DE LA RECHERCHE À L'INDUSTRIE

www.cea.fr

CADARACHE

R&D PROGRAMMES RELATED TO SEVERE ACCIDENT IN SFR

Nicolas DEVICTOR, Frédéric SERRE
Simon CAPELLE, Danièle VERWAERDE (EDF)
Bernard CARLUEC, Julien CHAMPIGNY (AREVA)

INTERNATIONAL WORKSHOP ON PREVENTION AND MITIGATION OF SEVERE ACCIDENTS IN SODIUM-COOLED FAST REACTORS
11TH -13TH JUNE, 2012 IN TSURUGA, JAPAN

nicolas.devictor@cea.fr

CONTENT

Core design approach

Strategy for R&D

References codes

Examples of R&D for mitigation devices

Examples of R&D on core catcher

Cooperations

CORE DESIGN APPROACH

ASTRID core design is mainly guided by safety objectives :

1. Prevention of the core meltdown accident

-by a natural behavior of the core and the reactor *(as 3rd line of defense in case of no actuation of the two shutdown systems)*

- **Natural behavior favorable for transients of unprotected loss of flow and loss of heat sink**

  Target criteria : no sodium boiling for a ULOSSP transient for CFV type core (CFV = Low Na void worth core)

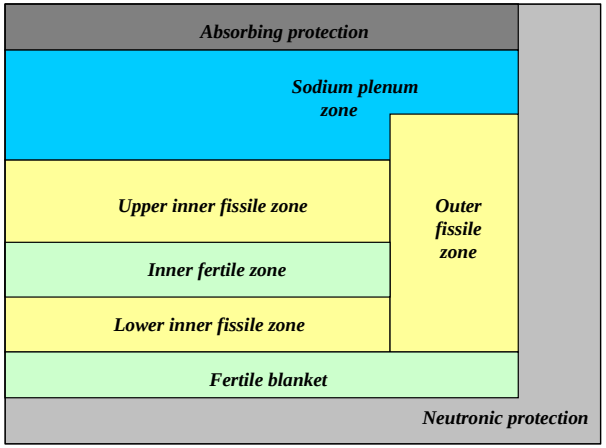
- **Sodium void effect minimized**

  Target criteria : Na void effect < 0 for CFV type core

- **Natural behavior favorable for a complete control rod withdrawal (with no detection)**

  Target criteria : no fuel fusion

-with adding passive complementary systems if natural behavior is not sufficient for some transient cases



(Patent CEA EDF AREVA)

2. Mitigation of the core meltdown

To garantee that core meltdown accidents don't lead to significant mechanical energy release, whatever initiator event

-by a favorable natural core behavior *(taken into account of the benefit from a negative sodium void worth for CFV type core)*

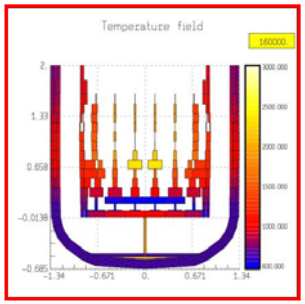
-with adding specific mitigation dispositions in case of natural behavior is not sufficient

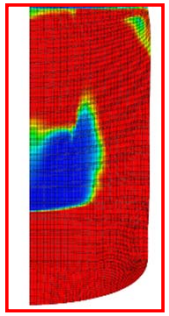
STRATEGY FOR R&D

Inputs
- Reactor layout
- SA Initiator or
- Postulated degraded core
- Uncertainties

'Scenario' approaches for reactor evaluations:
-Core degradation and corium progression
-Structures behavior
-Gas release evaluations

Development of mitigation devices





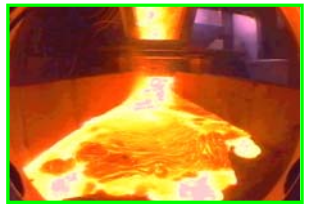
Codes and models
- Reference codes (SAS4A/SAS-SFR, SIMMER, ..)
- Simplified models

