Main elements of a work programme for the development of ATF :

Modelling tools

Second Meeting on Increased Accident Tolerance of Fuels for LWRs

28-29 October 2013

NEA Headquarters, Issy-les-Moulineaux

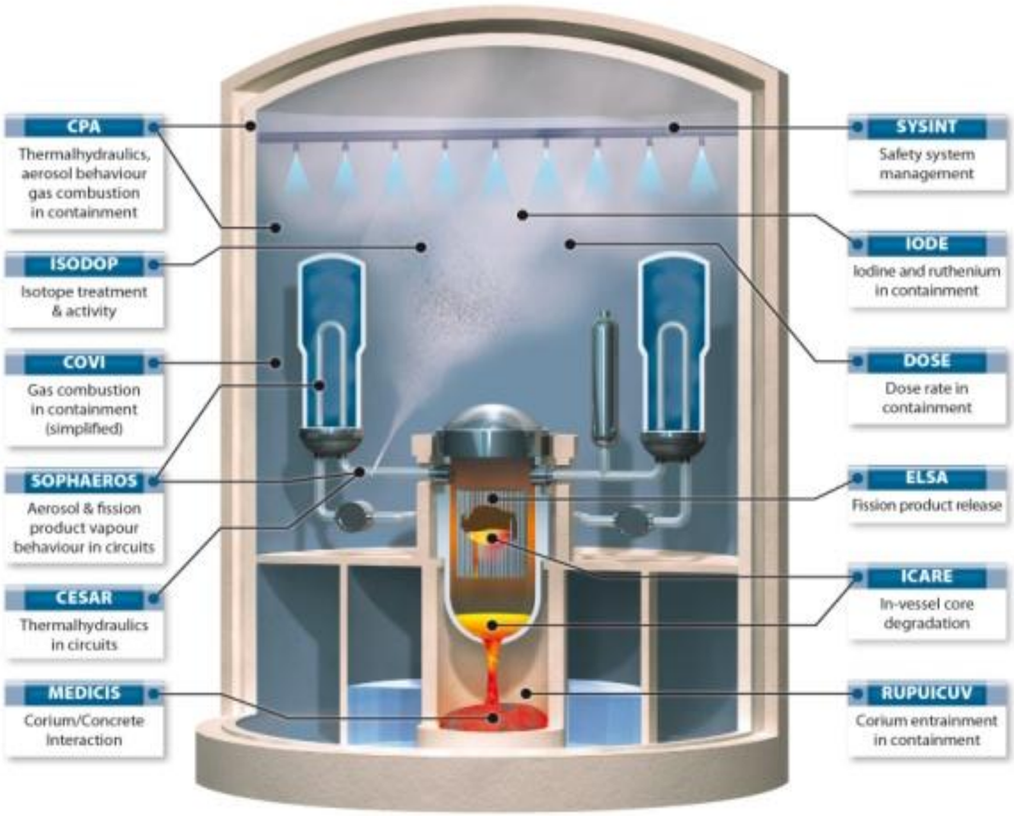
Objectives

- Introduction to severe accident modelling tools
  - Illustration of ASTEC development
- Identification of phenomena impacted by fuel properties
- Additional tools

