Introduction

Roadmaps are used extensively by many diverse organisations in order to indicate – in a general and often graphic way - a pathway which illustrates the major steps for the achievement of strategic objectives. Within the radiation protection community in Europe, roadmaps have been produced by several platforms to illustrate how Strategic Research Agendas (SRAs) may be carried out (e.g. EURADOS, NERIS, MELODI, EURAMET).

Graphical roadmaps may be written in many formats depending on the nature of the organisation and its SRA, but they contain some key common features:

(i) A statement of the desired objectives (Visions and Challenges);
(ii) A timeline;
(iii) Milestones showing key events;
(iv) An easily appreciated visual summary of the key workstreams (research lines).

The roadmaps in this compilation are derived from, and should be read in conjunction with, the EURADOS SRA (2020 revision[1]). The format is similar to that used by EURAMET[2]. Some elements have previously been used as input to the CONCERT Joint Roadmap (JRM)[3]. In the timescale covered by the current SRA, there are inevitably uncertainties in institutional, national and European funding priorities and therefore project timelines are at best approximate. The EURADOS SRA does not discuss resources (financial or human), so the roadmap timelines are mostly indicated by 5-year time bands. However, for some Challenges, even this categorization remains speculative.

In the SRA which forms the basis of these roadmaps, there are sections on *Education and Training*, *Harmonisation* and *Computational Dosimetry*. These important areas are common to all the SRA Visions. They are therefore an integral part of the roadmaps in this compilation and have not been shown separately.

This compilation is made up as follows:

- Slide 4 shows all the Visions and Challenges in the current version of the SRA. There is no timeline, but strongly linked Challenges are shown.

- Slides 5-21 show individual graphical roadmaps for all Challenges and include the objectives and more detailed Research Lines for each Challenge.

It is intended that this compilation (in ppt format) may be modified to reflect future dosimetry developments. The original version is included as a pdf.

Roger Harrison 23/7/2020

References

1. EURADOS Report (2020) (to be added)
2. Science and Technology Roadmaps for Metrology Foresight. Reference Document of the Technical Committees of EURAMET e.V. 2012
3. European Joint Programme for the Integration of Radiation Protection Research H2020 – 662287. D3.7 Second joint roadmap for radiation protection research 2020

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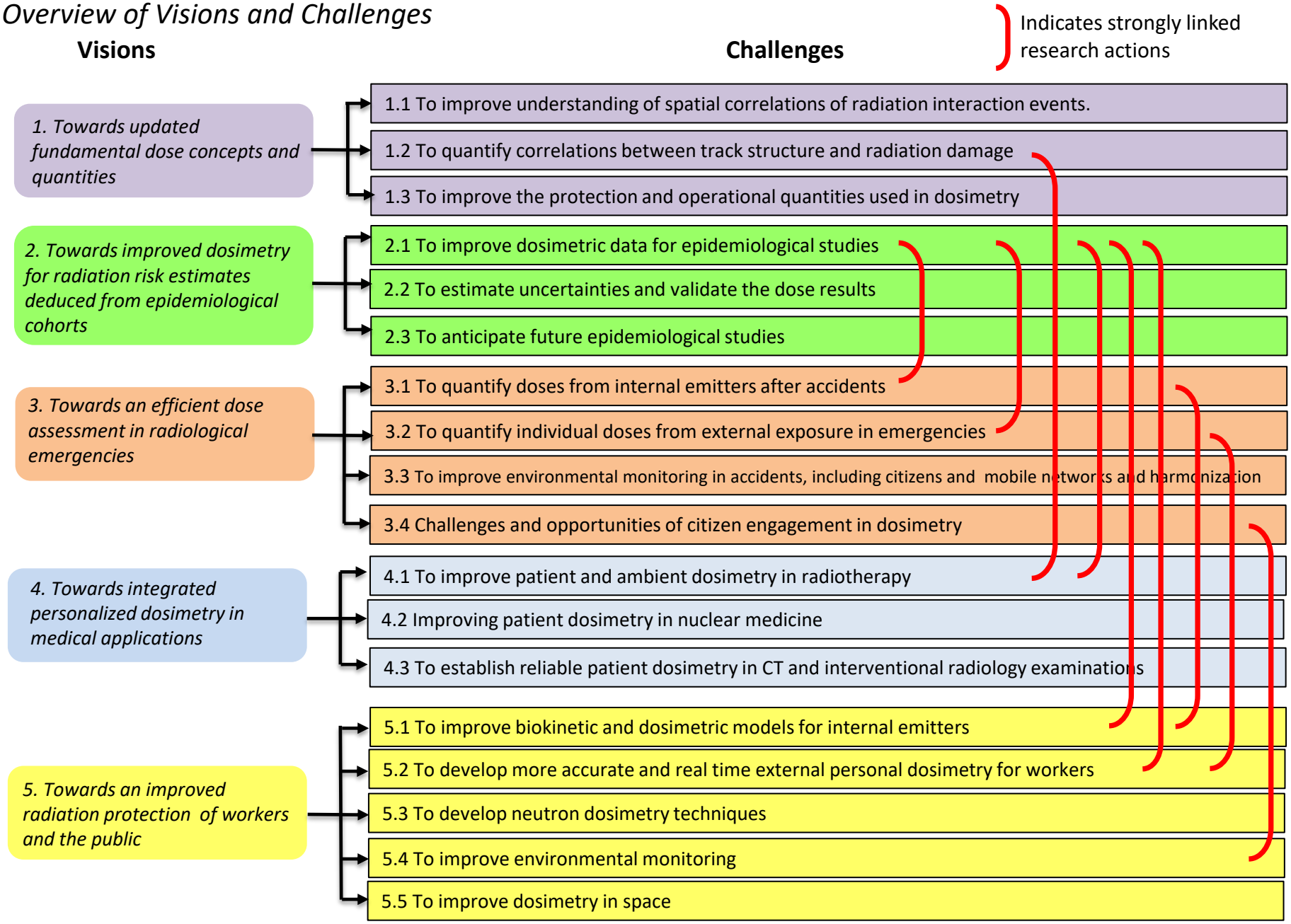
EURADOS Strategic Research Agenda: ROADMAP 2020