Knowledge Improvements

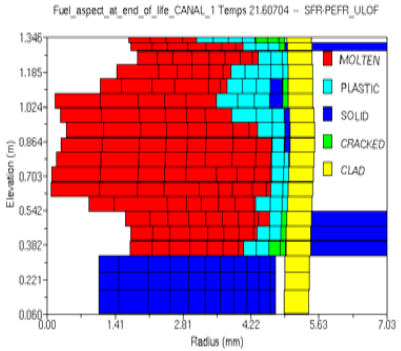
Devices assessment

Assessment

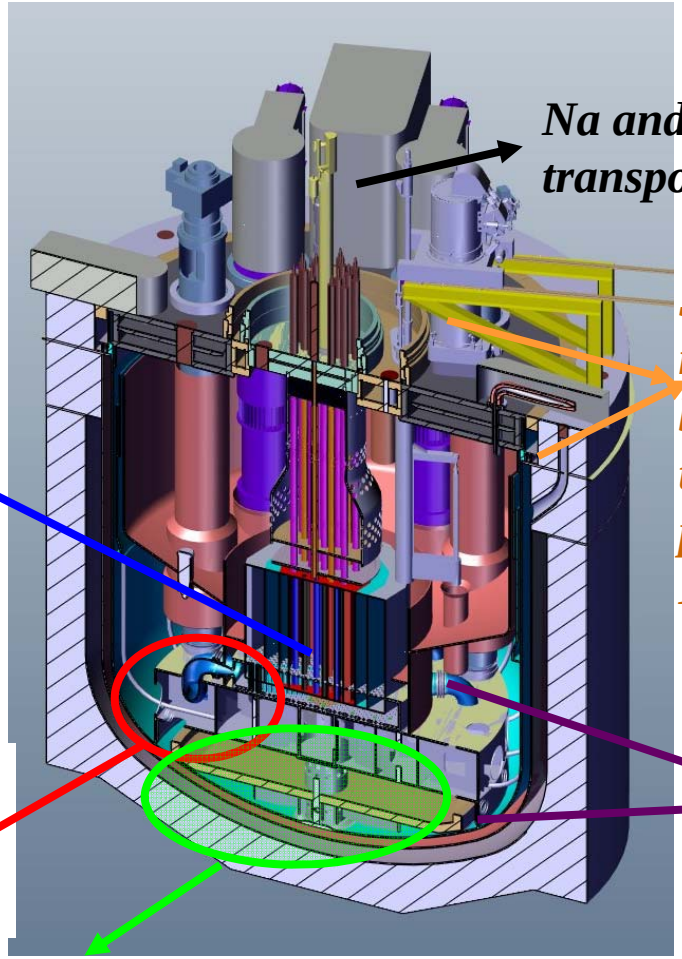
Experiments



REFERENCE CODES

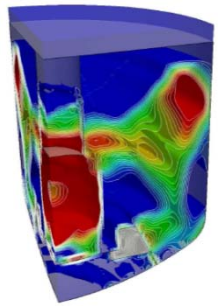


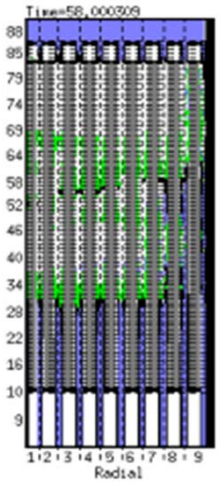
Core Degradation:
SAS4A/SAS-SFR
SIMMER III and IV



Na and FP aerosols and transportation: CONTAIN-LMR ?

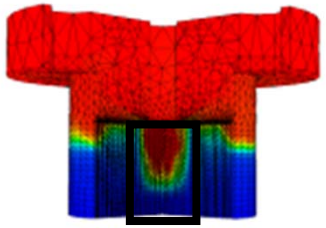
Structure mechanical behavior during the expansion phase: EUROPLEXUS