IRSN

An example of severe accident code : ASTEC

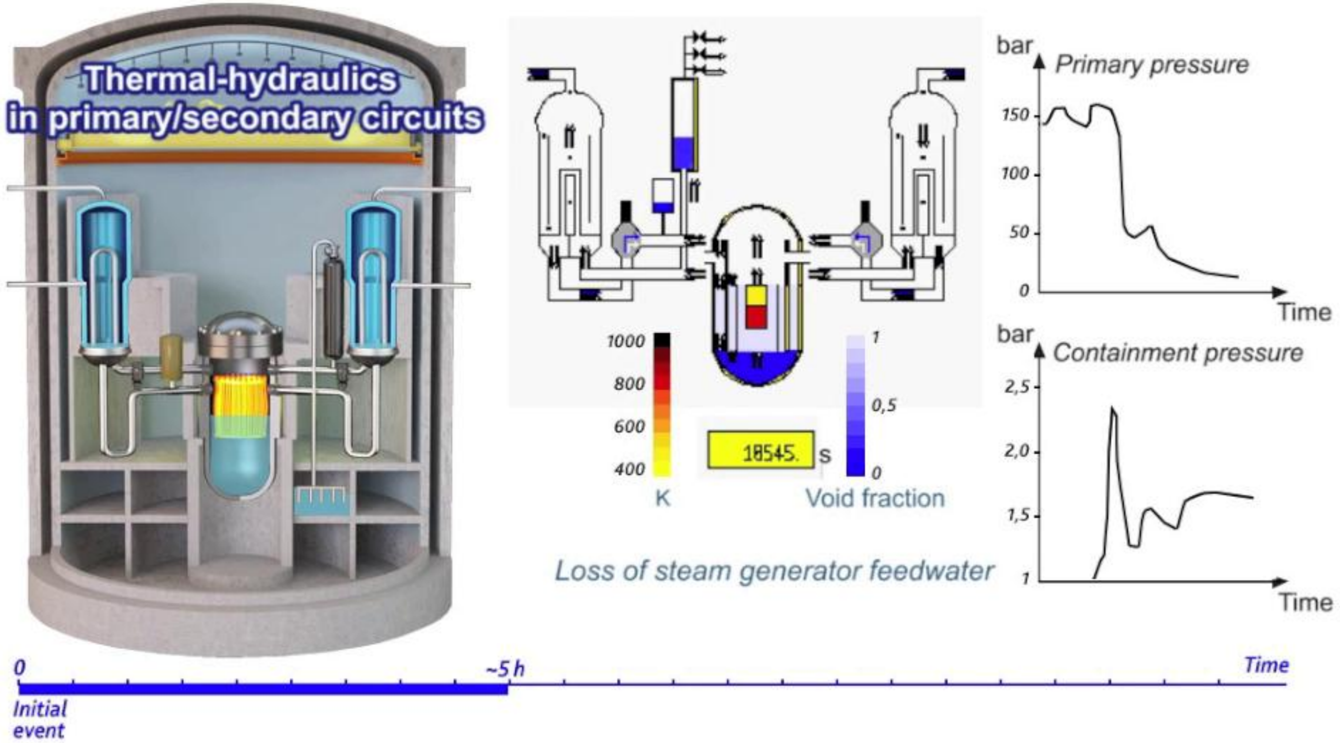
- ASTEC (Accident Source Term Evaluation Code) developed by IRSN (France) and GRS (Germany)
- Severe accident sequences from initiating event up to fission product release into the environment, initially only for water-cooled reactors
- Integration of EU research capacities manly through EC co-funded projects SARNET and CESAM
- Validated versus many experiments and OECD/NEA ISP exercises over more than 15 years
- V2.0 version used by organizations in Europe (incl. most TSOs) and outside (Rusia, Belarus, India, Canada, China)



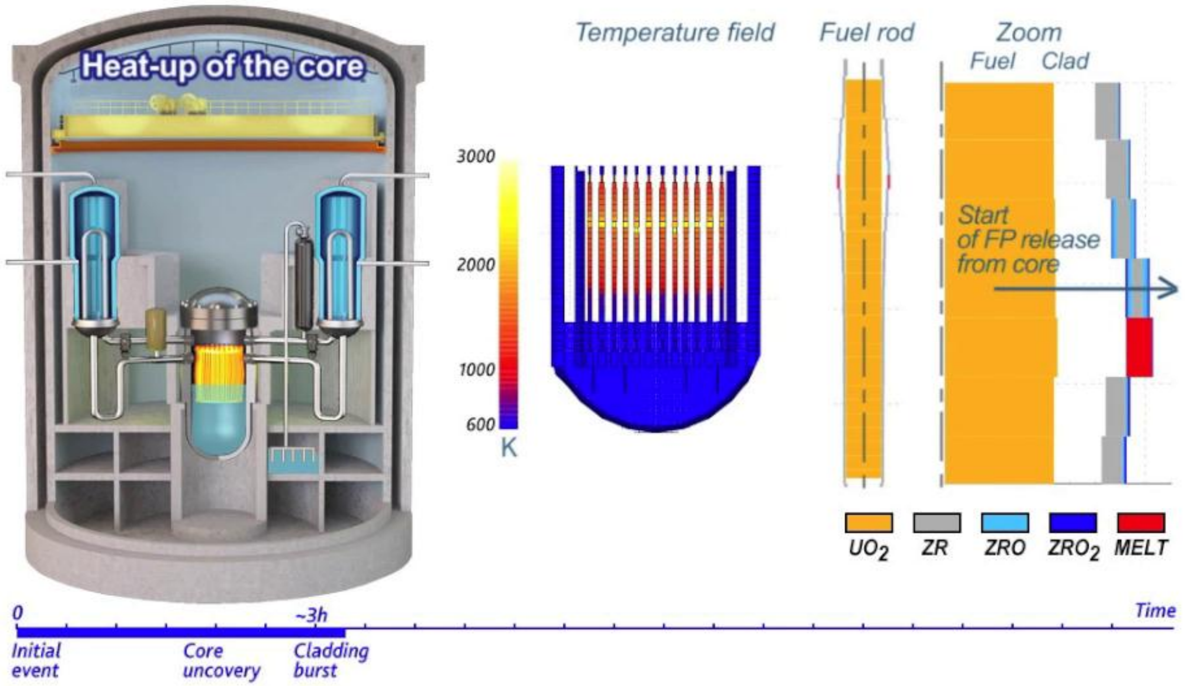
ASTEC development status illustration : simulation of a loss of steam generator feedwater scenario

