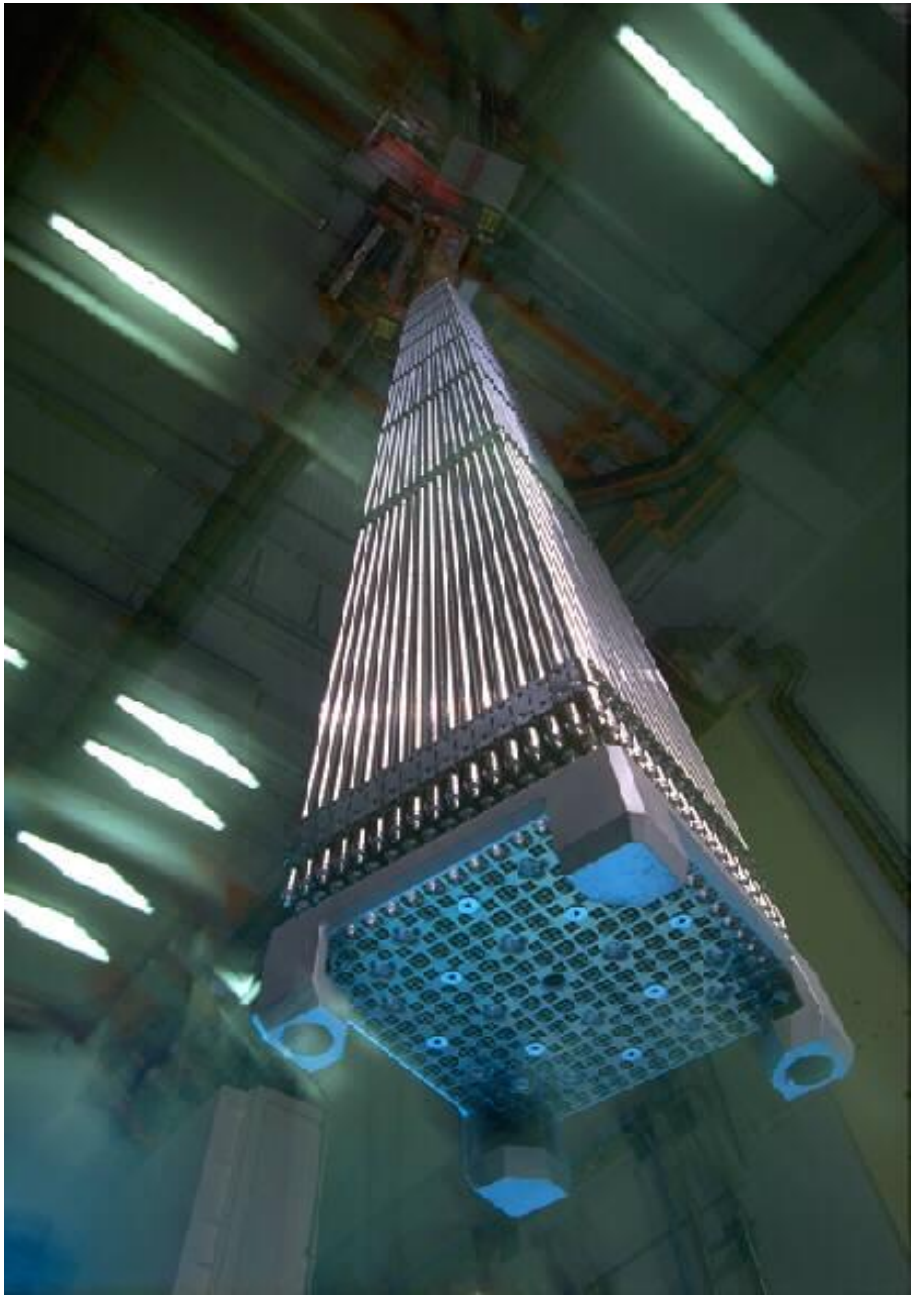


OECD/NEA Workshop on Accident Tolerant Fuels of LWRs

ATF licensing process for an industrial use

Utility's perspective

Nicolas WAECKEL

Fuel and Core Design Program Manager (EDF)

nicolas.waeckel@edf.fr

Safety requirements, from normal operation ….

