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ASTRID

Advanced Sodium Technological Reactor for Industrial Demonstration

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" Safety orientations during ASTRID conceptual design phase"

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CONTENTS

1.1 INTRODUCTION

- The current phase of ASTRID project is devoted to the choice of the most structuring options for the conceptual design

- In order to integer earlier the safety concerns into the design project, a Safety Orientations Document (DOrS) was delivered in 2012 with a double purpose :
  - To define the need of assessment studies for selecting the design options from safety viewpoint,
  - To initiate the exchanges with the licensing authority before the selection of the most structuring design options

- This presentation gives some information on major safety orientations specific to the ASTRID project

1.2 GLOBAL SAFETY OBJECTIVES

Consequences levels and probabilistic targets :

< 10^{-5} /year	• Prevention of Severe Accident with core meltdown, including whole events and hazards • Radiological releases not requiring off-site countermeasures
< 10^{-6} /year	• Mitigation of Severe Accident • Unacceptable radiological releases but consistent with off-site countermeasures i.e. postponed, limited in time and area
< 10^{-7} /year	• Prevention of massive or early radiological releases i.e. not consistent with efficient off-site countermeasures

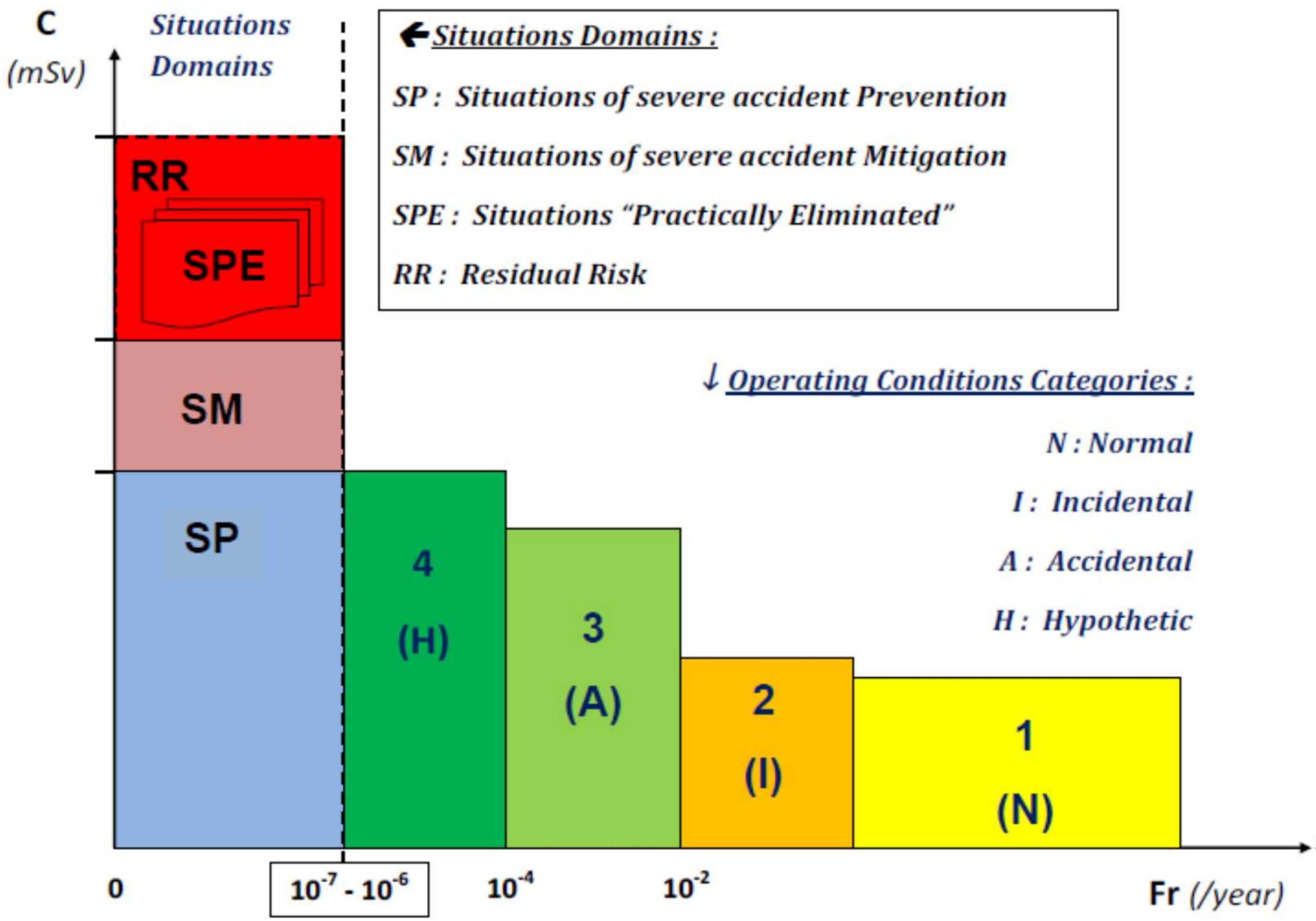
Approach basically deterministic

for a better safety implementation through the conceptual design

2.1 RISK DIAGRAM OF ASTRID

A specific approach beyond the design basis domain :