Thermal-hydraulics
in primary/secondary circuits

Identification of phenomena impacted by fuel properties ⇨ a way to underligne the needs for ATF specific data

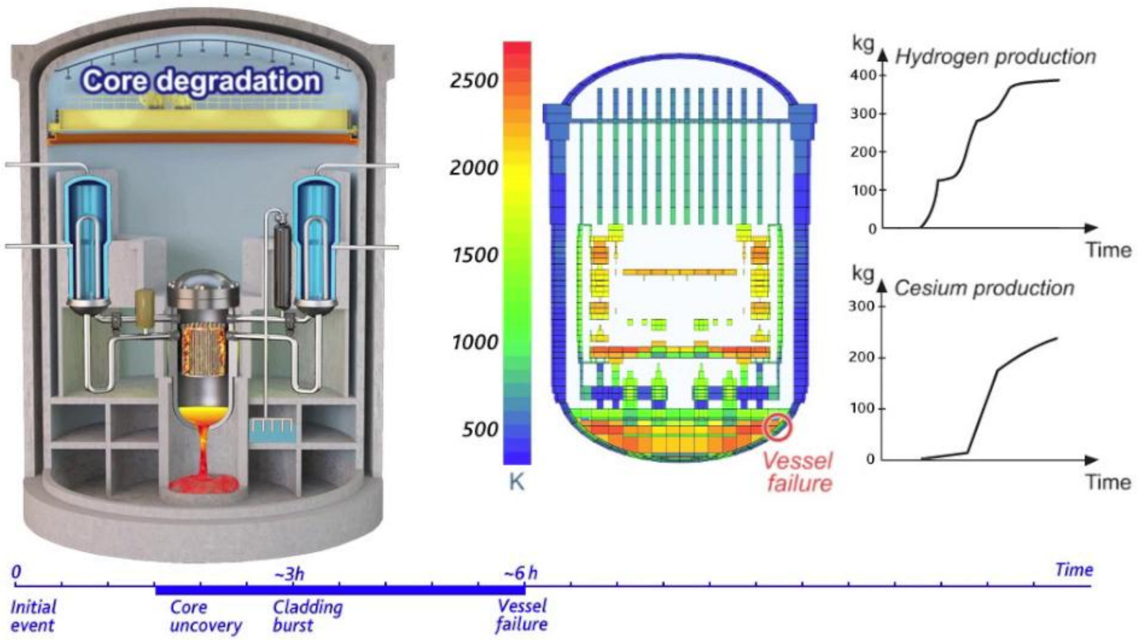


- **The fuel assemblies, the control elements and the water channels are described by 5-10 radial meshes and 20 axial meshes. Fuel geometry and thermal properties are reproduced to respect masses, thicknesses and heat exchange surfaces.**
  The singular pressure drops are adjusted to reproduce the behaviour under normal operation.
  The decay heat evolution is given or calculated according to an initial fission product inventory.



