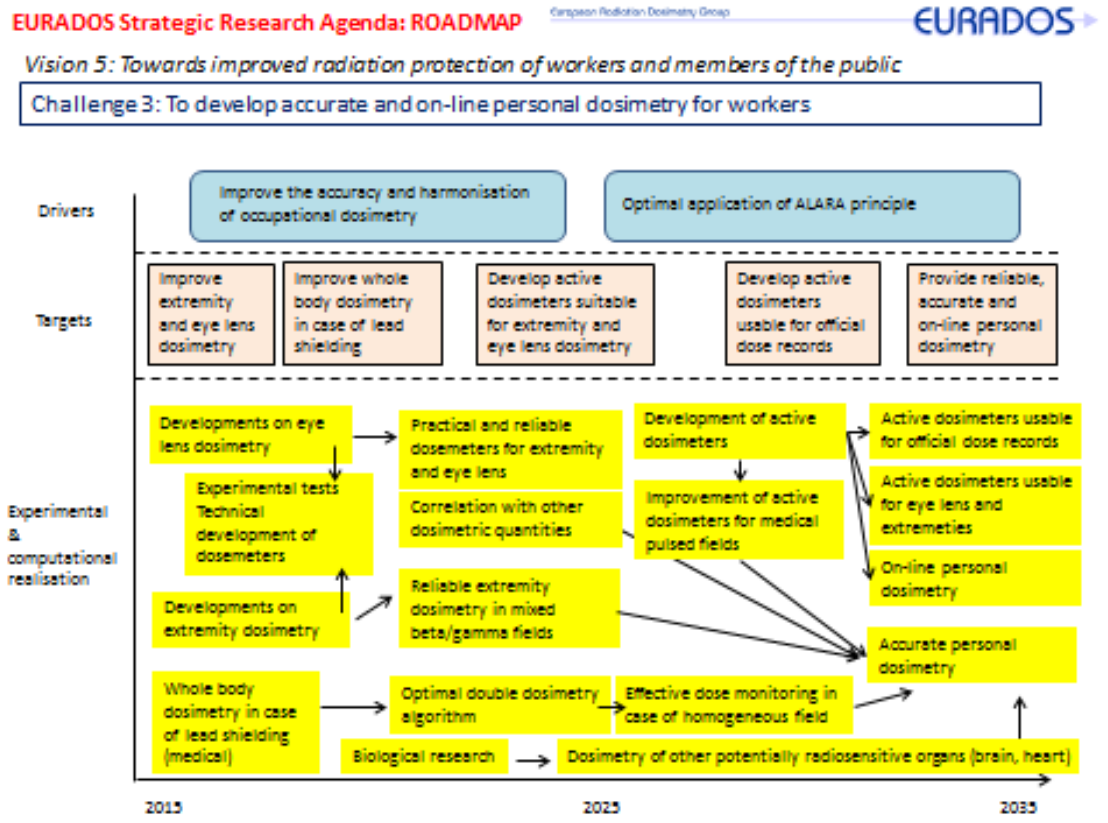

EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 4: Towards integrated personalized dosimetry in medical applications
Challenge 3: Internal micro- and nanodosimetry in radiotherapy and medical imaging
Drivers
Understand the stochastic nature of energy deposition & induction of radicals
Quantifying radiation doses in molecular and cellular levels
Characterize the health and biological effects of internal emitters
Targets
Effects of α, β and Auger-emitters in molecules, cells, tissues, organs and organisms.
Application of targeted nanoparticles in molecular imaging and innovative RT
Correlation between experimental biological findings at the cellular level and radiation doses in micro/nanodosimetric scale of these emitters
Experimental & computational realisation
Simulation of local doses at the molecular level for α, β and Auger-emitters, e.g. 123I
Functional targeting molecules, e.g. aptamer
Genetic radiotherapy applications
Interaction of x-rays with nanoparticles
Targeting cancer cells with monoclonal antibody conjugated nanoparticles in vitro and in vivo (xenografts) experiments & development of prototype of x-ray fluorescence imaging
Translational application of nanoparticles to improve molecular imaging and radiotherapy
X-ray fluorescence molecular imaging with nanoparticles
Biokinetic modelling and calculation of S-values in cellular level
Absorbed dose at cellular level in nuclear medicine
Temporal and spatial bio-distribution of targeted radionuclides, for example, 224Ra and 227Th in cellular and sub-cellular structures
new radiopharmaceuticals for molecular targeted α therapy
MC simulation and mathematical modelling
2015
2025
2035