- **Definition of SP, SM and SPE domains and related analyses rules**
  - Classification not based on frequency range but on level of degraded plant state
  - With the objective to class in “SP” prior to considering “SM” and at least “SPE”

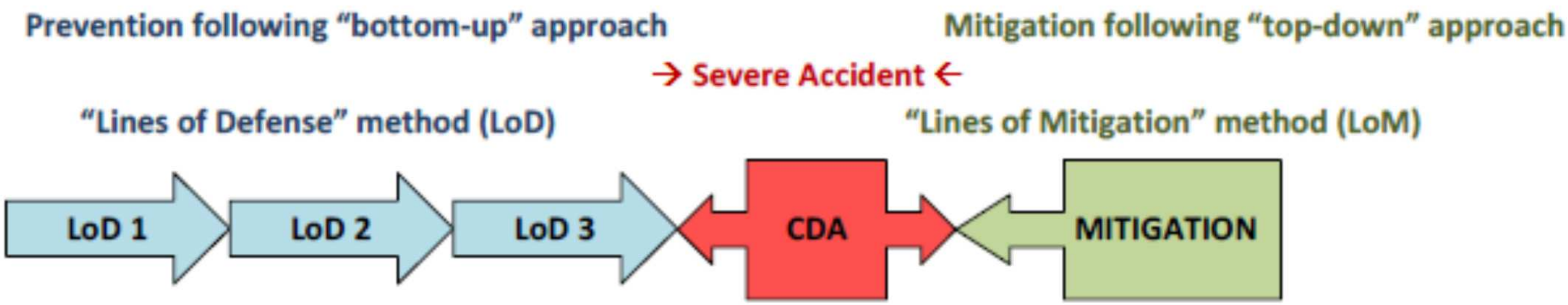


2.2 IMPLEMENTATION OF SAFETY DESIGN METHODS

To translate the safety principles into practical analyses tools
➔ a good way to get "robust" safety demonstrations

In addition to the existing French regulatory fundamental safety rules, some examples:

- Method of « Lines of Defense » *(from SFR feedback)*
- New concept of « Line of Mitigation » method
- Type of demonstration for practical elimination of some situations *(SPE)*
- New definition of safety classes for important equipment *(SSC)*
- Appropriate methods for specific SFR events *(ex. LBB implementation)*
- Definition of « hard core » provisions *(Fukushima feedback)*



2.3 « LOD » & « LOM » METHODS

	S.A. Prevention	S.A. Mitigation
Method :	**Lines of defense** (LoD)	**Lines of Mitigation** (LoM)
Approach type :	« Bottom-Up »	« Top-Down »
Objective :	Probabilistic targets	Consequences reduction
Lines validation criteria :	Number of lines, reliable, independent, common mode absence	Equipment ensuring all functions of one LoM. Each LoM homogeneous: approach ''weak link of chain''
Demonstration :	Equivalent to ''2 strong + 1 medium'' lines	Minimization of radiological release with 'decoupling' approach
Application domain :	Prevention including SPE	Complementary to ''analysis by barrier'' method
Safety classification of SSC :	Complementary to "analysis by function''	Complementary to ''analysis by function''
« Hard Core » contents:	One LoD per SPE	All equipment involved in one same LoM