- Ballooning, creeping and oxidation of the clad are calculated ⇨ geometry variation, flow redistribution…
  Hydrogen production and fission product release ⇨ onset, heat of reaction and kinetics
  In case of reflodoing ⇨ debris formation (clad and fuel) affected by clad embrittlement (hydruration, oxydation) and fuel microstructure (burn up)

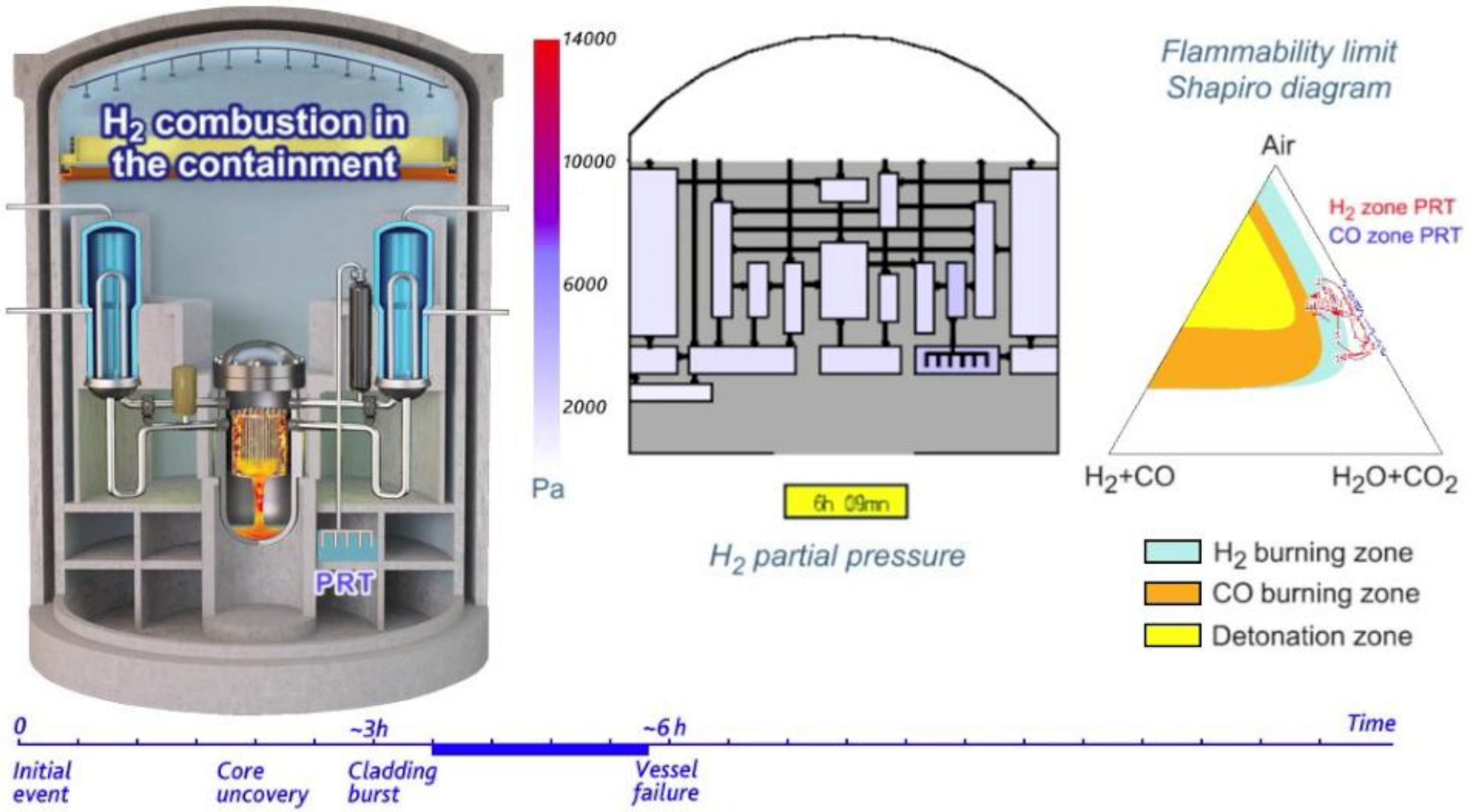
- Interaction between clad fuel and control material ⇨ eutectic formation , dissolution process…