Overview of Visions and Challenges



Vision 1: Towards updated fundamental dose concepts and quantities

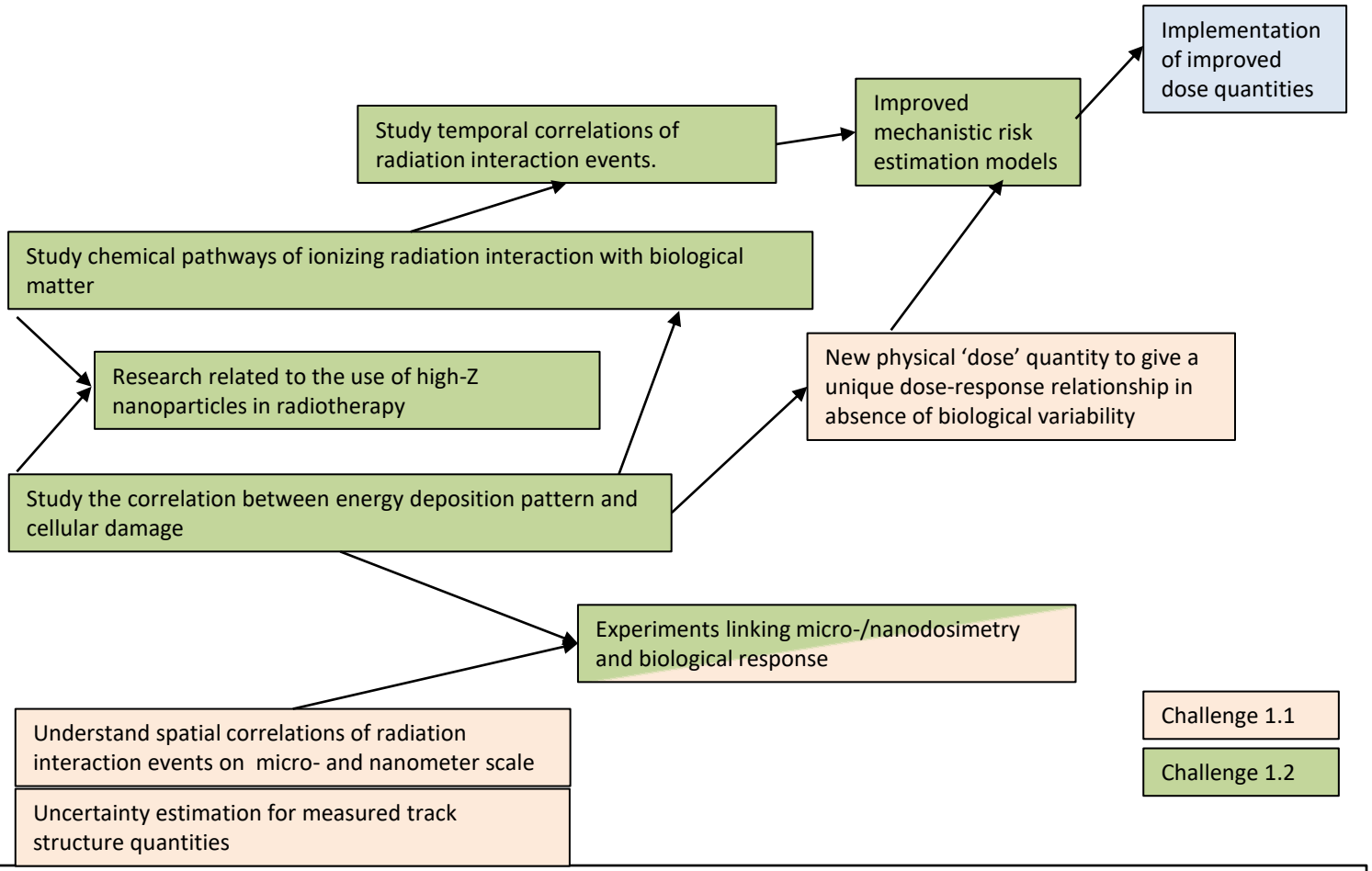
Challenge 1.1: To improve understanding of spatial correlations of radiation interaction events.
Challenge 1.2: To quantify correlations between track structure and radiation damage.

Objectives

1. Development of a novel, unified concept of radiation quality as a general physical characteristic of the radiation field. Development of a physical 'dose' quantity that in the absence of biological variability would give a unique dose-response relationship.

2. To investigate potential correlations between the track structure of ionizing radiation and the radiation damage caused after exposure.

Research lines

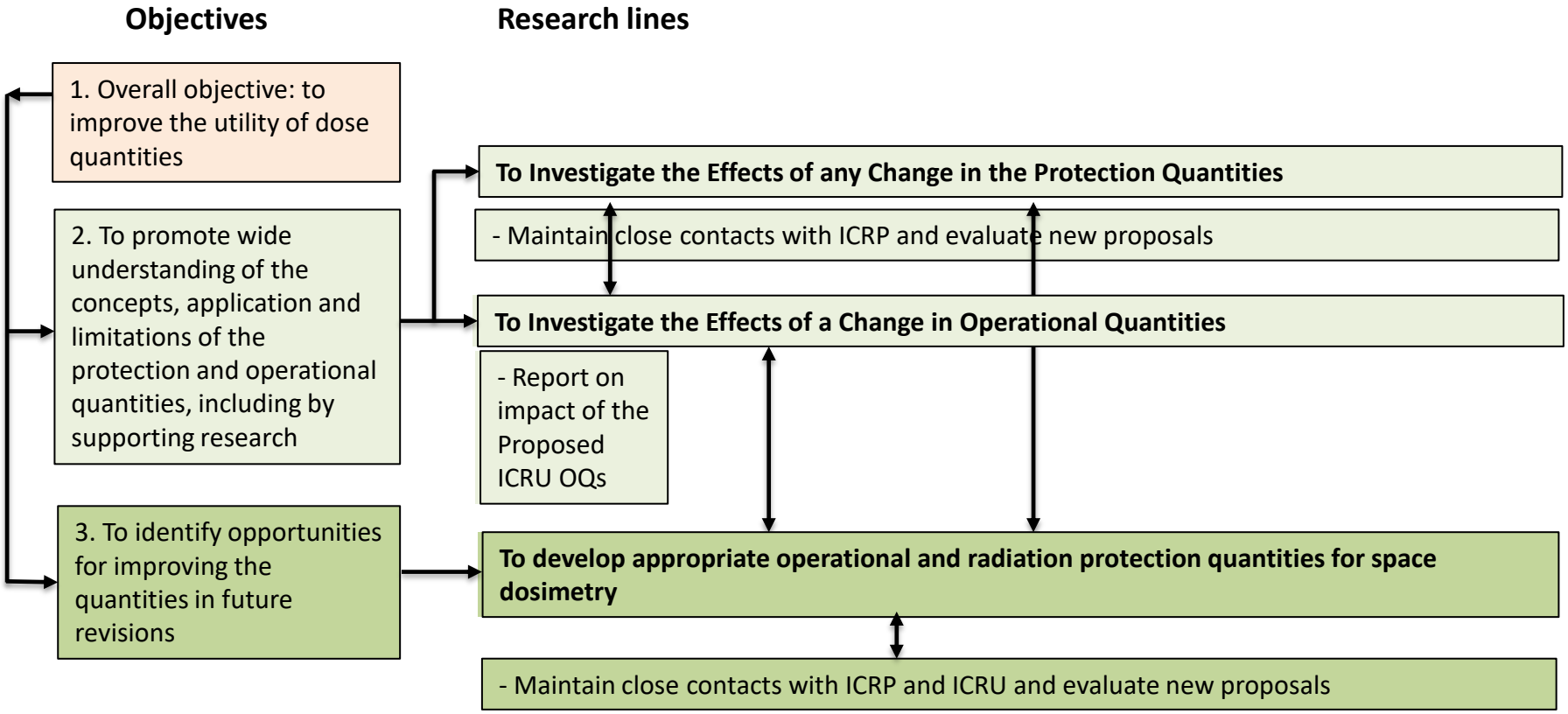


Needed Science and Technology	1.Advanced detectors for measuring ionising radiation interaction at the micro- and nanometer scale 2.Metrological methods for improved detection of radiation-induced biological endpoints with automated assays 3. Improved multi-scale Monte Carlo simulations for predicting radiation-induced damage

1-5 years 5-10 years > 10 years **Time (y)**

Vision 1: Towards updated fundamental dose concepts and quantities

Challenge 1.3: To improve the protection and operational quantities used in dosimetry



1-5 years 5-10 years > 10 years Time (y)