3.1 TO PROMOTE "NATURAL BEHAVIOR" OF THE PLANT

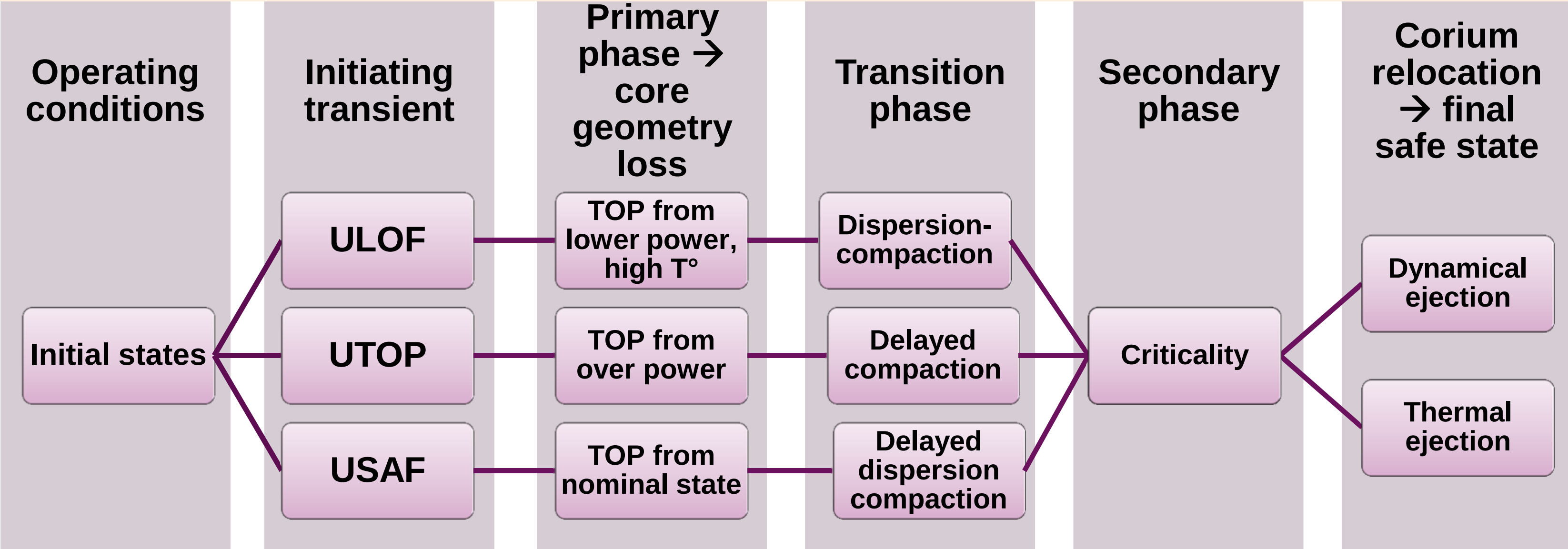
Objective is not to substitute "natural behavior" for safety systems but to improve the safety level by additional diverse safety provisions :

- Enhanced "natural behavior" (i.e. unprotected transients) as a backup of the safety systems
- To complete the part brought by the "natural behavior" by complementary safety devices if needed (ex. CSD for achieving a final safe state)
- To promote favorable "natural behavior" both :
  - in SA prevention domain, as a third defense level
  - in SA mitigation domain, in order to reduce the potential consequences and then to less attack the safety mitigating provisions
- Improvement of the "natural behavior" concerns all safety functions (reactivity mastery, DHR, confinement …) against all type of initiating events families

3.2 NEW APPROACH of CORE SEVERE ACCIDENT

CDA studies from different events families (initiating transients) with identification of :

- typical core degraded states shared by different scenarios (crosscut states)
- key parameters leading to a range of consequence results.