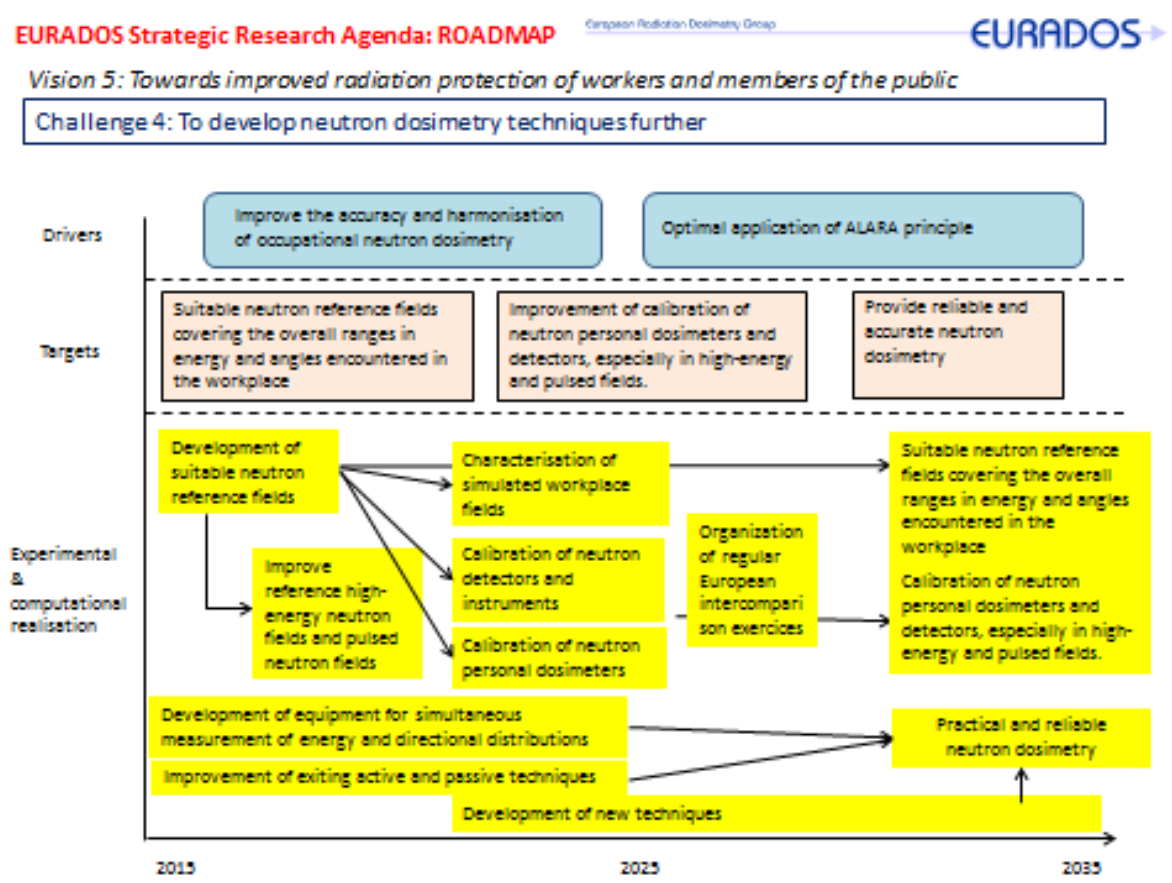

EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 4: Towards integrated personalized dosimetry in medical applications
Challenge 4: To optimize dose estimations in interventional radiology
Drivers
Clinical risk / benefit decisions
Benefit to patients
Optimize the use of man-made radiation exposures
Reduce radiation burden to European citizens
Targets
Improve use of DRLs, ADLs and skin dose alert levels
optimization of patient doses, improved accuracy of skin and other organ doses
improved accuracy of population dose estimation.
individualised dosimetry and unified patient dose records across the EU
harmonized occupational monitoring in medical imaging
Experimental & computational realisation
skin dose measurement & uncertainties
large area detectors, TLD methods and advanced detectors
testing
Define, measure DRLs and ADLs
patient-specific real time dose mapping of skin dose, other organ doses, effective doses and practical dose quantities (Dose Area Product (DAP), Cumulative Air Kerma (CK))
automatic dose mapping tools
calibration
Input from industry and standardization bodies
Equipment dose rates
recommendations on skin dose alert (trigger) levels
Develop dosimetric quantities for:
Fluoroscopy
CT
Cone beam CT
Hybrid imaging
Calibration procedures
DRLs for equipment
Inter-clinic comparisons
On-line patient dosimetry
Calibration & testing of risk indicators (organ & ED)
Improve patient dose records
On-line monitoring of personnel
guidance on occupational dosimetry in medical applications
harmonized occupational monitoring in medical imaging
2015
2025
2035