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

Challenge 2.1:To improve dosimetric data for epidemiological studies

Objectives	Research lines
1. Improve methodology to reconstruct doses in the context of missing data	Estimation of doses to organs and tissues originally not included in dosimetric monitoring and dose assessment:
	Estimation of doses to organs not originally considered
	Estimation of doses to non-targeted organs
	Estimation of doses from radiation type/pathways not originally considered
2. Re-evaluate historical records	Improvement in the quality and further completion of the initial data used for external and internal dose reconstruction.
	Improvement in the data archiving and re-evaluation systems and methods
	Improvement in the treatment and methods for large scale data analysis
3. Develop refined models of the human body	Improvement of the basic models used for assessments of external and internal doses
	Improvement of adaptable computational human models
	Improvement of age and gender specific biokinetic models

1-5 years 5-10 years > 10 years Time (y)

EURADOS Strategic Research Agenda: ROADMAP 2020

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

Challenge 2.2: To estimate uncertainties and validate the dose results

Objectives	Research lines
1. To strengthen benchmarking with retrospective dosimetry	Validation of calculated doses with the use of independent methods for retrospective dosimetry
	Identification and harmonisation of sampling and storage methods
	Expand from external uniform fields to internal or combined exposure and non-uniform fields
2. To further improve quantification of uncertainties	Uncertainty analysis in the calculated doses and estimation of their influence on the radiation-risk coefficients
	Understand type, magnitude and interrelationship of uncertainties in models, parameters and data
	Quantify uncertainties and incorporate them in risk analyses

1-5 years 5-10 years > 10 years Time (y)

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

Challenge 2.3: To anticipate future epidemiological studies

Objectives	Research lines
1. Improve specification to record dosimetric data for future use	Prepare future epidemiological studies
	Document characteristics of exposure
	Establish structure/specifications for systematic data collection and anticipate access in the future
2. Improve dose estimation in biological samples with focus on non-invasive techniques	Molecular epidemiological studies
	Large scale sample collection (non-invasive) and associated dose reconstruction

1-5 years 5-10 years > 10 years Time (y)

Vision 3: Towards an efficient dose assessment in radiological emergencies

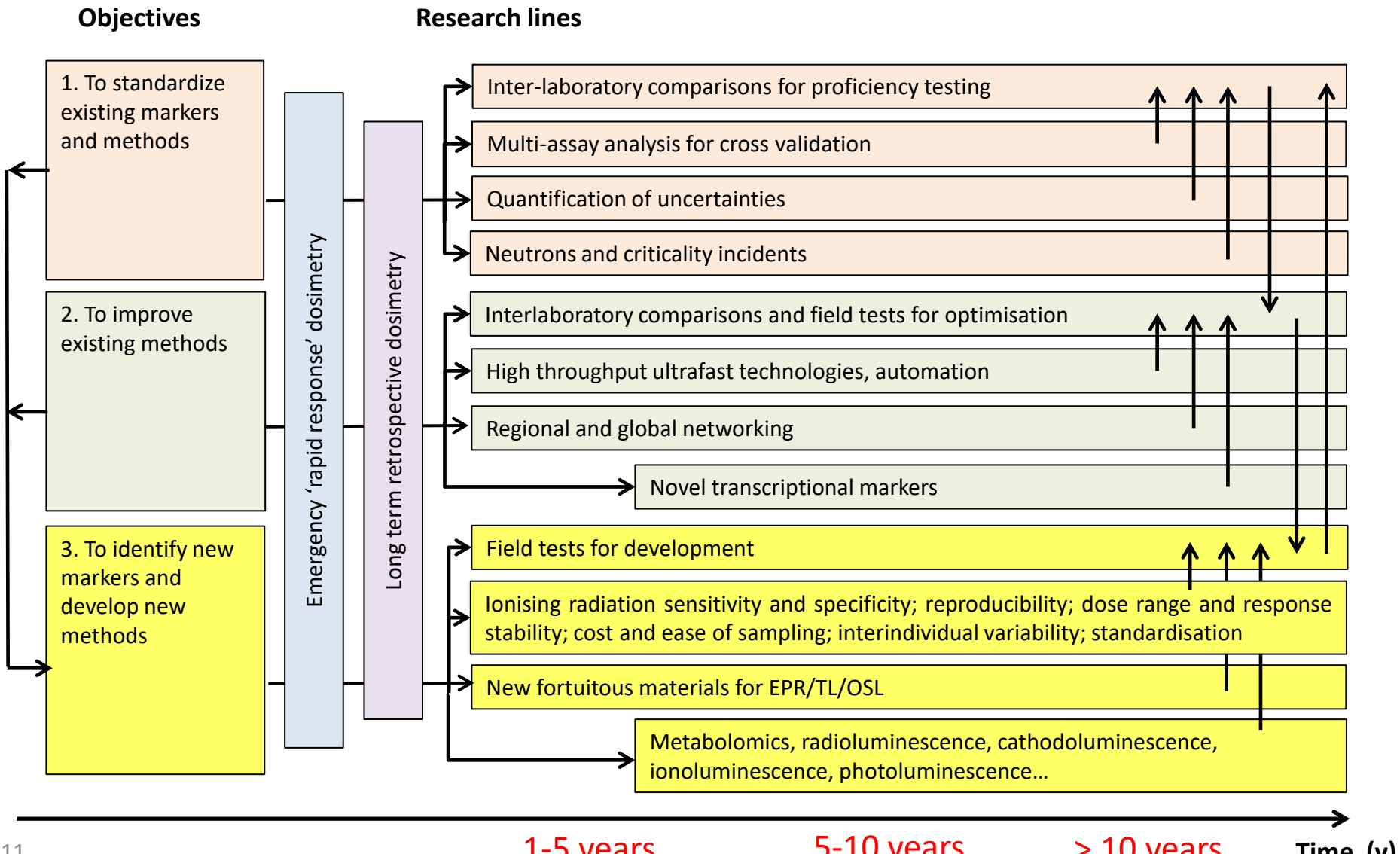
Challenge 3.1: To quantify doses from internal emitters after accidents

Objectives	Research lines
1. New developments of equipment and methods for individual monitoring of radionuclides incorporated in the body due to accidental internal exposures	Improvement of calibration of in vivo monitoring techniques for children
	New developments of Monte Carlo methods using computational phantoms (voxel phantoms, mesh phantoms) scaled by age for the calibration of body counters
	More rapid in vitro emergency bioassay methods for alpha emitters (actinides) and ^{90}Sr
2. Protocols and tools for a rapid and reliable assessment of absorbed doses to organs and committed effective doses of exposed persons of different genders and ages during a nuclear accident.	To link internal dosimetry with biological dosimetry of internal emitters
	Development of Apps to use for organ and effective dose estimation with on-line free access using age dependent dose coefficients for children, new OIR models for adults
	Measurement systems and tools for dose assessment for wound contaminated persons
3. Improvement in the transfer of the dosimetry data to decision makers and on the communication with stakeholders and civil society	Networking and optimization in the use of in vivo mobile units, portable devices and other transborder equipment
	Rapid transfer of internal dosimetry data to decision-makers
	Involvement of citizens of contaminated areas in measurements of incorporated radionuclides
	Improvement of communication between dosimetry experts, stakeholders and public
4. Modelling of biokinetics of incorporated radionuclides in human and non-human biota	Modelling of biokinetics of chelating agents
	New developments in wildlife internal dosimetry
5. Dose reconstruction. Epidemiology studies.	Development of a standard methodology and computational tools for the calculation and use of internal doses for epidemiology studies

1-5 years | 5-10 years | > 10 years | Time (y)

