REDUCTION OF RADIOLOGICAL ACCIDENT CONSEQUENCES

# Overview of the EU H2020 R2CA project:

## Reduction of Radiological Consequences of Accidents

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IRSN

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# Origin & Context

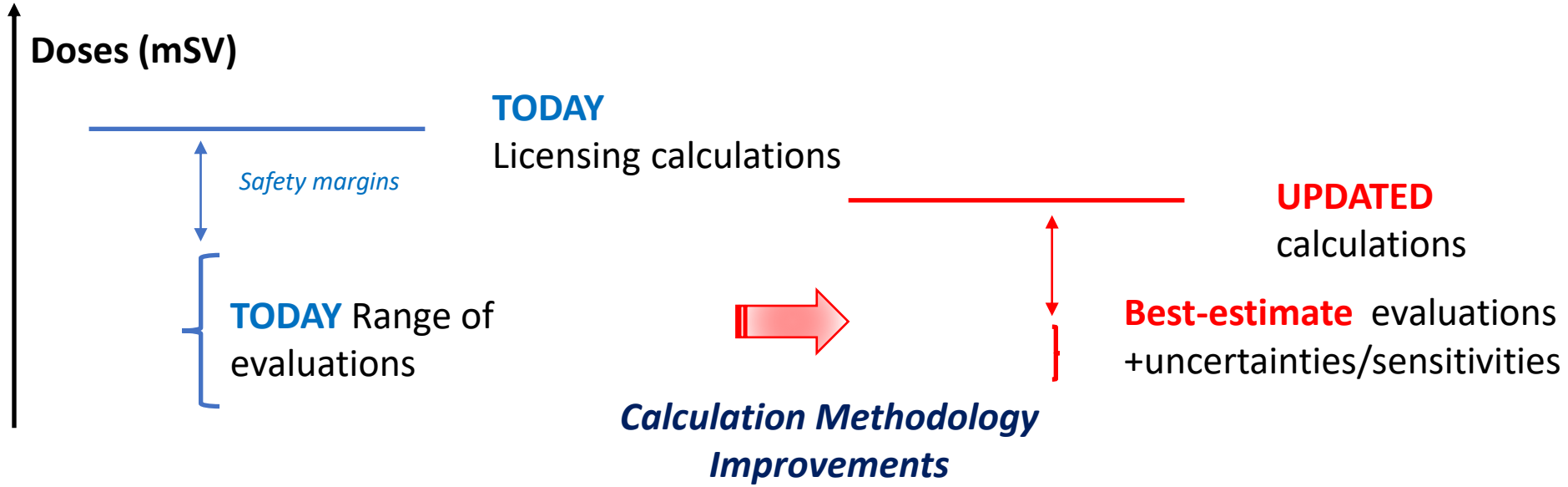
REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Issued from 4th periodic safety review of French 900 MWe PWR but also worldwide due to more challenging safety objectives targeted for NPPs
  - ❖ Increased NPPs safety required in terms of RC reduction in addition to safety criteria in safety accident analyses
    - ⇨ *For DBA : tend to reduce the RC down to levels where no more population protection measures*
    - ⇨ *Considering scenarios more severe than DBA (incl. DEC-A situations)*
- After FKS large R&D efforts on the evaluation of Severe Accident progression and consequences lead to increase the predictability of SA progression, evaluate AMPs and improve their consequence mitigation
  - ❖ Less efforts paid on ***DBA and DEC-A situations leading to reduce the differences in risks associated to DBA and BDBA***
- DBA largely studied and modeled for establishing safety criteria to fulfill safety objectives, but evaluations usually done with very conservative deterministic assumptions/decoupled approaches and fewer efforts paid to best estimate evaluation of RC
  - ❖ For LOCA DBA objectives related to clad integrity and core coolability and RC evaluated with specific decoupled assumptions (i.e. in France 33% of the fuel rods assumed to fail)
    - ⇨ Optimisation of EP&R actions + quantification of gains (in terms of RC) of additional measures/devices impossible

# Motivation

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Refine the assessments of radiological consequences of explicit DBA and DEC-A accidental scenarios **in Gen II, Gen III and Gen III+ NPPs focusing on LOCA and SGTR scenarios**




- Increase the level of NPP safety by more realistic evaluations of DBA
  - **FKS studies evidenced the decrease in** differences between evaluated risks for DBA and BDBA conditions and the use of very conservative assumptions/tools for RC evaluations of DBA
- Strengthen assessments of NPP safety levels considering situations more severe than those integrated in plant designs (DEC-A domain ↔ wo "*significant fuel melting*")