Melt Progression
SIMMER/
SIMMER LT -type

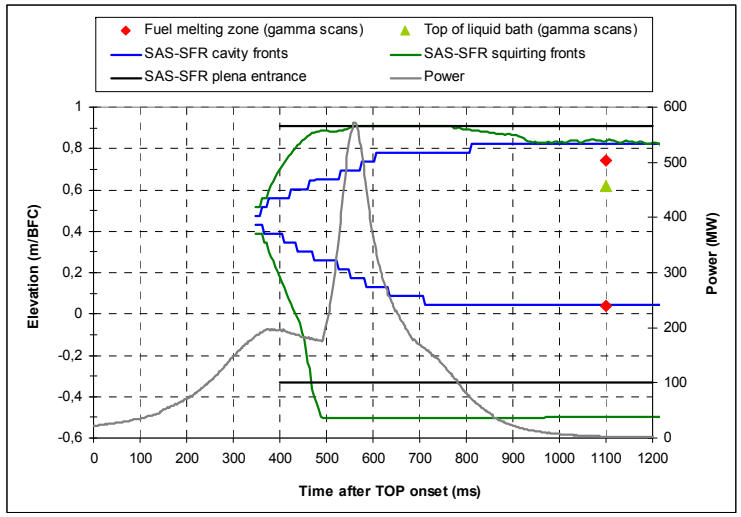
FCI:
SIMMER
and MC3D?

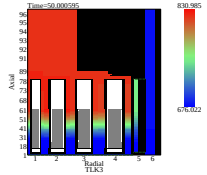


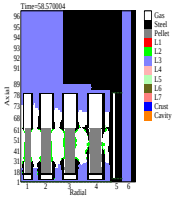
Core Catcher
SIMMER, TOLBIAC-SFR, CFD,
Structure mechanical codes, PARIS, TRIPOLI…

Contributions to V&V of SA CODE
(in the frame of an international cooperations)

SA4A/SAS-SFR - CABRI-FAST LT2







SIMMER – SCARABEE BE3+

+ EAGLE 1 & 2 programs

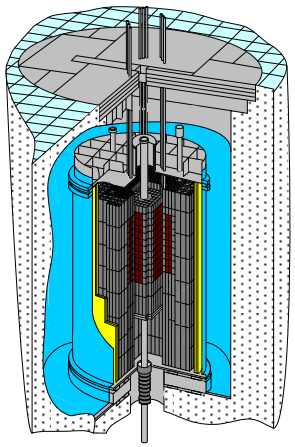
EXPERIMENTS IN SUPPORT TO V&V

Degradation of CFV fuel elements in Severe Accident Conditions

CFV characteristics:

- Heterogeneities in pins, and possible new clad material
- Ratio (space wirer diameter / pin diameter) → small hydraulic channel

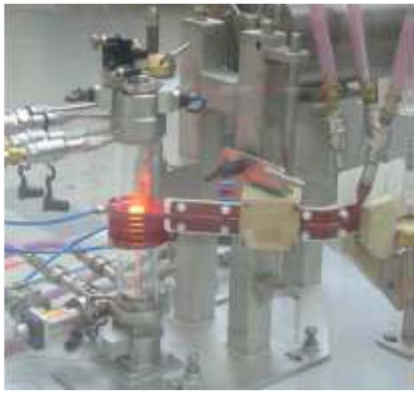
Реактор ИГР



Existing experimental database for homogenous pins : CABRI, TREAT, SCARABEE, EAGLE1&2

Need for additional experimental results — Installation

- Behavior in case of ITB
- Behavior in case of TOP (slow or fast gradient) — IGR ?