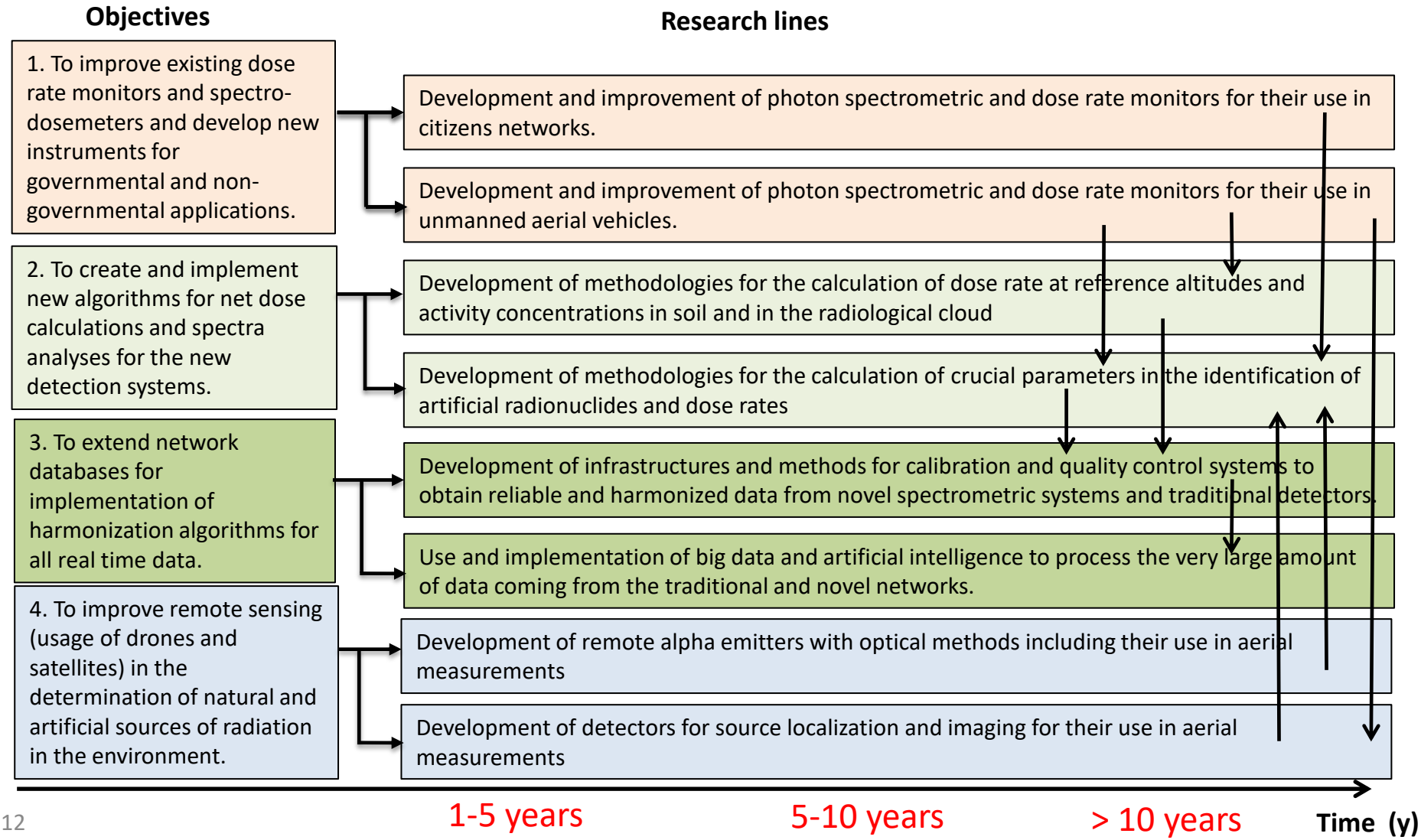
Vision 3: Towards an efficient dose assessment in radiological emergencies

Challenge 3.2: To quantify individual doses from external exposure in emergencies



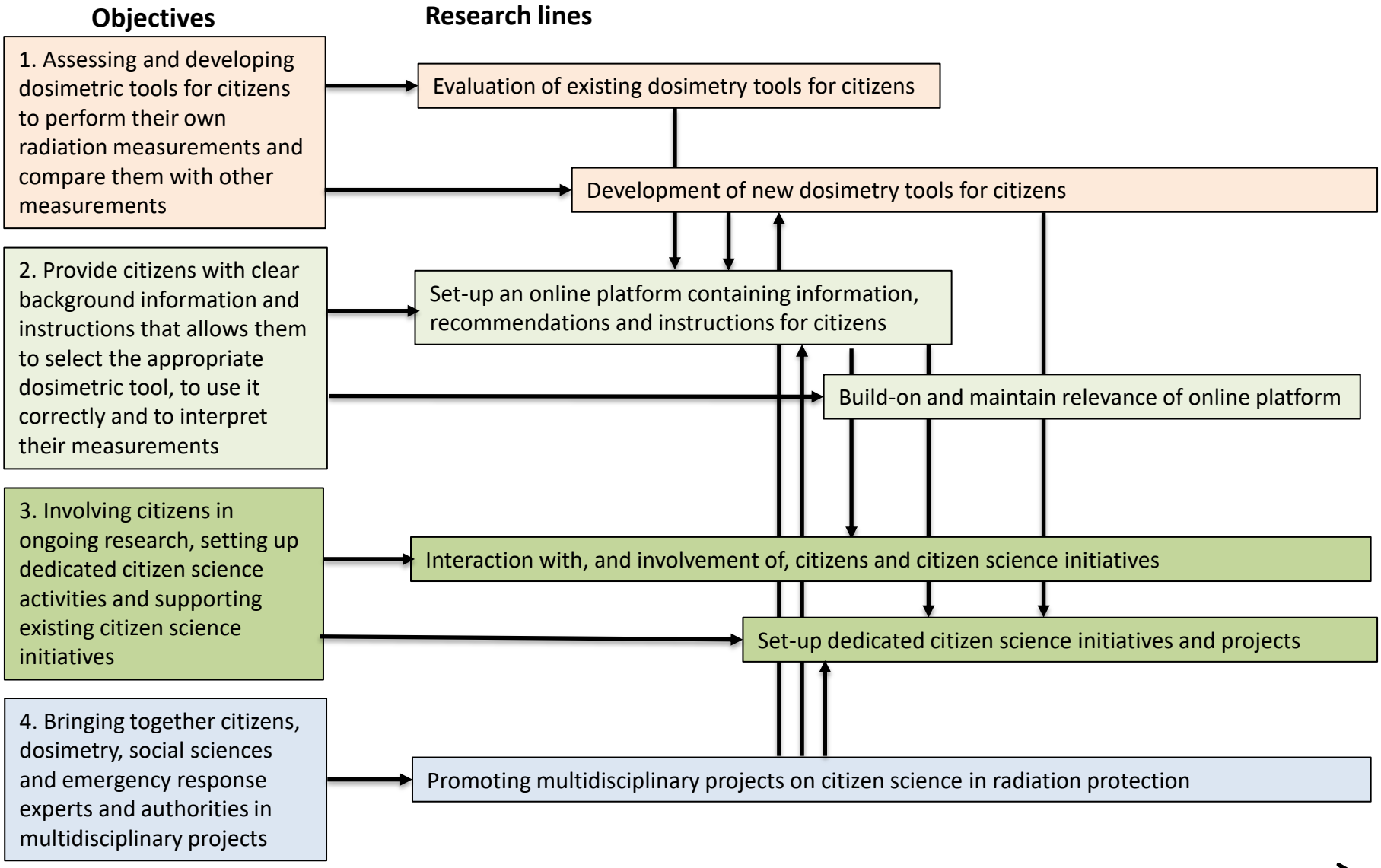
Vision 3: Towards an efficient dose assessment in radiological emergencies