Some features of the new approach :

- Taking account of SA despite high reliability of safety systems and "natural behavior" contribution in prevention
- CDA studies not based on only one scenario but from different events families
- Objective of "non energetic" CDA by conceptual core design and CSD if needed
- Decoupling between CDA results and lines of mitigation design

3.3 DECOUPLING between CDA STUDY and 'LOM' DESIGN

Approach adapted to get robust mitigation countermeasures :

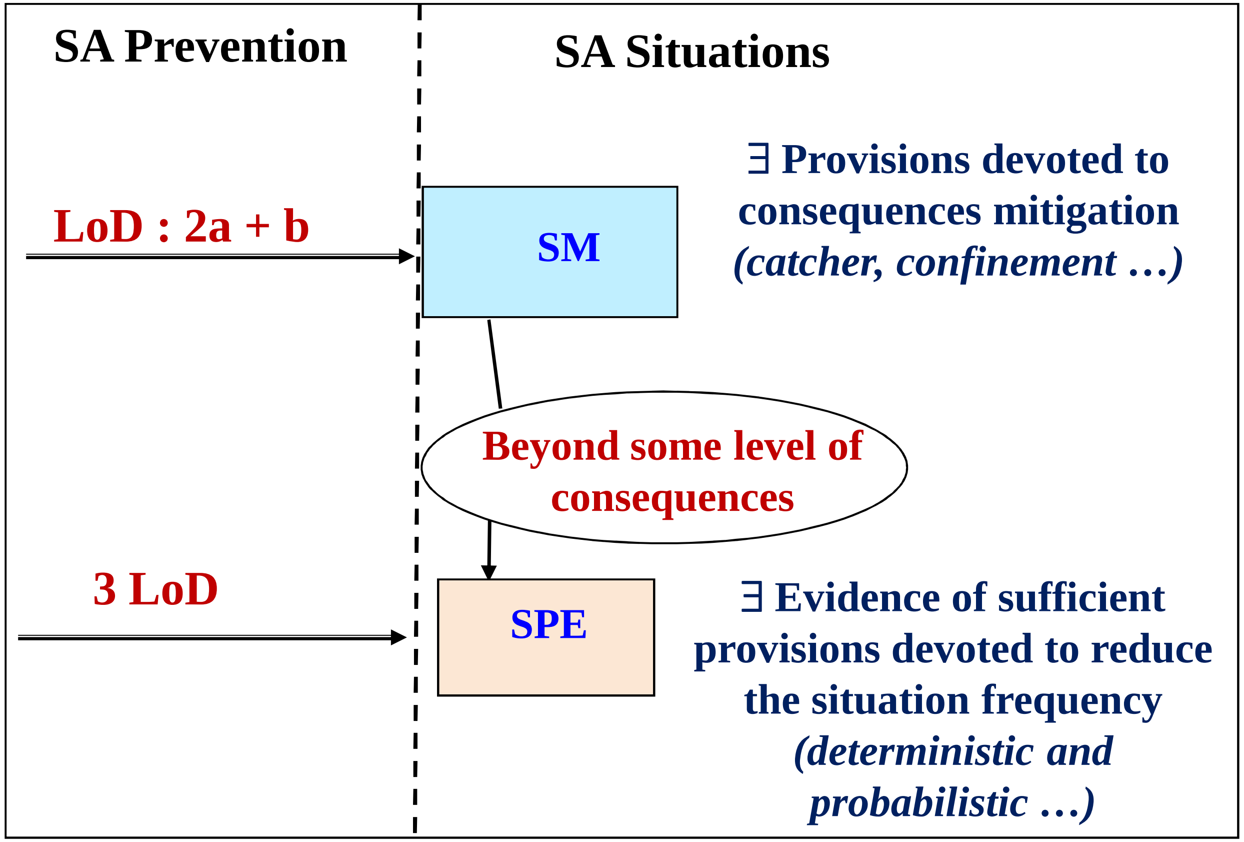
➔ « Top-Down » approach through the « Lines of Mitigation » method

- Implementation of the Defense-in-Depth level 4 (mitigation provisions) should prevent a 'common mode' fault into the approach; for this purpose it is recommended :
  - As regards the containment : the reactor should be designed so that any scenario of core degradation cannot lead to a high mechanical energy release. Nevertheless, components and structures required to mitigate CDA consequences, should be designed to withstand, as far as reasonably feasible, against a hypothetical mechanical energy release.
  - As regards the confinement : even if the source term mobilized by a SA scenario involving core meltdown might be limited, the design provisions related to the confinement function should be optimized as far as reasonably feasible.