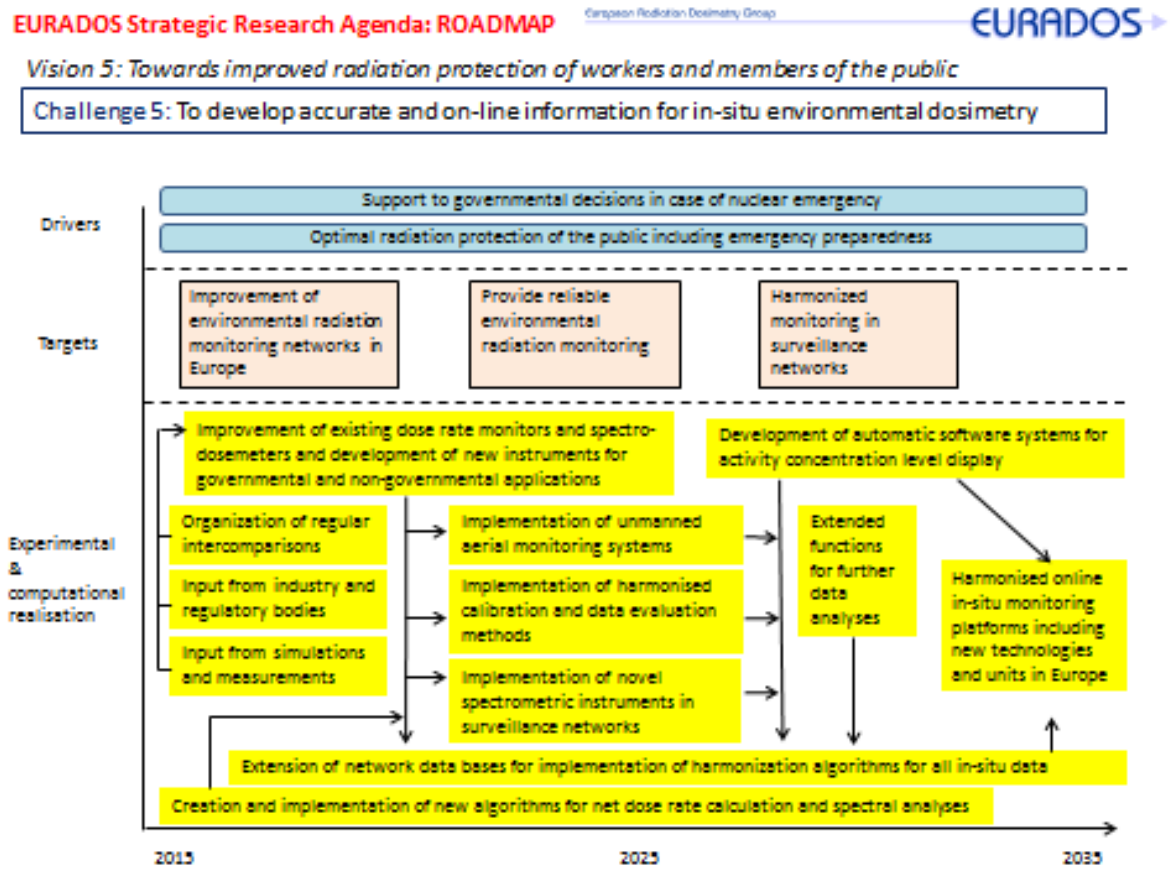

EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 4: Towards integrated personalized dosimetry in medical applications
Challenge 5: To establish reliable patient dosimetry in CT examinations
Drivers
Clinical risk / benefit decisions
Benefit to patients
Optimize the use of man-made radiation exposures
Reduce radiation burden to European citizens
Targets
easy use of DRLs
improved optimization of patient doses especially for paediatric patients
improved accuracy of organ dose determination for risk estimations
improved accuracy of population dose estimation
individualised dosimetry and unified patient dose records across the EU
Experimental & computational realisation
parameters of interest for dose
evaluation of the feasibility of using automatic systems
analysis of commercially available and individually developed systems
Test different approaches for patient dose determination and scanner calibration
Input from industry and standardization bodies
Harmonisation
Development of automatic dose mapping systems
Identify & test phantoms for scanner calibration / QA
Identify, produce and distribute best phantoms
SSDE, CDTI, DLP studies
Practical quantities for patient CT dosimetry
Personalised dosimetry
Voxel phantoms
MC studies
Experimental verification
Patient-specific conversion factors
2015
2025
2035


EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 5: Towards improved radiation protection of workers and members of the public
Challenge 1: To refine, validate and implement new biokinetic models
Drivers
To improve the accuracy and harmonisation of occupational and public dosimetry
Targets
To refine and validate new biokinetic models
To implement new biokinetic models
To reduce uncertainties on internal dose assessments
To provide reliable individual dosimetry for internal emitters
Experimental & computational realisation
Developments in biokinetic models (e.g. DTPA therapy model)
Experimental tests with animals
Validation and QA of biokinetic models
Implementation and application of new biokinetic models (e.g. ICRP/OIR Models)
Use of appropriate computational tools
Assessment of dose quantities
To reduce uncertainties on internal dose assessments
Improvement of internal dosimetry for radiation protection