Challenge 3.3: To improve environmental monitoring in case of an accident, including citizens and mobile networks and harmonization



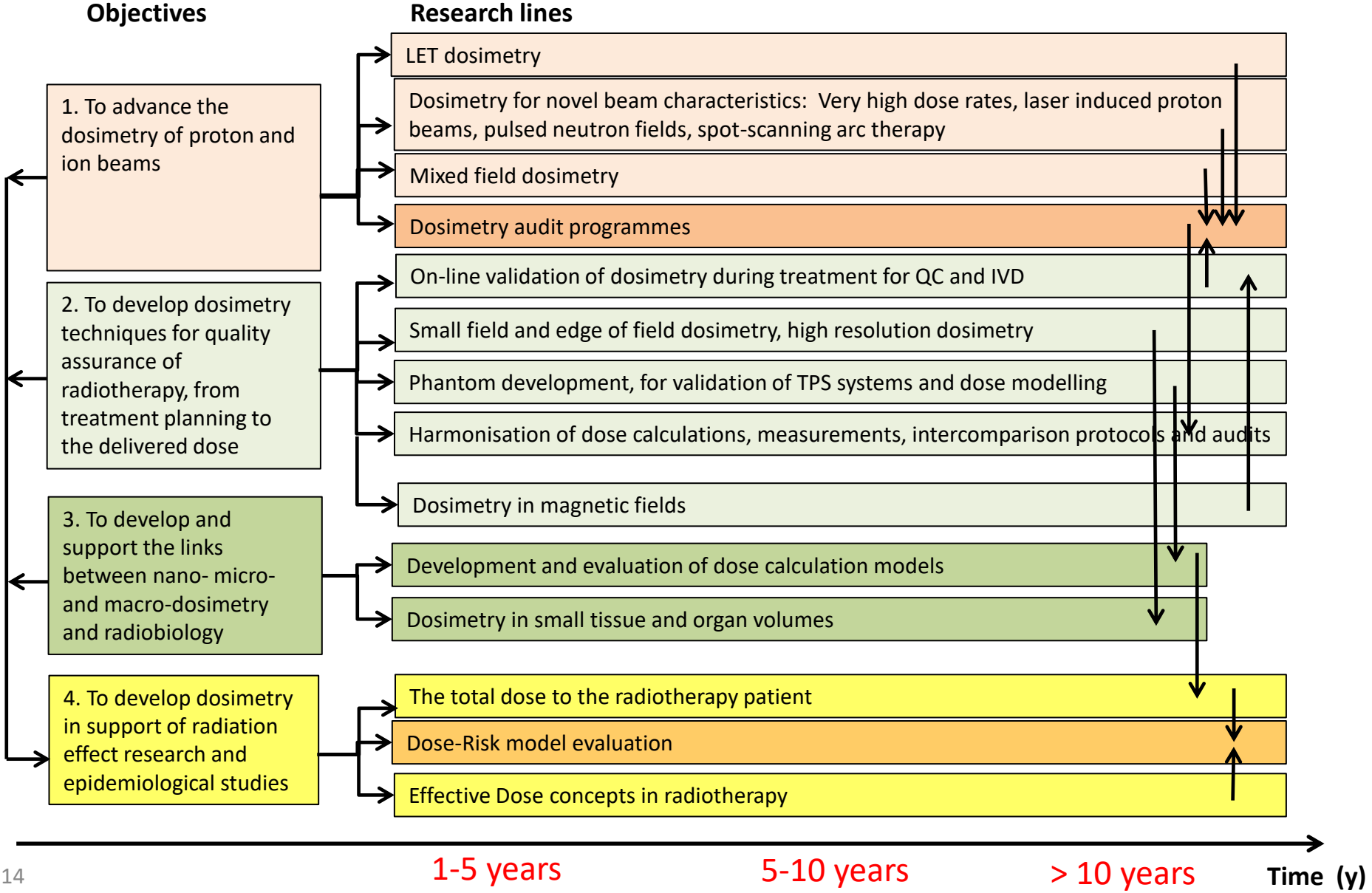
Vision 3: Towards an efficient dose assessment in radiological emergencies

Challenge 3.4: Challenges and opportunities of citizen engagement in dosimetry



Vision 4: Towards integrated personalized dosimetry in medical applications

Challenge 4.1: To improve patient and ambient dosimetry in radiotherapy



Vision 4: Towards integrated personalized dosimetry in medical applications

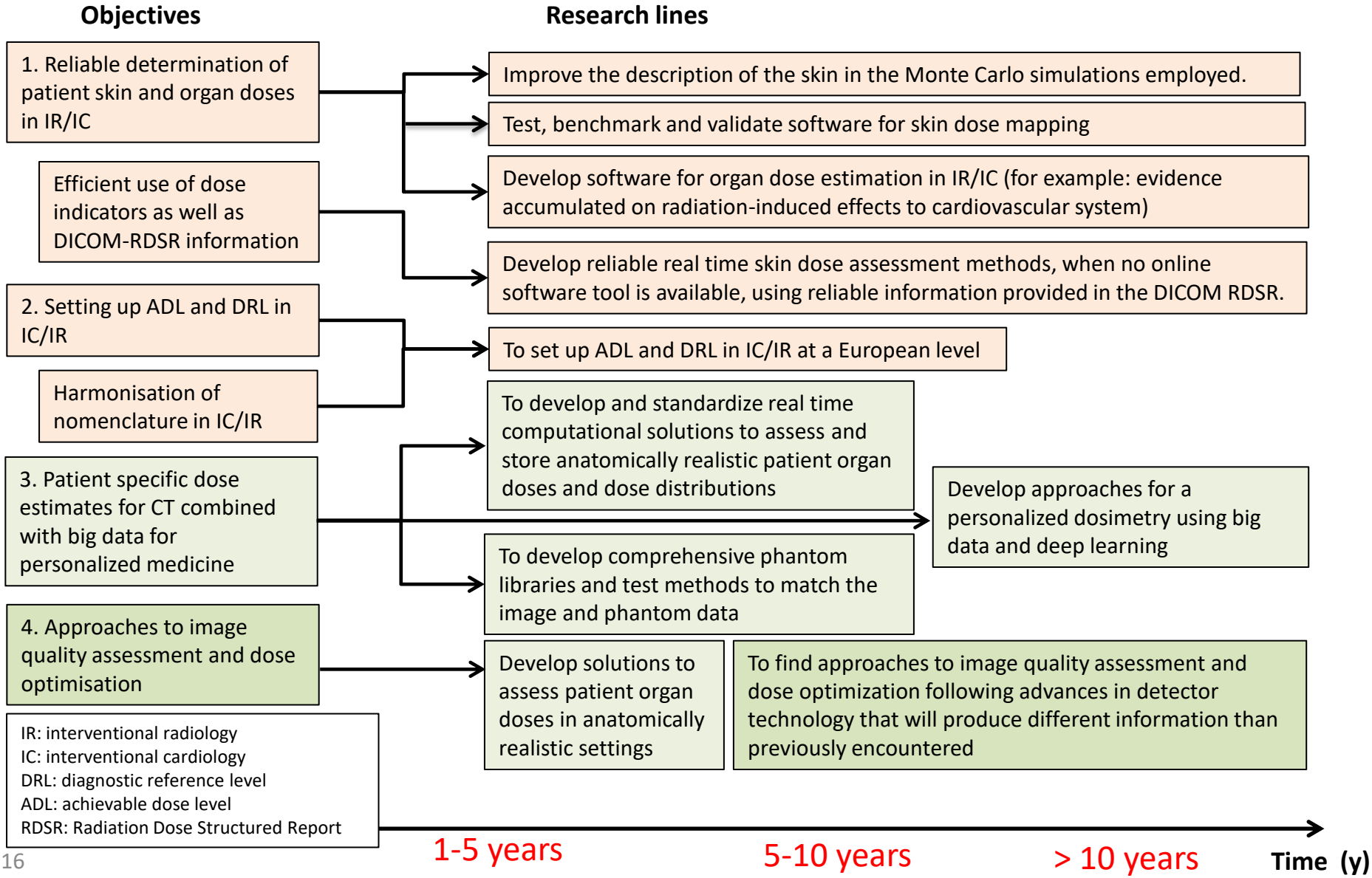
Challenge 4.2 Improving patient dosimetry in nuclear medicine