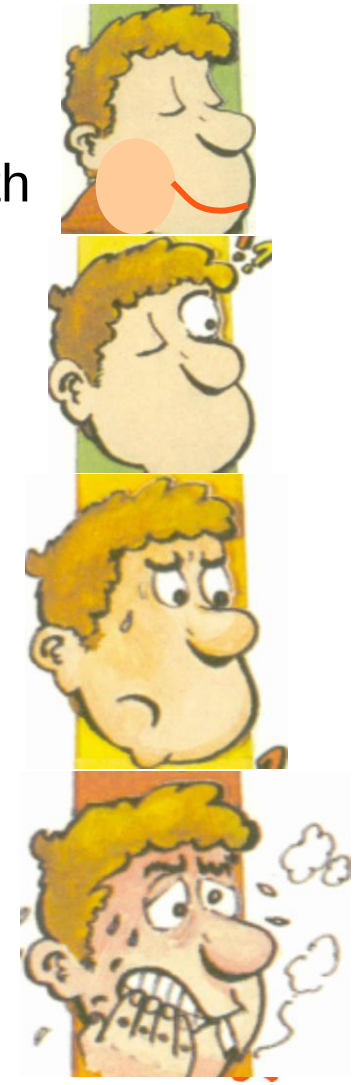
In depth defense principle (3 barriers)

- **CLASS 1 : Normal operation**
  - No failure of the first barrier (cladding)
  - Performance of the purification system consistent with a few leaking rods

- **CLASS 2: Low frequencies events**
  - No failure of the first barrier

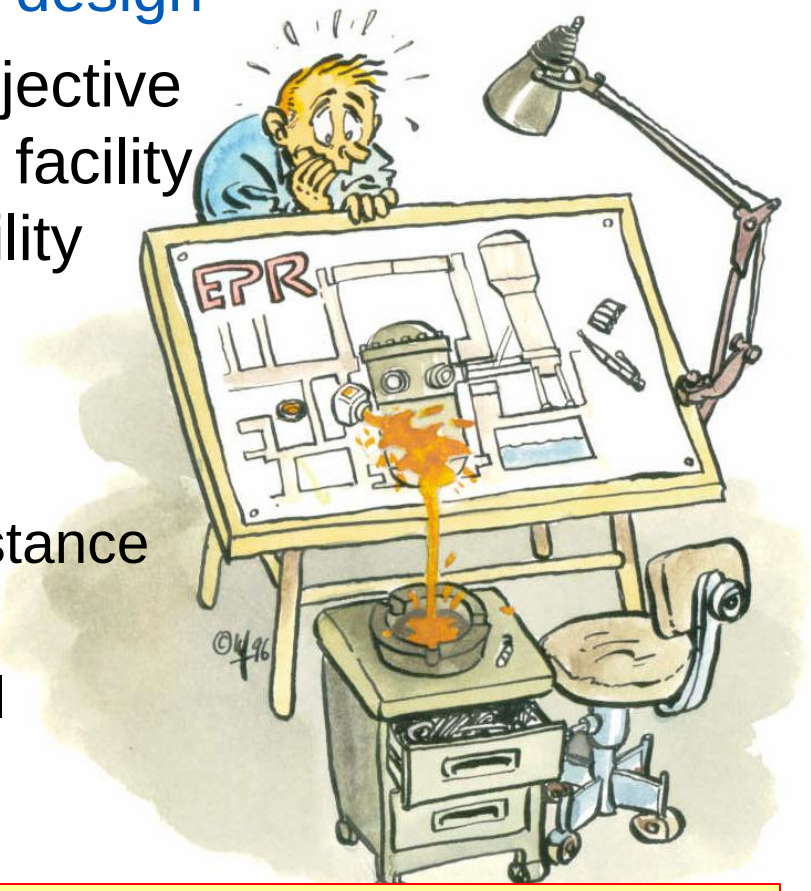
- **CLASS 3 : Low probabilities accidents**
  - The 3 barriers might be damaged
    - » Bring back the reactor to a safe state,
    - » Few damaged rods

- **CLASS 4 : Hypothetical accidents**
  - Fuel core remains sub-critical
  - Core geometry remains coolable



… to severe accidents

- Not directly included in the fuel design
- In those extreme cases, the objective is not to preserve the industrial facility but to ensure long term coolability and confinement
- **Multiples Accidents**
  - Steam Pipe Break + Steam Generator Tube Failure for instance
- **Severe Accidents**
  - Melting of a fraction of the fuel
- **Core melting**



NB : ATF should not focus on severe accident conditions only, normal operation is as much as important

For EDF, a new type of fuel has to be …

Reliable

No bad surprises degrading operation

- -Manufacturing defects
- -Grid-to-rod fretting
- -Fuel Assembly distortion, Etc..