Fission Product releases from fuel elements in SA Conditions

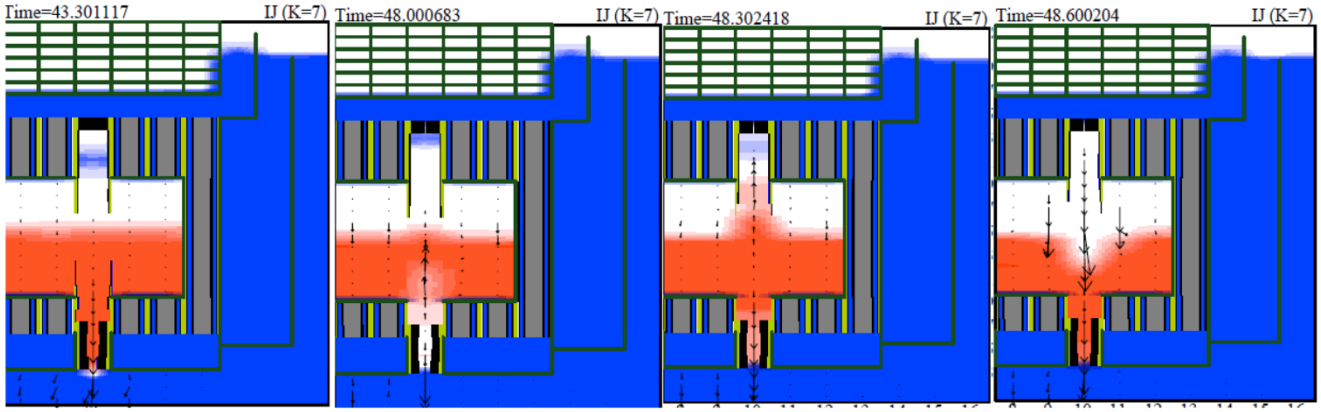
Existing experimental database: 2 Japanese tests with low BU

Need for additional experimental results — Installations

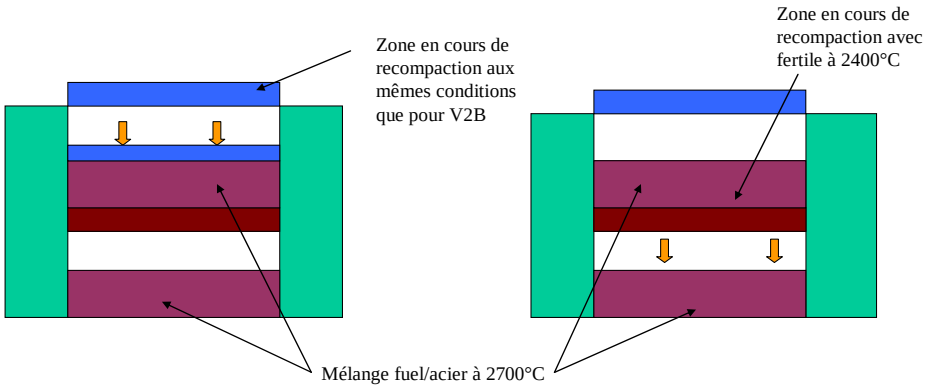
- Temperature, JOG, steel clad, oxygen potential effects — MERARG, VERDON?

EXAMPLES OF R&D ON MITIGATION DEVICES

SIMMER IV study of corium discharges through CRGT-type devices

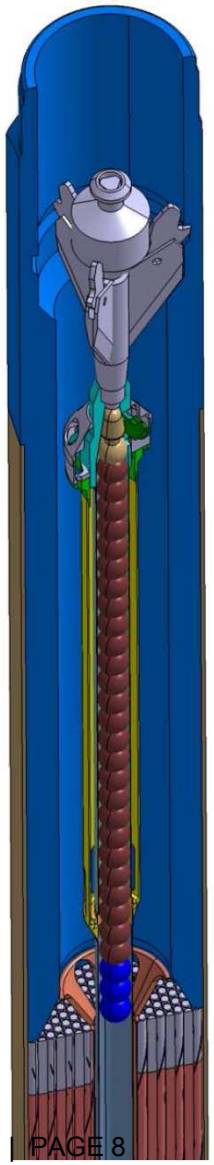


ERANOS study of the collapse of the Upper axial protection layer made of B_4C

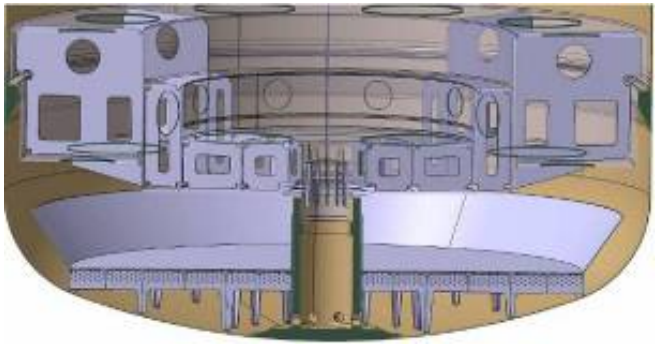


SEPIA: 3rd shutdown system to prevent SA
(patent)