Objectives	Research lines
1. To gain insight on the heterogeneity of deposited energy on micro- & nano-scale in case of high-LET radiation	Determination of heterogeneous activity distribution on cellular level & microdosimetry on in vitro scale
2. To optimize & harmonize quantitative multimodality (pre)-clinical imaging for γ-, β- and α-emitting radiopharmaceuticals	Imaging heterogeneous activity distribution on organ level & small-scale dosimetry on in vivo scale
	Biokinetics of decay products of parent targeting molecules
3. To investigate dose-effect relationship both on cell- & organ-level for β-, α- & Auger-emitting radiopharmaceuticals	Systematic study of dose-effect relationships for internal emitters (β, α)
4. To implement accurate clinical dosimetry methods & determination of uncertainties in the chain from measured activity to calculated absorbed doses	Validation of pharmacokinetic models and internal dosimetry
	Uncertainty quantification of patient doses in clinical practice
	Quantitative imaging of radiopharmaceuticals
5. To gain insights on validity of available pharmacokinetic models of emerging treatments on individual patient basis	Optimization of patient doses in radionuclide diagnostics and therapy
6. To improve the accuracy of activity measurements for γ-, β- and α-emitting radiopharmaceuticals both in radionuclide diagnostics & therapy	Accuracy of radionuclide activity measurements with radionuclide calibrators

1-5 years | 5-10 years | > 10 years | Time (y)

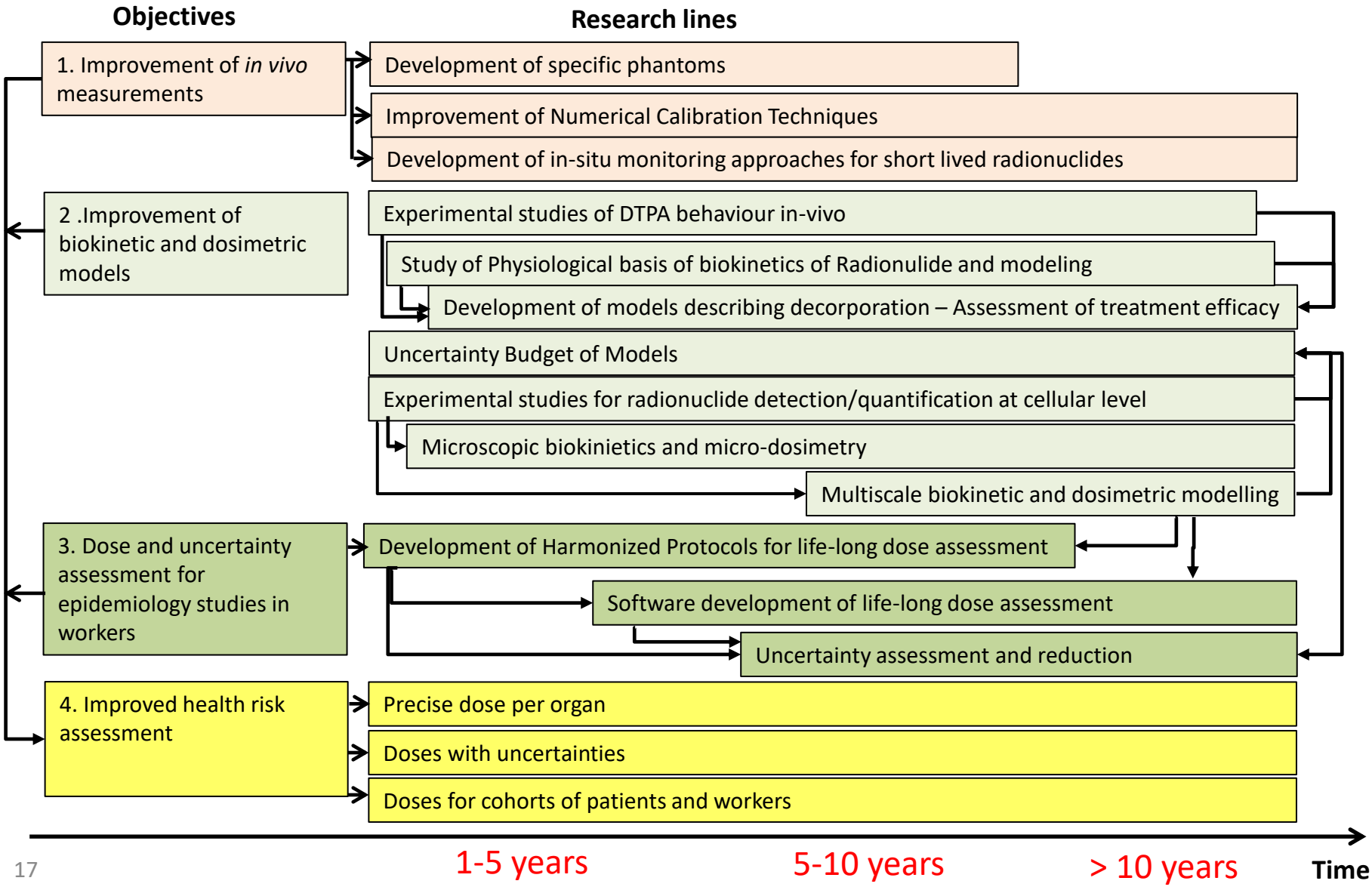
Vision 4: Towards integrated personalized dosimetry in medical applications

Challenge 4.3 To establish reliable patient dosimetry in CT and interventional radiology examinations