Robust

Resistant to unexpected events or conditions modifications

- -Chemical reaction
- -Debris
- -Handling, Etc..

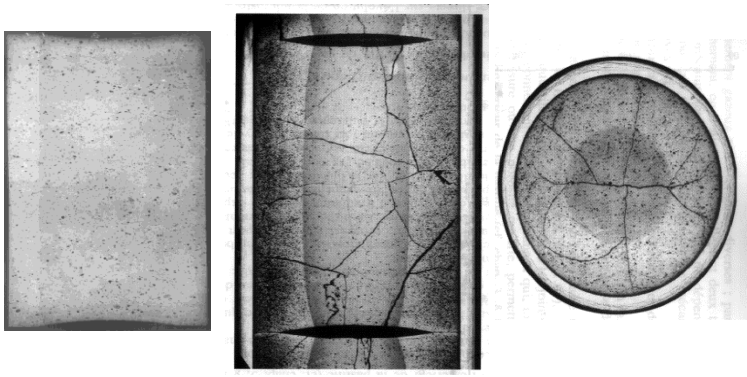
High Performance

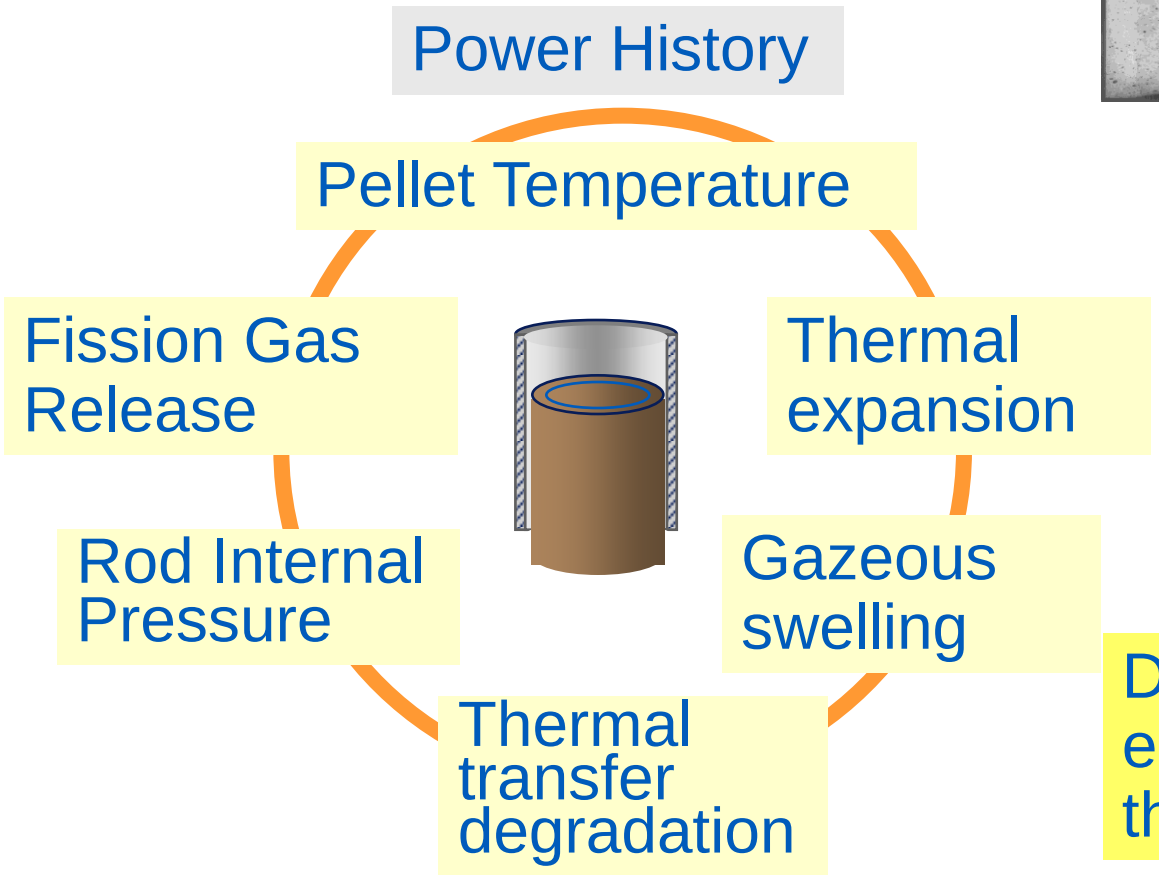
Provide additional safety margins to be used by the operator