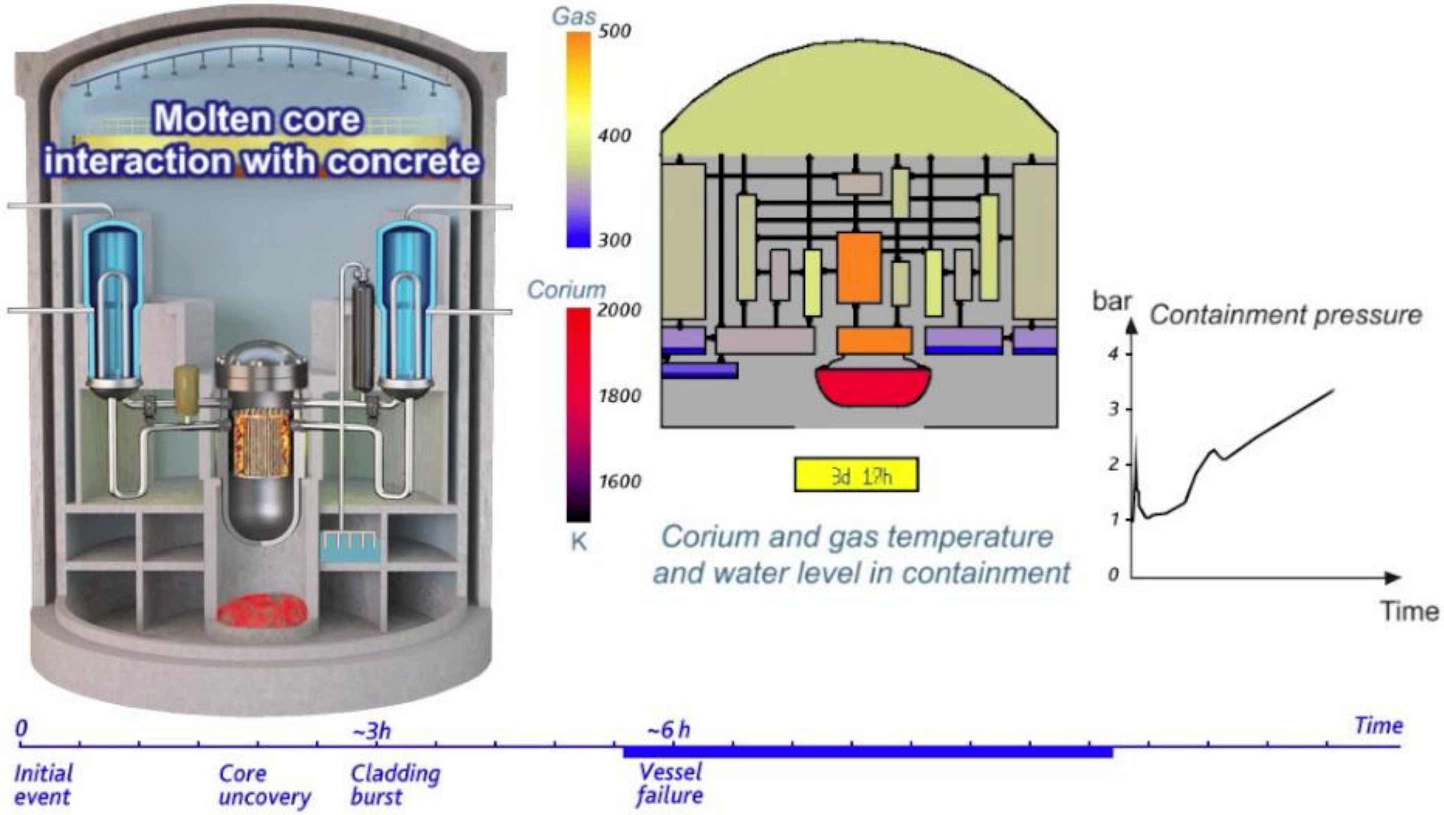
- Corium pool evolution and lower head thermal loading (focussing effect) are affected by melt composition (metal thickness on top of oxide pool) ⇨ initial mass and composition ratio, oxidation level, miscibility and density of the different liquids, history of melt progression.

- Corium miscibility with control material or risk of segregation during the solidification ⇨ recriticaliity risk evaluated separately

- Air ingress after vessel failure ⇨ oxidation (onset and kinetic) and fission product release (also for fuel assembly handling or SFP accidents)