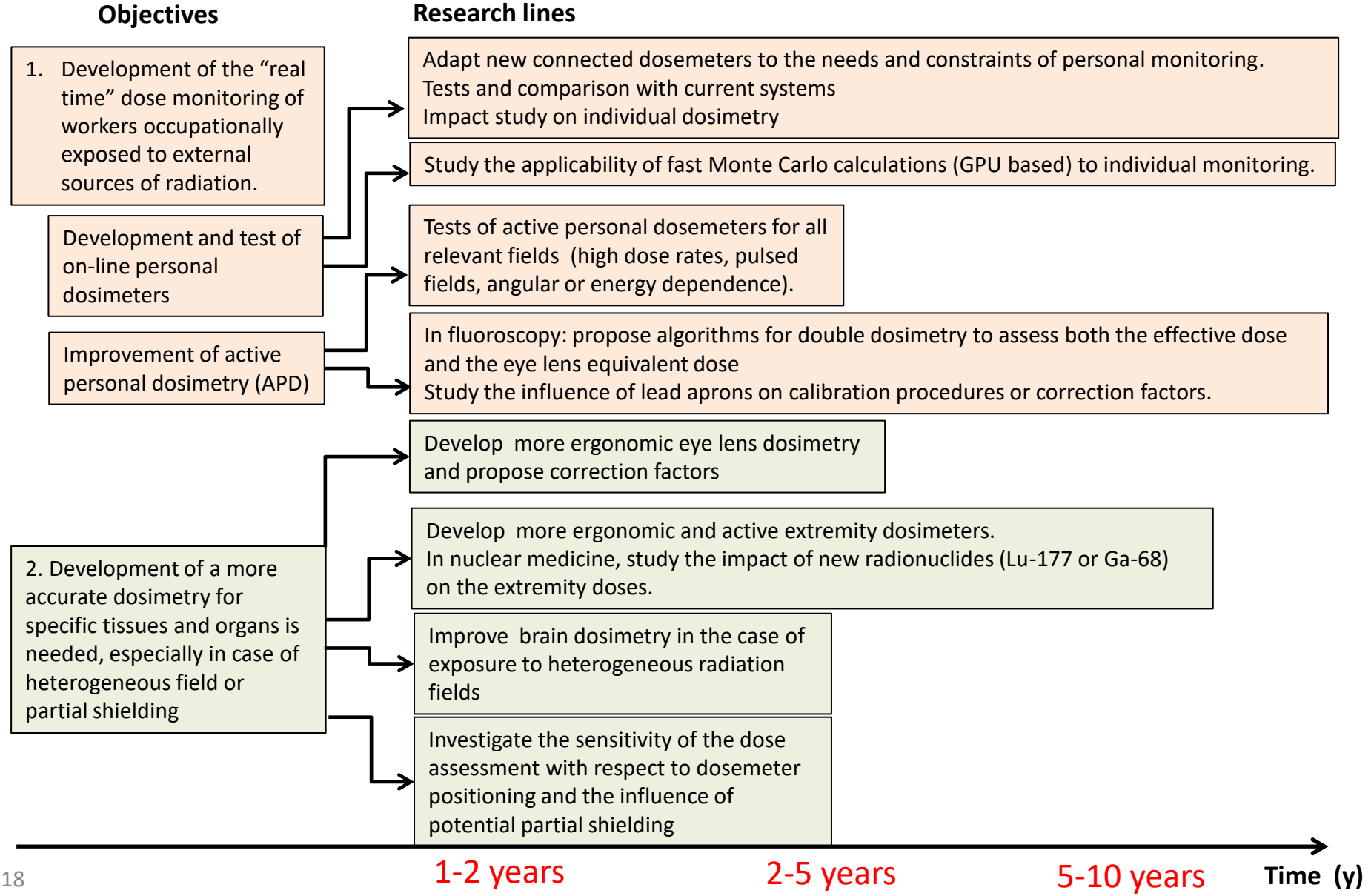
Vision 5: Towards an improved radiation protection of workers and the public

Challenge 5.1: To improve biokinetic and dosimetric models for internal emitters



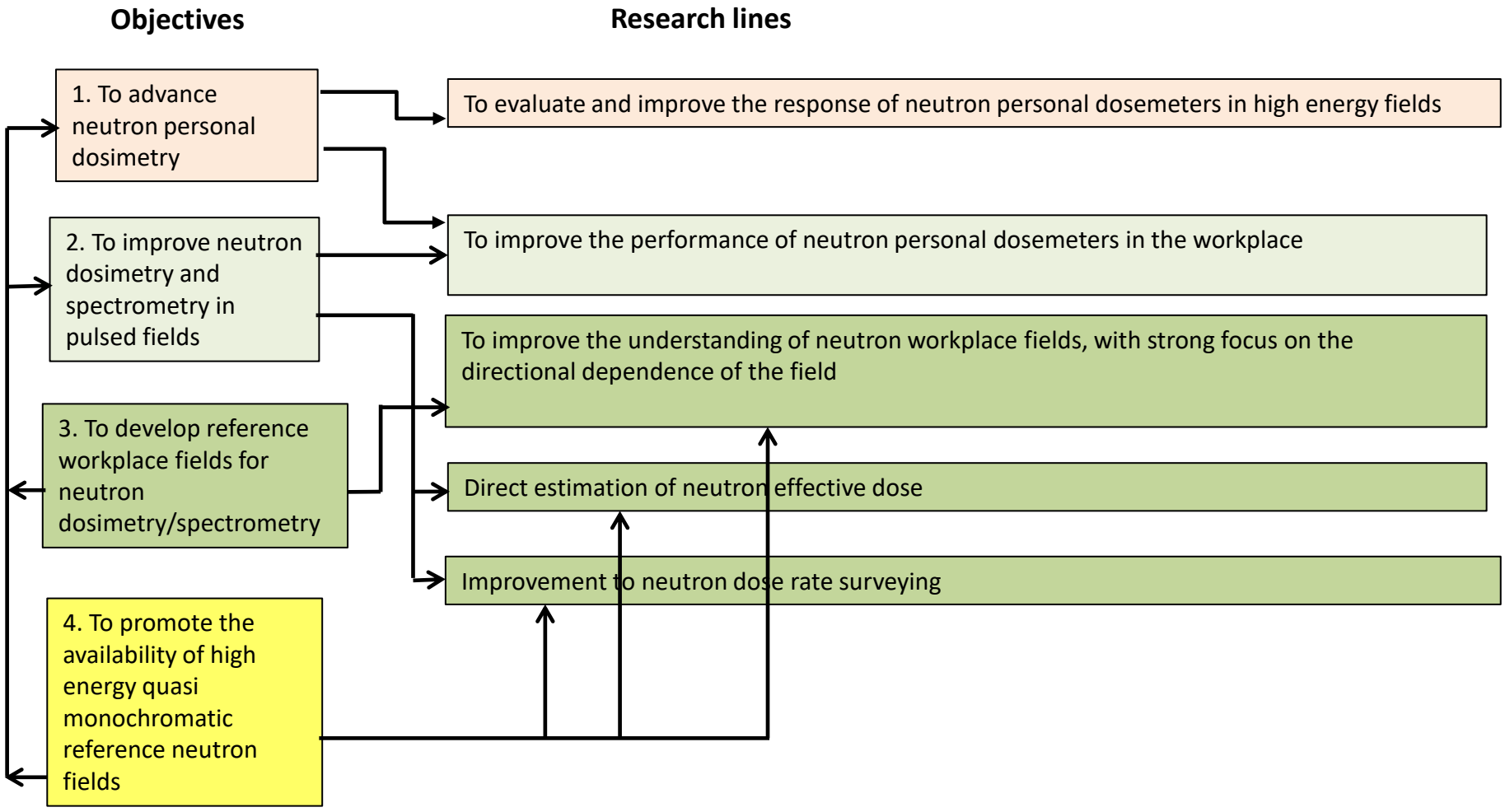
Vision 5: Towards an improved radiation protection of workers and the public

Challenge 5.2: To develop more accurate and real time external personal dosimetry for workers