# Objectives & Methodology

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Specific objectives of R2CA for a best estimation of LOCA & SGTR radiological consequences
  - Upgrade simulation tools (integral, detailed) & improve calculation schemes (coupling…)
  - Harmonize calculation methodologies: *derivation of some principles for EP&R action optimization*
  - Optimize accident management procedures (development of new/improved algorithms…)
  - Evaluate innovative systems (ATF, safety devices, algorithms…)
  - Develop innovative tools based on AI for earlier diagnosis and accident anticipation (SGTR)

- Methodology
  - Review of existing base (methodologies, simulation schemes, calculation tools, experimental data)
  - Identification of reactor cases covering all aspects (conditions, accidents, reactors) & simulation scheme needs
  - Upgrade of simulation schemes through re-assessments of experimental data and model improvements
  - Identification of gains through comparison of initial/final reactor case calculations (+ *uncertainty*)
  - Evaluation of innovative systems (ATF, AMP algorithms…) with improved calculation schemes

Focus on : PWRs/EPR/VVERs/BWR, LOCA/SGTR, DBA/DEC-A, Radiological Consequences, AMPs

# Methodology

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Approach for LOCA reactor calculations

Agree on Accidental Scenarios for each reactor type

Perform simulations according to the **conservative approach** (regulatory practices in each country, decoupling factors)

1- Improve failed rod number prediction: statistical approach, core modelling refinement

2- Improve fuel rod failure models: clad burst criteria update

3- Improve FP-release/transport models: consideration of HBS, fuel oxid./frag…

Improvements

Reduction of conservatism (decoupling factors)

Perform simulations according to a **more realistic** (≈ **Best-Estimate) approach**

**same scenarios with improved calc. schemes**

Quantify the gains through RC evaluation of the new method compared to conservative approach

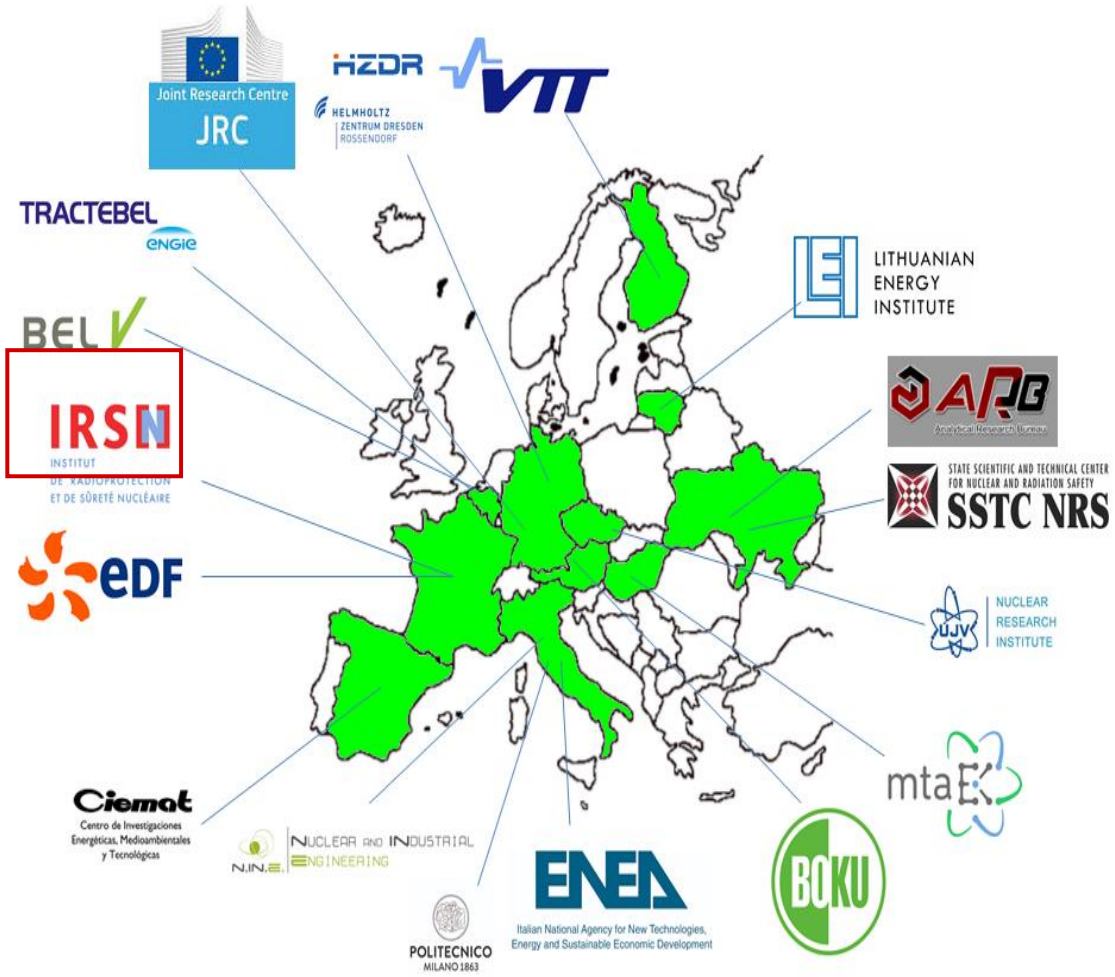
Evaluate innovative systems (ATF…)