- -PCI limits
- -LOCA, RIA at high B-up,
- -Severe accidents, Etc..

Cladding and fuel pellets cannot be studied separately …

Various inter-linked phenomena

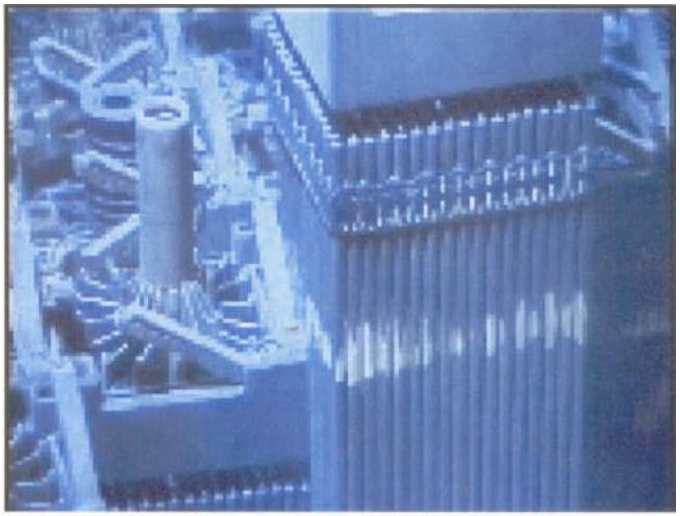




- Fuel Pellet Cladding Interaction (PCI)
- Stresses
- Strains

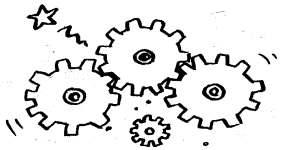
Design Safety Limits ensure the integrity of the first barrier

… and, as a matter of fact, Fuel Rods interaction with the FA structure cannot be neglected neither



- Most of the recent in-reactor issues were related to FA behavior (rather than to fuel rods)
  - Grid-to-rod-fretting (GTRF) : still « number one » cause of failure in many countries
  - FA distortion and increased inter-FA gaps
    - » IRI (incomplete control Rod Insertion)
    - » Additional cross flow
    - » Neutronic impact
    - » Handling problems
  - Grid Springs and Holdown Spring System design

Development roadmap



ATF development
-Variants selection
-Small scale fab^{on}
-Large scale fab^{on}

Models, Calc. Tools, Design limits, Methods

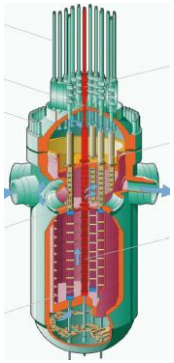
Simulation (limiting transients)