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

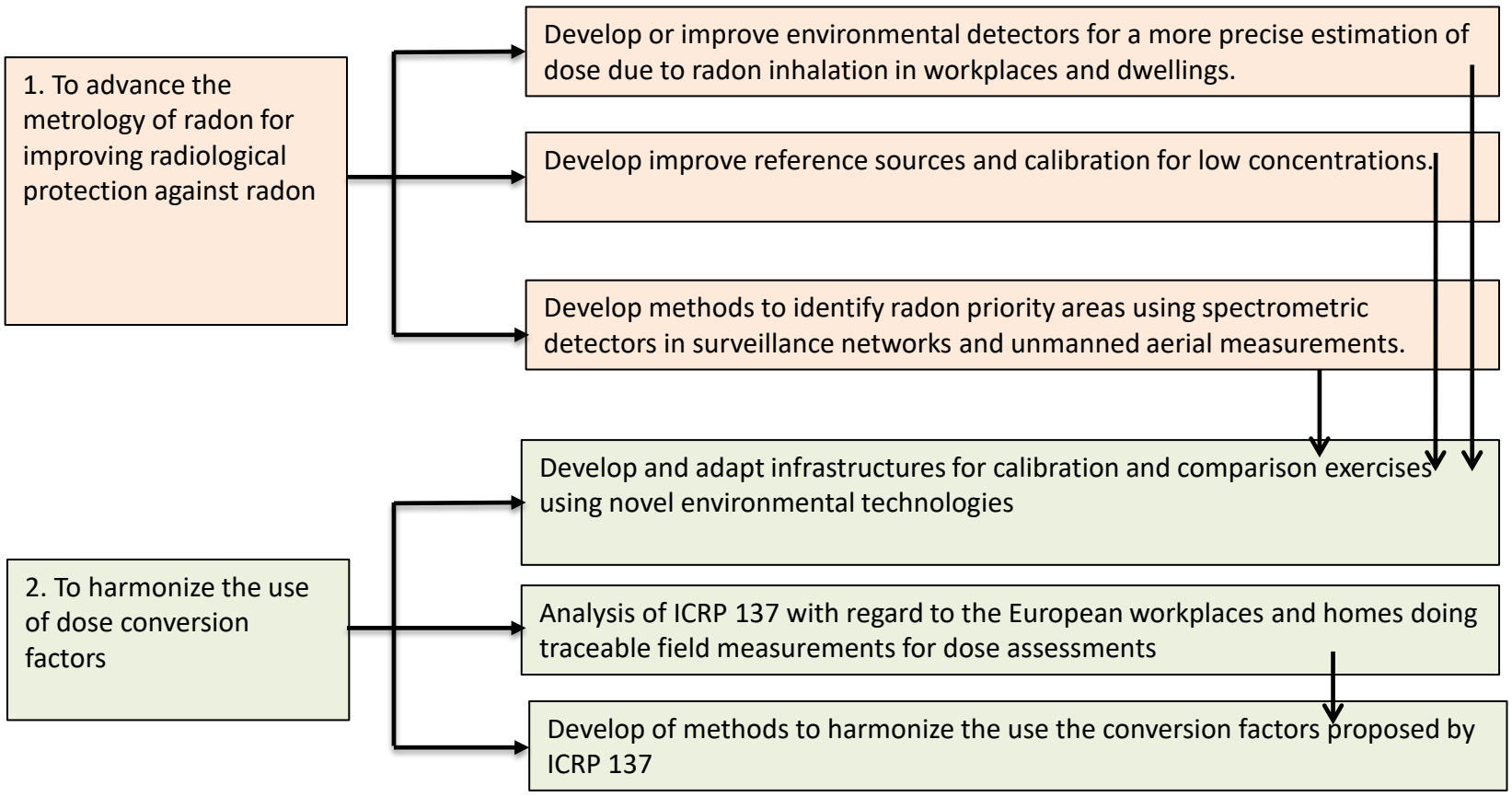
Challenge 5.3: To develop neutron dosimetry techniques



1-5 years 5-10 years > 10 years Time (y)

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

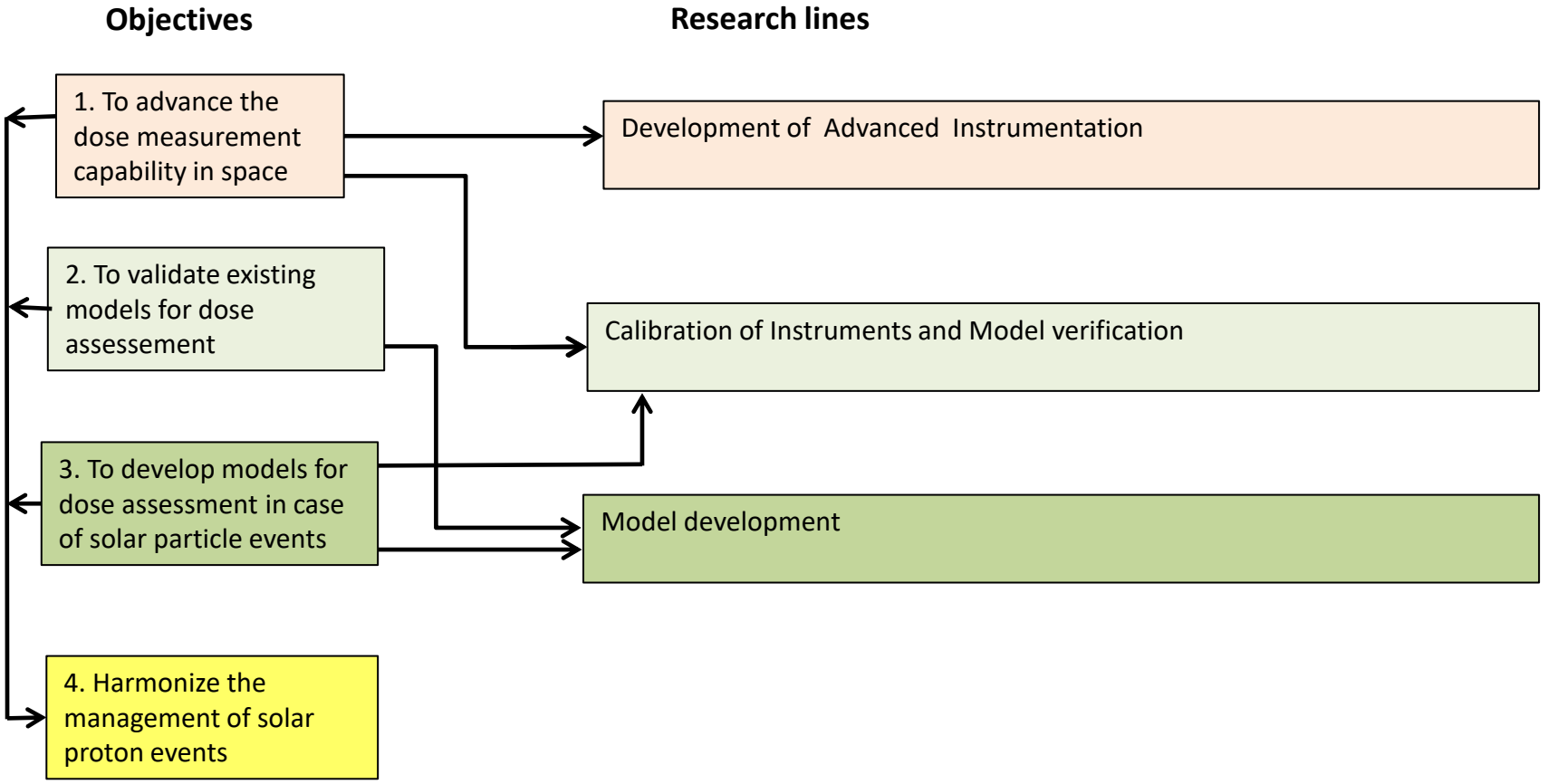
Challenge 5.4: To improve environmental monitoring



1-5 years 5-10 years > 10 years Time (y)

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

Challenge 5.5: To improve dosimetry in space



1-5 years 5-10 years > 10 years Time (y)