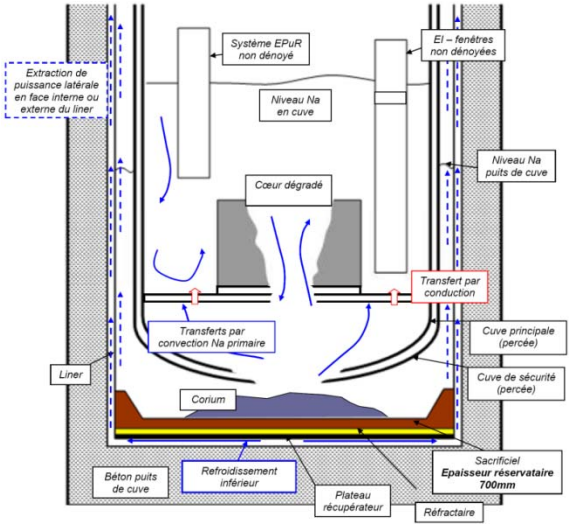
Assessment of the SEPIA capability to mitigate the core degradation



EXAMPLES OF R&D ON CORE CATCHER



Internal core-catcher

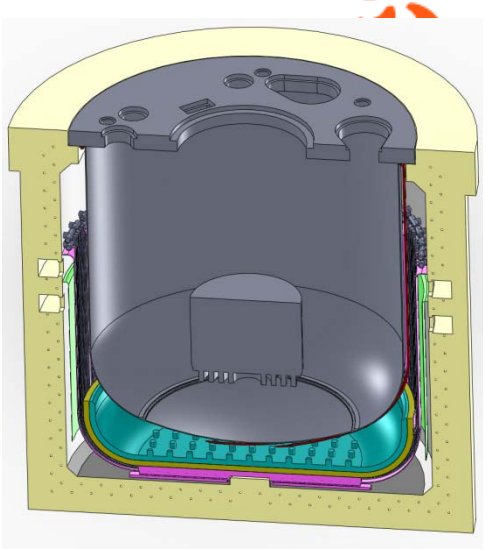


External core-catcher

R&D on
•Corium progression
•Materials behavior
3 open options

Strong cooperation
with AREVA in charge of the design

Link with PADHR design



Core-catcher
between 2 vessels

POST-ACCIDENTAL DECAY HEAT REMOVAL

PA-DHR systems considered on past reactors

Loop Na- Air in primary circuit

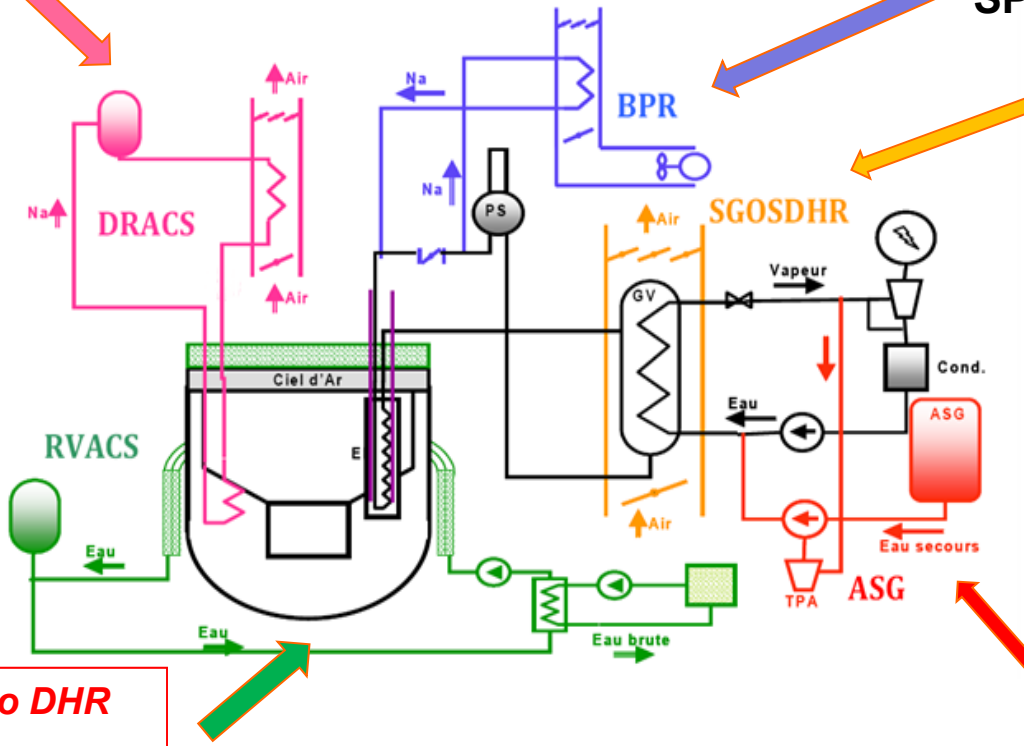
SPX **PASSIVE**

Loop **Na- Air** on secondary circuit

SPX **ACTIVE**

DHR system on **SG** (heat sink = air)

PHENIX **PASSIVE**



More importance to DHR by structures
→ R&D on emissivity
→ Management of fluids outside the primary vessel

Capabilities for DHR by structures (main vessel + guard)

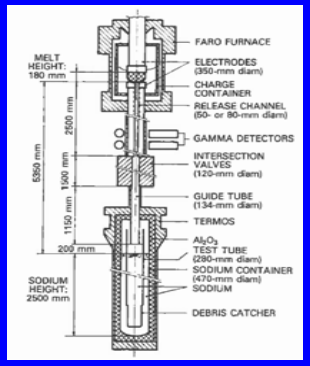
SPX (with water as heat sink) **ACTIVE**

ASG : emergency SG feeding system

(system with water) **PASSIVE**

EXAMPLES OF R&D ON CORE CATCHER

FOURNAISE



- **Corium-Sodium interaction**
  - Cooperation on SOFI (IGCAR) (to 10kg)
  - Design for a new facility Fournaise (to 300kg d'UO2)
    - Extension of database with saturated sodium
    - Extension of database for various corium discharge flowrates (up to 300kg)
    - Influence of steel quantity in the corium, of a liquid jet
    - Debris formation (size)
    - Transport of debris in a tube

CORRONA

- **Sacrificial material**
  - R&D to support the specifications
  - Thermodynamic calculations and experimentations
  - VITI (eutectic, miscibility), CORRONA (compatibility)