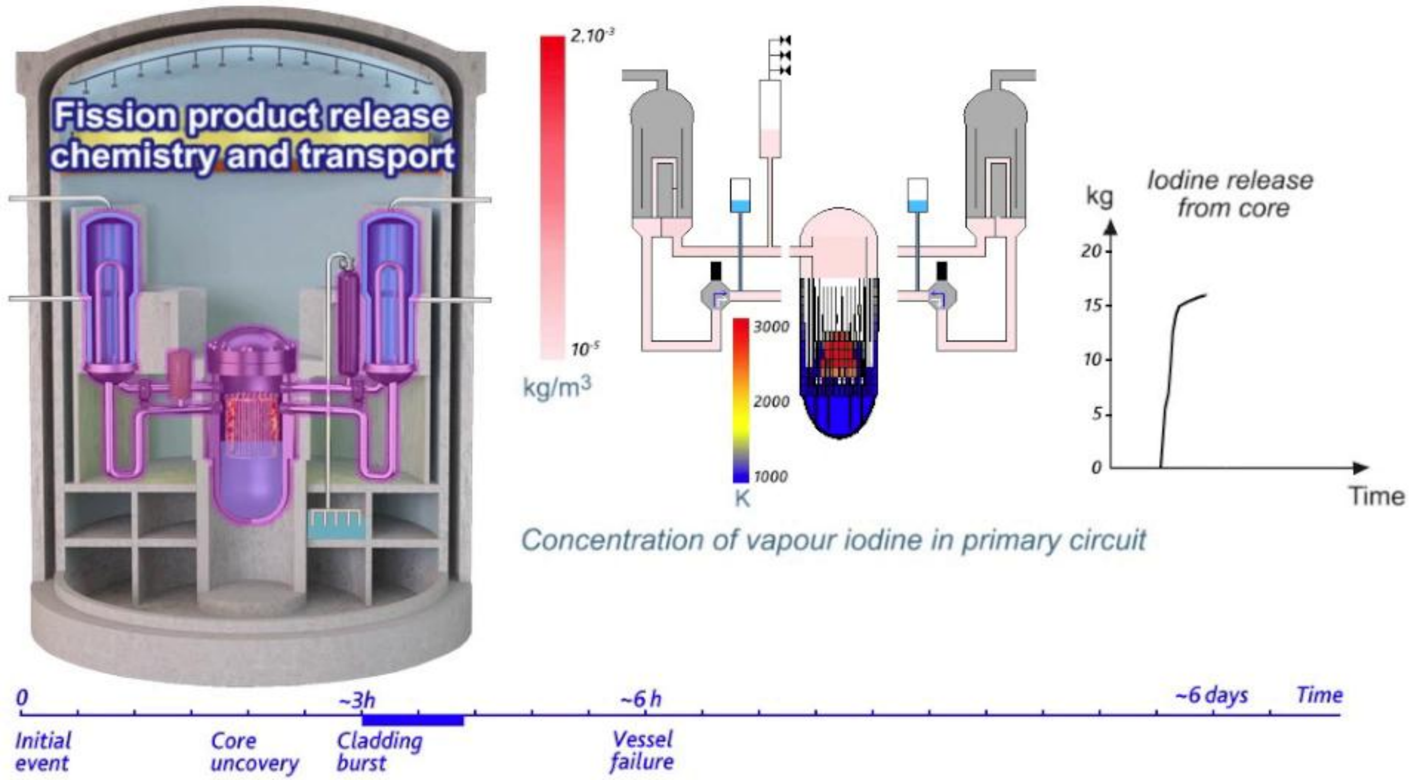


- Hydrogen produced initially by clad oxidation and later by oxidation of metallic corium phase (H_2 and CO)
- Hydrogen distribution and hydrogen concentration limitation with the help of recombiners ⇨ gas release kinetic