Uncertainty evaluation

# Structure

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- Ressources 17 organisations
- Time frame 01.09.2019 – 31.08.2023




# Structure

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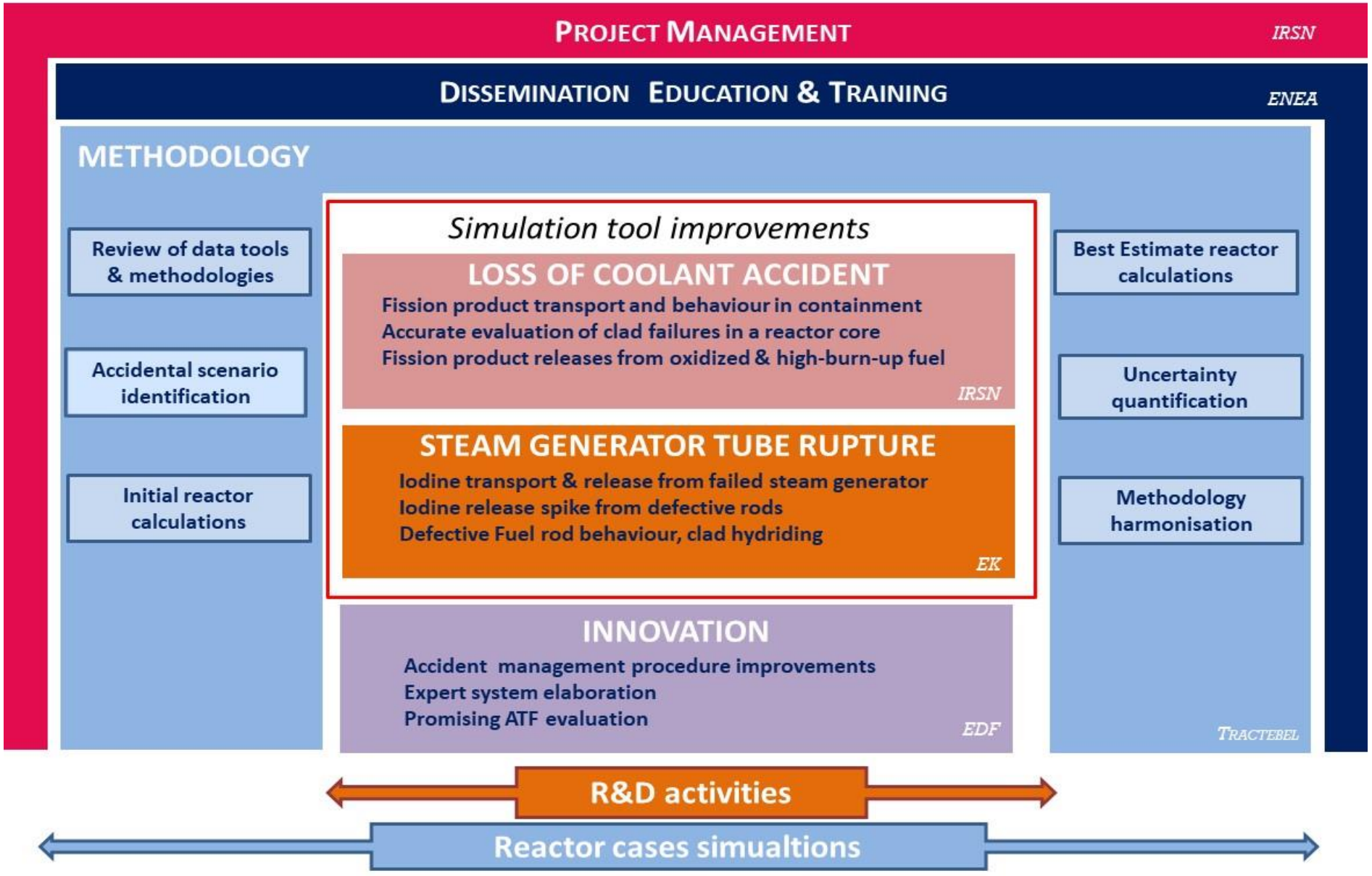

# Structure – WP3 LOCA

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

**Improve calculation tools for more realistic evaluations of LOCA DBA & DEC-A csqces**

- Identifying main relevant phenomena
- *Developping models, coupling tools to reduce the conservatisms*
- *Verifying/validating models & tools within the range of DBA/DEC-A conditions on the selected exp. database*

## T3.1 « FP releases from primary circuit»

**AMBITION**

Better evaluation of environt source term for more appropriate decisions in EP&R.