4.1 SAFETY DEMONSTRATION FOR "SPE"

To use a safety demonstration method suitable for ''practical elimination'' of some situations (SPE)

- Situations that could lead to a massive or quick radiological off-site release (i.e. not manageable by countermeasures)
- SPE stemming from possible « cliff edge » effect on consequences or from SA scenario without possible efficient mitigation provisions



Deterministic approach completed by probabilistic insight :
at least equivalent to 3 lines of defense with "common mode" resistance and high confidence level

4.2 PROGRESSIVENESS OF THE APPROACH

Progressive escalation by events family

« DB »

- Slow or fast LOF
- Slow or fast TOP
- SAF

« SP »

- DB initiators with additional failures including safety systems (Uxxx)
- Initiators more severe than DB initiators (ex. postulated fuel assembly melting)

« SM »

- S.A. scenario from SP by additional aggravating hypothesis per family
- Generic approach not connected to a reference scenario to be justified

« SPE »

- Safety demonstration based on robust prevention provisions (3 LoD)
- As for situations in continuation of SP, the mitigation measures (SM) could have favorable effects

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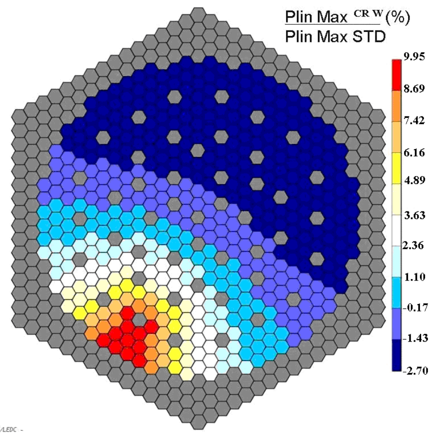
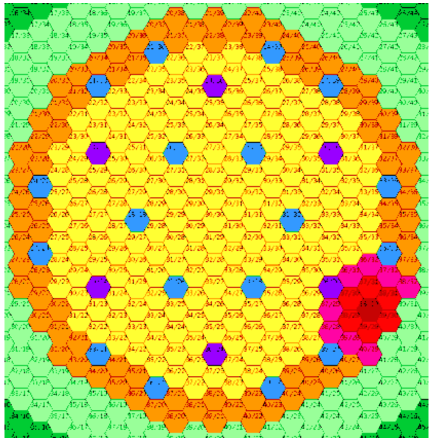
- High energetic Severe Accident
- Massive or early radiological off-site release

4.3 EXAMPLE OF PROGRESSIVENESS: "SAF" FAMILY

SAF family : a new strategy as regards the postulated « fuel assembly meltdown »

- Previous SFR approach (TIB)
  ''Total & Instantaneous Blockage'' scenario with detection and protection
  - No other case of local fuel melting considered except for an unprotected control rod withdrawal (CRW)
- New approach for ASTRID
  Progressiveness considering various events from a « partial fuel assembly blockage » without melting towards the « global core meltdown » situation :
  - Exhaustive sensitivity study on efficient detection-protection means
  - Knowledge and understanding of physical evolution of different cases of fuel assembly blockage (size and delay)
  - Tacking account of global core meltdown (SM) from the SAF family with the same joint objective : ''no energetic'' CDA





5. CONCLUDING REMARKS ON SAFETY ORIENTATIONS

In comparison with previous SFR, safety improvement is expected through the conceptual design by implementation of ASTRID safety orientations. Some of them are :

- Appropriate treatment of local faults (detection, progressiveness …)
- Approach by events family for both prevention and mitigation of SA
- Enhanced inherent plant behavior as a third prevention level of SA
- Generic approach of CDA considering : all types of initiating transients, typical degraded core states, key parameters leading to a range of results
- New concept of “lines of mitigation” method (LoM)
- Decoupling between CDA results and design of SA mitigation provisions facing :
  - Hypothetical mechanical energy release,
  - Potential radiological source term.
- Rational demonstration of practically eliminated situations (SPE)
- Integration of Fukushima lessons through hazards concerns beyond the Design Basis, including the “hard core” notion (see dedicated presentation during FR13).

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