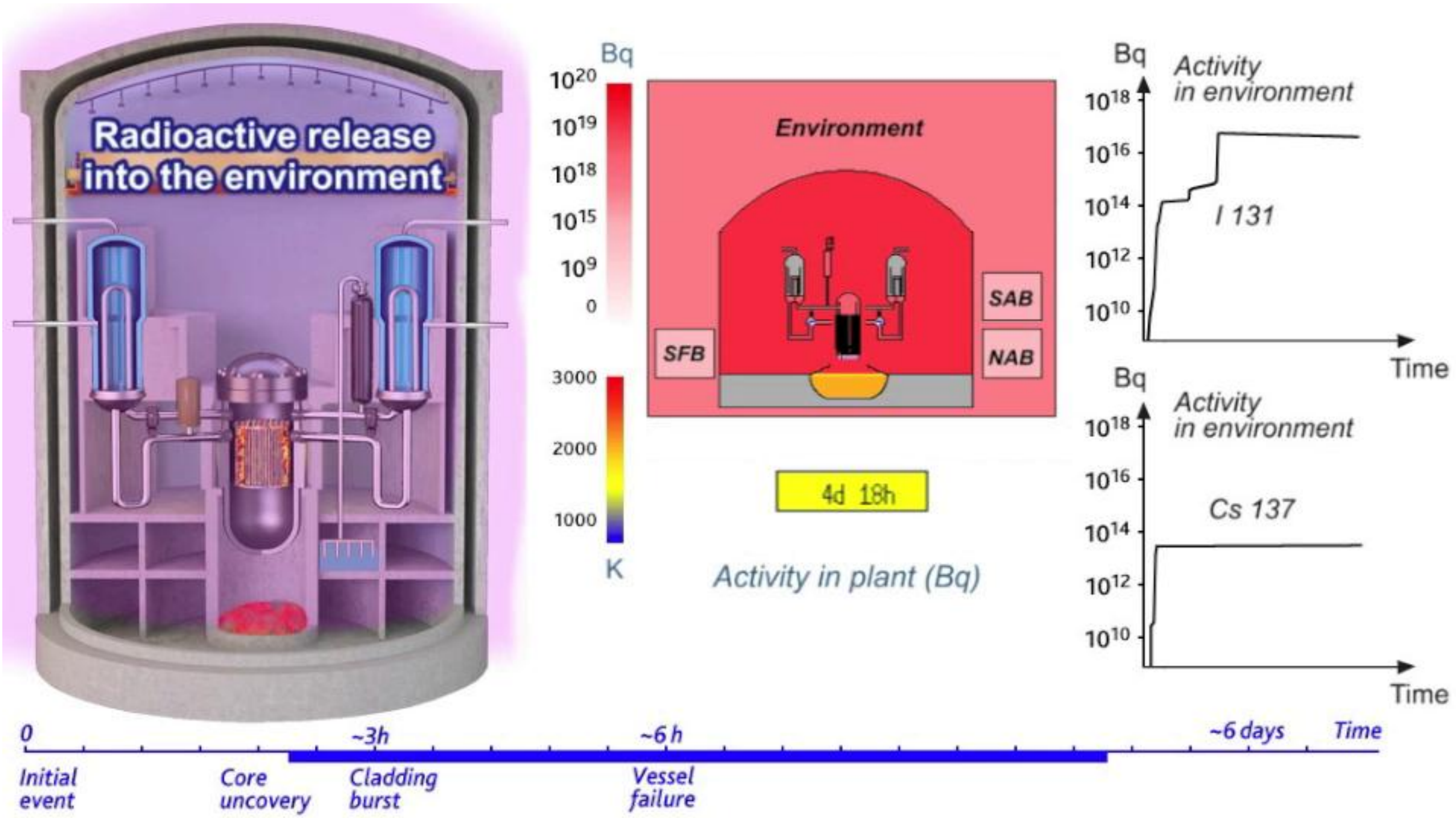


- **During corium concrete interaction phase, axial ablation kinetics increased in case of metal stratification ⇨ initial metal inventory and oxidation kinetics.**
  Zirconium oxidise first with larger additional heat release and then steel coming from structural material and concrete rebar
  Metallic phases produces H_2 and CO by oxidation ⇨ containment pressurisation

IRSN



- Fission products releases are influenced by fuel microstructure (sensitive to burn-up) and by PO_2 evolution (sensitive to atmosphere composition) ⇨ onset of the different release but also kinetics are important
  Sensitive to the change of atmosphere composition, oxygen starvation, air ingress… and to the degradation kinetic.



- **Release into the environement depends of fissions products speciation within the containment**
  Speciation at the breach influence by kintetics of chemical reaction during the transport within the RCS ⇨ interaction between I/ Ru with other fission products or control materials affected by FP release from the fuel

Additional tools

Additionals tools

- Severe accident simulation needs to consider material properties but also thermodynamic properties to reproduce complex interaction between fuel, clad control and structural material.

  - Specific thermodynamic bases has been developed : NUCLEA and MEPHISTA

- Fission product release deduced from integral and semi-integral experiments but now multiscale approaches offer the possibility to develop a mechanistic understanding of the phenomena to address all the different situation that could be encountered during severe accident scenario.

  - IRSN promotes an approach at the size of the grain with the support of calculation at lower scales ⇨ needs for more analytical experiment for the validation

  - Has already been used to evaluate fission products mobility in carbide fuel.

- Fission products chemistry take also benefit of theoretical approaches in a complementary way with experimental support to address reactivity and kinetics in homogeneous or heterogeneous phases