  - Interaction corium – sacrificial material
    - VULCANO, and later FOURNAISE
    - Impact of jets on core catcher, miscibility
  - COLIMA (Sacrificial Material effects on FP releases)
  - …
- **Cooling of debris bed and core catcher**

VITI

COLIMA

COOPERATIONS

EDF and AREVA

Part of the R&D is supported by several international co-operations

- European co-operations
  - EC programs as for example EERA, PCRDT (CP-ESFR, ADRIANA, GETMAT, FAIRFUELS, *SARGENIV*, ASAMPSA2, THINS, MATTER, etc.)
    + new proposal SOFIA
  - CEA SRC (Swedish Research Council) agreement
  - Rolls-Royce
  - KIT, HZDR, ITU, ENEA, PSI, …

- IAEA
  - by contribution of several CRP, as for example on some PHENIX End Of Life Test, passive systems,
  - and also INPRO

- GIF *(CD&BOP, Safety & Operation, GACID…)*

- Bilateral or Multi-lateral co-operations with JAEA, IGCAR, US DOE, Russia, NNC, CAEA, KAERI

The talk provides an overview of the R&D programmes related to Severe Accident in SFR, and in support to the prototype ASTRID.

A new topic of R&D is starting on the instrumentation development for post-accidental situations.

That R&D is done in relationship with other R&D topics (primary circuit and lay-out, design of prevention systems…), and takes into account the need for improving ISIR.

Thank you for your attention

nicolas.devictor@cea.fr

CADARACHE

Commissariat à l'énergie atomique et aux énergies alternatives
Centre de Cadarache | 13 108 Saitn-paul-lez-Durance
T. +33 (0)4 42 25 30 05

Etablissement public à caractère industriel et commercial | RCS Paris B 775 685 019

DEN
CAD
DER
DIR