Improvement in the assessment of absorbed doses of organs and tissues
Reliable internal dosimetry usable for official dose records
On-line individual dosimetry for internal emitters
Internal Dosimetry for epidemiology studies
Dosimetry in the medical field (individual patient dosimetry, radiopharmaceuticals, internal micro- and nanodosimetry)
To elaborate Guidance on the implementation of new biokinetic models
Studies on Biological Dosimetry for internal exposures
To link Biological dosimetry with internal dosimetry: appropriate endpoints and dose quantities
2015
2025
2035


EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 5: Towards improved radiation protection of workers and members of the public
Challenge 2: To develop calibration procedures for Partial Body Counters
Drivers
To improve the accuracy and harmonisation of occupational and public dosimetry
Targets
To improve in vivo monitoring techniques
To develop new phantoms and detectors for the calibration of in vivo monitoring systems for internal emitters
To reduce uncertainties in internal dosimetry (monitoring and dose assessments)
To provide reliable and on-line individual dosimetry
Experimental & computational realisation
To improve calibration procedures for Partial Body counters, for workers and members of the public and for patients
To improve in vivo monitoring techniques
In vivo monitoring in case of emergency
In vivo monitoring in the medical field
Studies on development of new detectors and portable spectrometric devices
Development and validation of new physical phantoms
Development and use of new computational phantoms: application of Monte Carlo methods for calibration
Study on the use of portable non-spectrometric devices for in vivo monitoring
To improve internal activity measurements and dose assessments
To reduce uncertainties associated to measurements and dose
To increase reliability in internal dose assessments: appropriate calibration factors and dose parameters depending with sex, age and size
Reliable individual dosimetry in routine for official dose records
On-line individual Dosimetry for internal emitters
Dosimetry usable for the medical field and epidemiology
Dosimetry usable for emergency scenarios
2015
2025
2035


EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 5: Towards improved radiation protection of workers and members of the public
Challenge 3: To develop accurate and on-line personal dosimetry for workers
Drivers
Improve the accuracy and harmonisation of occupational dosimetry
Optimal application of ALARA principle
Targets
Improve extremity and eye lens dosimetry
Improve whole body dosimetry in case of lead shielding
Develop active dosimeters suitable for extremity and eye lens dosimetry
Develop active dosimeters usable for official dose records
Provide reliable, accurate and on-line personal dosimetry
Experimental & computational realisation
Developments on eye lens dosimetry
Experimental tests Technical development of dosemeters
Developments on extremity dosimetry
Practical and reliable dosemeters for extremity and eye lens
Correlation with other dosimetric quantities
Reliable extremity dosimetry in mixed beta/gamma fields
Development of active dosimeters
Improvement of active dosimeters for medical pulsed fields
Active dosimeters usable for official dose records
Active dosimeters usable for eye lens and extremeties
On-line personal dosimetry
Accurate personal dosimetry
Whole body dosimetry in case of lead shielding (medical)
Optimal double dosimetry algorithm
Effective dose monitoring in case of homogeneous field
Biological research
Dosimetry of other potentially radiosensitive organs (brain, heart)
2015
2025
2035


EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 5: Towards improved radiation protection of workers and members of the public
Challenge 4: To develop neutron dosimetry techniques further
Drivers
Improve the accuracy and harmonisation of occupational neutron dosimetry
Optimal application of ALARA principle
Targets
Suitable neutron reference fields covering the overall ranges in energy and angles encountered in the workplace
Improvement of calibration of neutron personal dosimeters and detectors, especially in high-energy and pulsed fields.
Provide reliable and accurate neutron dosimetry
Experimental & computational realisation
Development of suitable neutron reference fields
Characterisation of simulated workplace fields
Improve reference high-energy neutron fields and pulsed neutron fields
Calibration of neutron detectors and instruments
Calibration of neutron personal dosimeters
Organization of regular European intercomparison exercices
Suitable neutron reference fields covering the overall ranges in energy and angles encountered in the workplace
Calibration of neutron personal dosimeters and detectors, especially in high-energy and pulsed fields.
Development of equipment for simultaneous measurement of energy and directional distributions
Improvement of exiting active and passive techniques
Development of new techniques
Practical and reliable neutron dosimetry
2015
2025
2035


EURADOS Strategic Research Agenda: ROADMAP
European Radiation Dosimetry Group
EURADOS
Vision 5: Towards improved radiation protection of workers and members of the public
Challenge 5: To develop accurate and on-line information for in-situ environmental dosimetry
Drivers
Support to governmental decisions in case of nuclear emergency
Optimal radiation protection of the public including emergency preparedness
Targets
Improvement of environmental radiation monitoring networks in Europe
Provide reliable environmental radiation monitoring
Harmonized monitoring in surveillance networks
Experimental & computational realisation
Improvement of existing dose rate monitors and spectro-dosemeters and development of new instruments for governmental and non-governmental applications
Development of automatic software systems for activity concentration level display
Organization of regular intercomparisons
Input from industry and regulatory bodies
Input from simulations and measurements
Implementation of unmanned aerial monitoring systems
Implementation of harmonised calibration and data evaluation methods
Implementation of novel spectrometric instruments in surveillance networks
Extended functions for further data analyses
Harmonised online in-situ monitoring platforms including new technologies and units in Europe
Extension of network data bases for implementation of harmonization algorithms for all in-situ data
Creation and implementation of new algorithms for net dose rate calculation and spectral analyses
2015
2025
2035