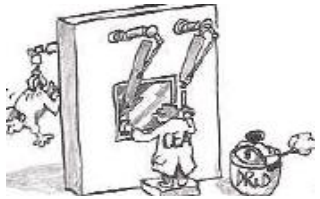
Design Margins

Safety Case Analysis Files

Separate effect tests

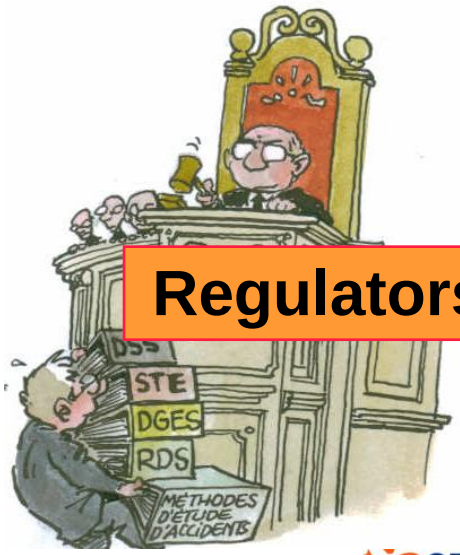
In-reactor Experience





In-pile tests

Out-of-pile tests

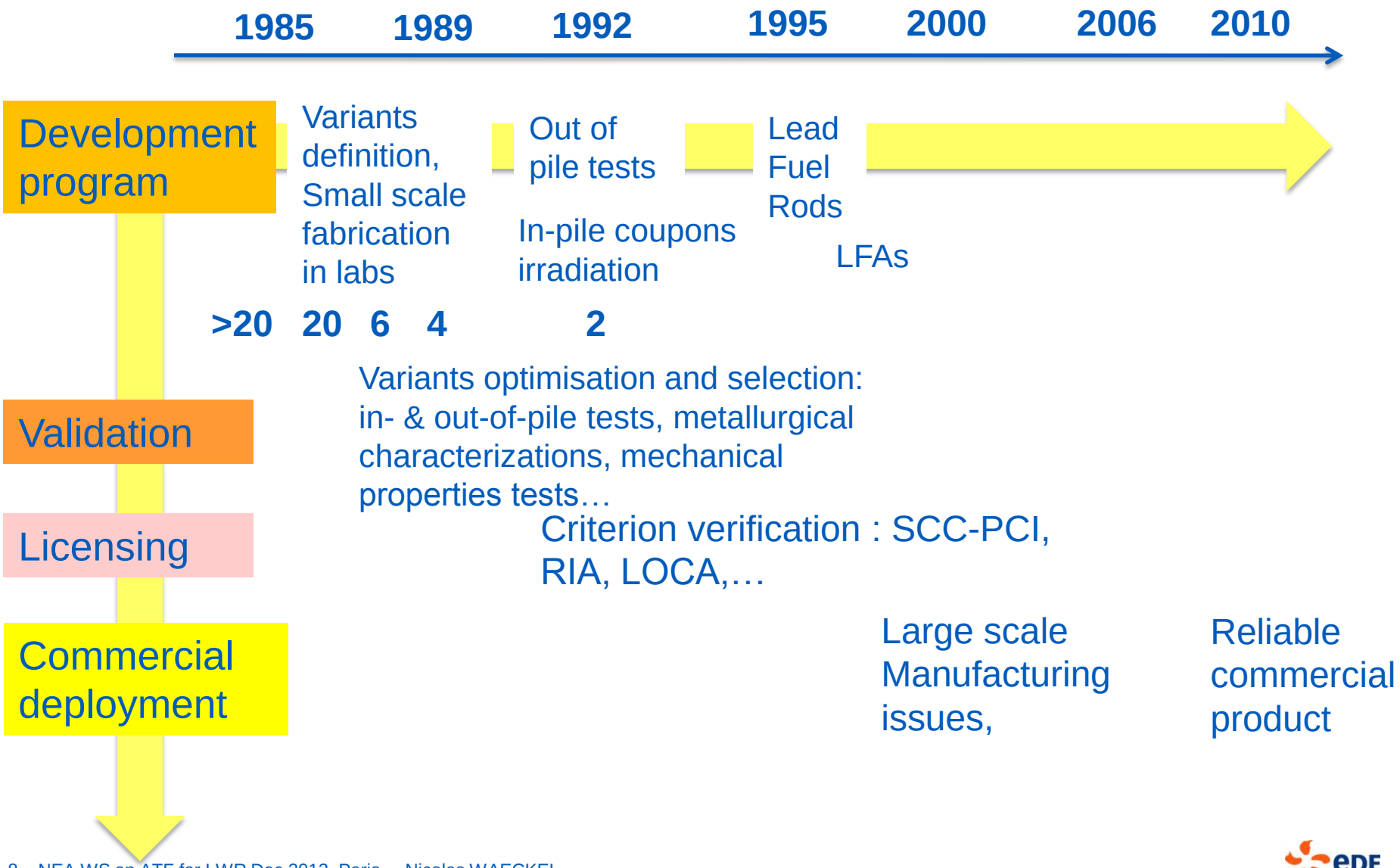


Regulators

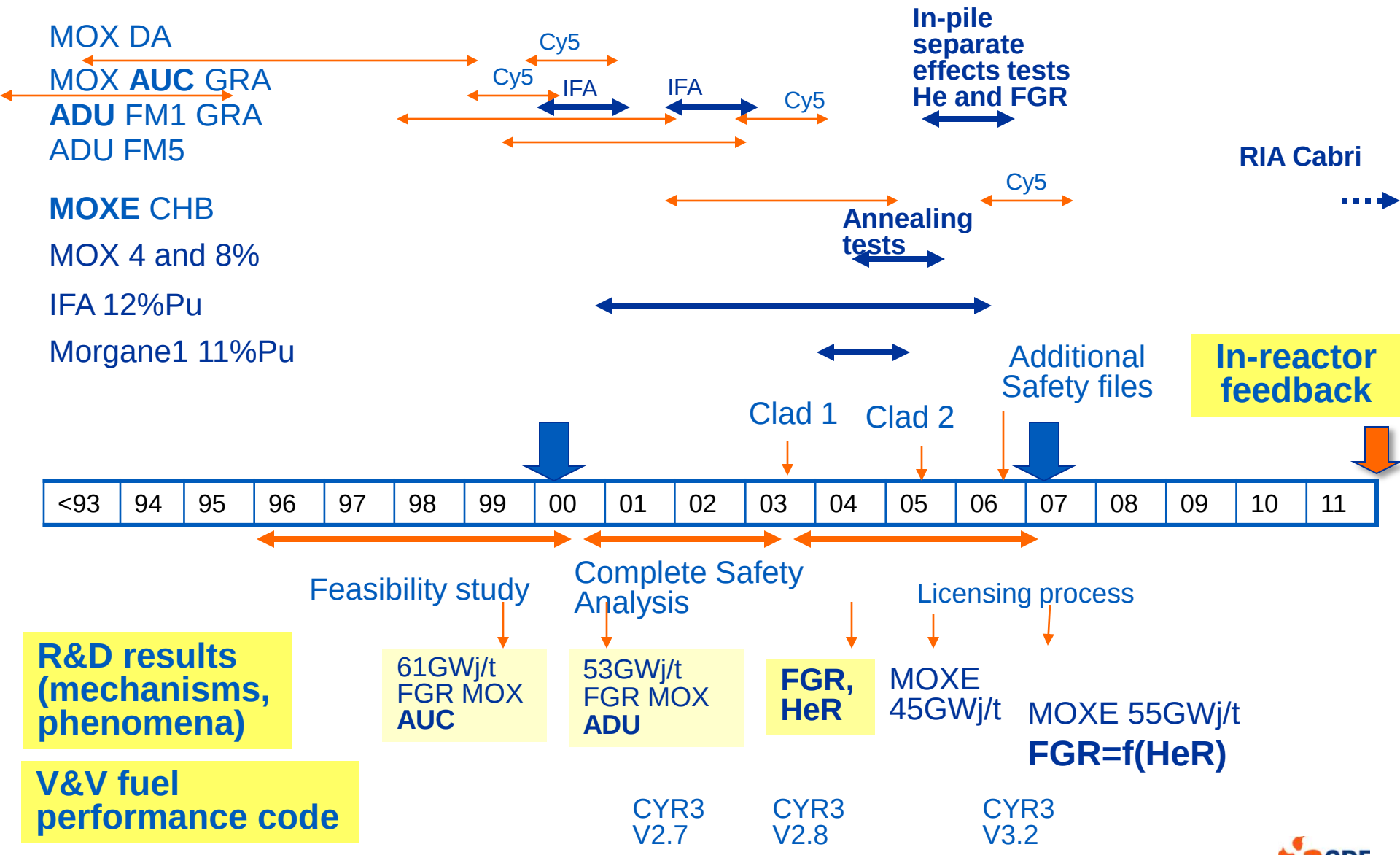
ATF will require adapted investigations devices