**OBJECTIVES**

**Upgrading of models for FP transport in primary circuit (incl. FP behaviour (iod.) in containment)**

## T3.2 « Clad burst failure»

**AMBITION**

More accurate evaluation of the number of fuel rod burst failures

**OBJECTIVES**

**Elaboration of new clad burst criteria (revisitation of the exp. database) and core modelling approach**

## T3.3 « Fuel rod T/M & FP releases»

**AMBITION**

Refined evaluations of FP release amount & kinetics from fuel

**OBJECTIVES**

**Improvt of FP release models from fuel (incl. chemistry) & coupling of FP release-fuel T/M tools (incl. fuel oxidation, high BU fuel formation)**

# Structure – WP4 SGTR

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

**Improve calculation tools for more realistic evaluations of SGTR DBA & DEC-A csqces**

- **Identifying main relevant phenomena**
- ***Developping models, coupling tools to reduce the conservatisms***
- ***Verifying/validating models & tools within the range of DBA/DEC-A conditions on the selected exp. database***

**T4.1 «« FP releases from primary circuit»»**

**AMBITION**

Better evaluation of environt source term for more appropriate decisions in EP&R.

**OBJECTIVES**

**Upgrading of models for FP releases (esp. iodine) from primary circuit to environment (incl. T/H flashing, carry-over)**

**T4.2 « FP releases from defective rods»**

**AMBITION**

More accurate evaluation of primary circuit activity evolution in NO & transients

**OBJECTIVES**

**Elaboration of models for FP releases from defective fuel rods (incl. spiking release phenomena, fuel leaching)**

**T4.3 « Clad secondary hydriding & failure»**

**AMBITION**

Evaluation of the risks of defective fuel rod failure

**OBJECTIVES**

**Developt of integrated models for clad secondary hydriding in defective fuel rods & clad failure criterion**

# Structure – WP5 INNOV

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

## Develop technological innovations for reduction of RC of DBA & DEC-A

- ***Accelerating*** **integration of technological breakthroughs (providing *global and long-term vision*)**
- **Identifying and tackling *technological and scientific challenges***

### T5.1 « Pro and Cons of innovative devices and management approaches »

**AMBITION**

Best measurement at the right spot for better decisions.

**OBJECTIVES**

**Improvement of AMP : New instrumentation, optimized procedure, neural network**

### T5.2 « Innovative diagnosis tools and devices »

**AMBITION**

In real time, collect, analyse, harvest values of all operating parameters plants to optimise their safety

**OBJECTIVES**

**Elaborate an expert system based on AI for identification of rod defects from RCS activity variation**

### T5.3 « E-ATF Anhanced accident tolerant fuel »

**AMBITION**

Give all nuclear power plants benefit of a fuel that can even better withstand accidents.

**OBJECTIVES**

**Evaluate promising ATF (sensitivity analysis on relevant parameters): focus on Cr-coated Zr clad and Cr-doped & high-density fuels**

# Summary

REDUCTION OF RADIOLOGICAL CONSEQUENCES OF DESIGN BASIS & DESIGN EXTENSION ACCIDENTS

- R2CA project devoted to the elaboration of generic & more realistic methodologies for radiological consequence evaluations of LOCA and SGTR transients in DBA & DEC-A conditions focussed on:
  - Upgrading, coupling & validation of reference tools (detailed and/or integral) from fuel behaviour to environmental FP releases
  - Harmonization of the calculation methodologies applicable to all existing European NPP designs (PWR, BWR, VVER)
- Innovative actions also investigated for their potential applications to reduce the radiological consequences of LOCA/SGTR within those conditions
  - Evaluation of near-concept ATFs for LOCA with updated calc. schemes (sensitivity analyses on material base properties)
  - Investigation/evaluation of innovative devices/systems (algorithms), optimisation of accidental management procedures (additional water injection, dedicated instrumentation…)
  - Use of “Artificial Intelligence” for anticipation of SGTR accidental sequences (turn the prognosis tools into diagnosis ones for early detection of defective fuel rods)

# Thank you!

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