EDF

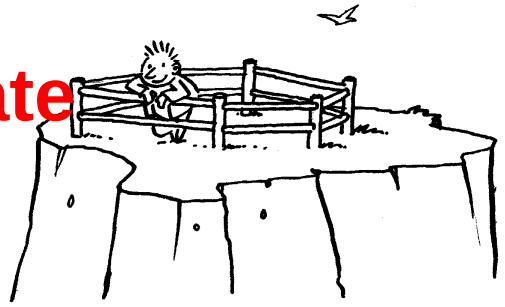
Example 1 : developing an advanced Zr based alloy may take > 25 years (with Std UO2)



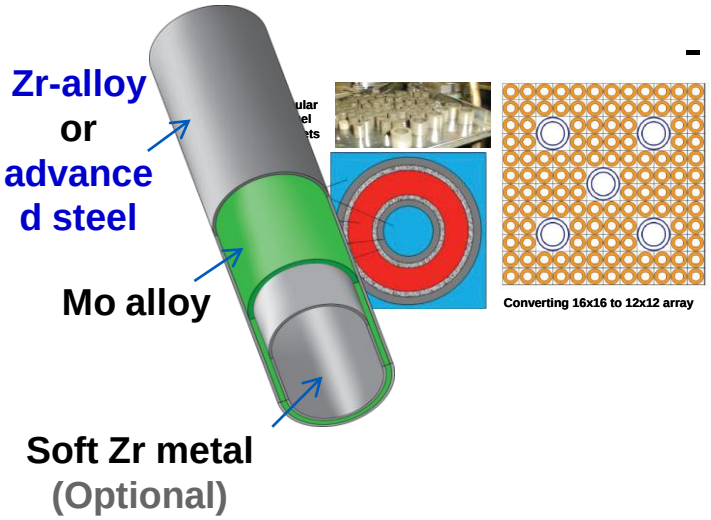
Example 2 : Justifying new MOX Fuel required >20 years of R&D data collection



ATF development : find the appropriate Safety Analysis Design Limits



- Identify and investigate all possible failure/ruins scenarios (not only during a severe accident)
  - Some might be a « killer » in the development phase
- Adapt or define the new Limits (and the experimental protocol to determine them)
  - Might differ significantly from the SAFDLs defined in the 70's for std UO2-Zr fuels

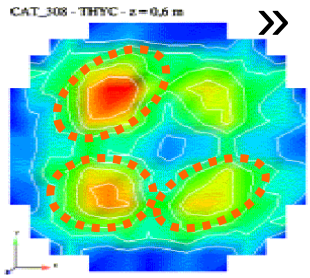


- Need to include in-reactor fuel behavior
  - Ex: OD coating might be locally worn out by fretting → consequences?
  - Ex : Flow blockage in the central hole of the Dual-Cooled fuel → risk?

- The new / specific SAFDLs will have to be endorsed by the regulators

In-reactor validation of the ATF : a sensitive path

- A commercial NPP is not an MTR : irradiating Lead Test Fuel Rods (LTFRs) or Lead Test Assemblies (LTAs) implies strict requirements
  - All the manufacturing process, including the chemicals (additives, solvants,..) used by the manufacturers have to be compatible with the nuclear technical specifications
  - Robustness and reliability of the ATF rods (within the hosting FA) have to be garantied
    - » Out-of pile endurance tests, in-pile irradiation tests (in prototypical conditions), etc..
    - » A single « bad » rod failure could result in a premature shutdown of the NPP → **$$** !
    - » NB:
      - In-reactor experience (PIEs) will take >7y to get collected
      - LTFRs or LTAs have to be compatible with the hosting fuel core (geometry, enrichment, T/H performance,etc…)
      - All positions in the core are not alike



In-reactor validation of the ATF : a sensitive path

- If the ATF rods or assemblies are not compatible with the current NPPs fuel cores designs
  - ATF concept validation will rely on MTRs irradiation only
  - Will need to remove the whole core before introducing the new fuel concept → **$$$** and associated risk analysis
  - Focus on new build and /or SMR?

Summary : Developing ATFs

- Main Issues
  - » Find the right concept
  - » Resolve (small and large scale) manufacturing concerns
  - » Address accidental **and** normal operation behaviors (cladding, fuel pellet AND their interactions with FAs)
  - » Address economics vs benefits vs risks
- A motivating challenge : define an appropriate licensing process
  - New concept means new requirements / limits
- The entire development / licensing process will be likely much longer than expected (>>30y?)