

DE LA RECHERCHE À L'INDUSTRIE



# **Safety reassessment of OSIRIS after the accident in Fukushima Daiichi**



[www.cea.fr](http://www.cea.fr)

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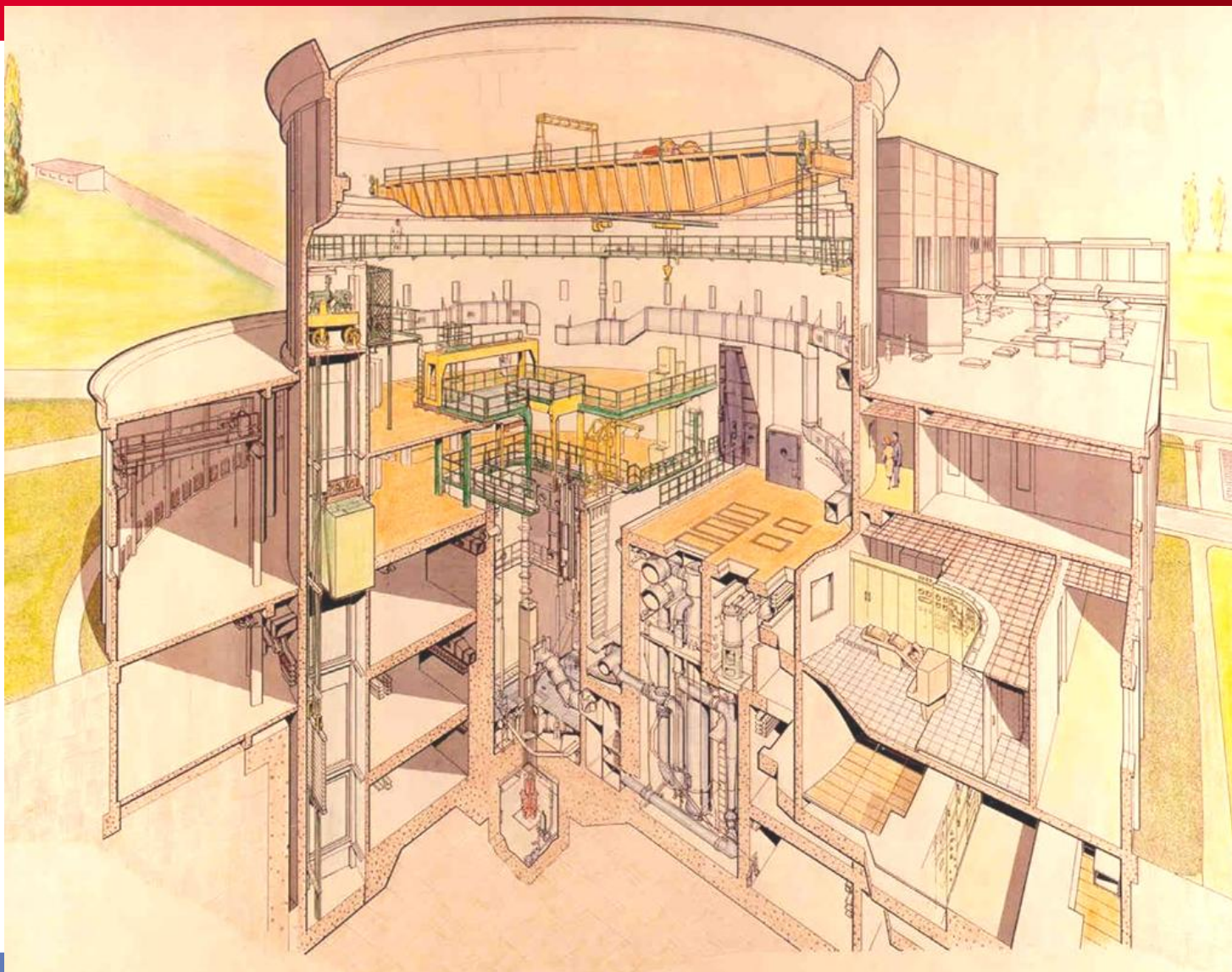
Nuclear Energy Division

Reactors & nuclear services Dpt

OSIRIS reactor operation unit



# OSIRIS material testing reactor





## Permanent groups of experts advice (November 16<sup>th</sup> 2011 letter)

*« Concerning OSIRIS reactor in Saclay, in case of cooling complete loss and electrical power complete loss, delays before the occurrence of core fusion are significant and largely compatible with routing of external rescue means »*

Fukushima March 11<sup>th</sup> 2011



OSIRIS design basis

Study of utilities loss

Study of earthquake and flooding hazards

Crisis management

Hardened safety core definition

Conclusions

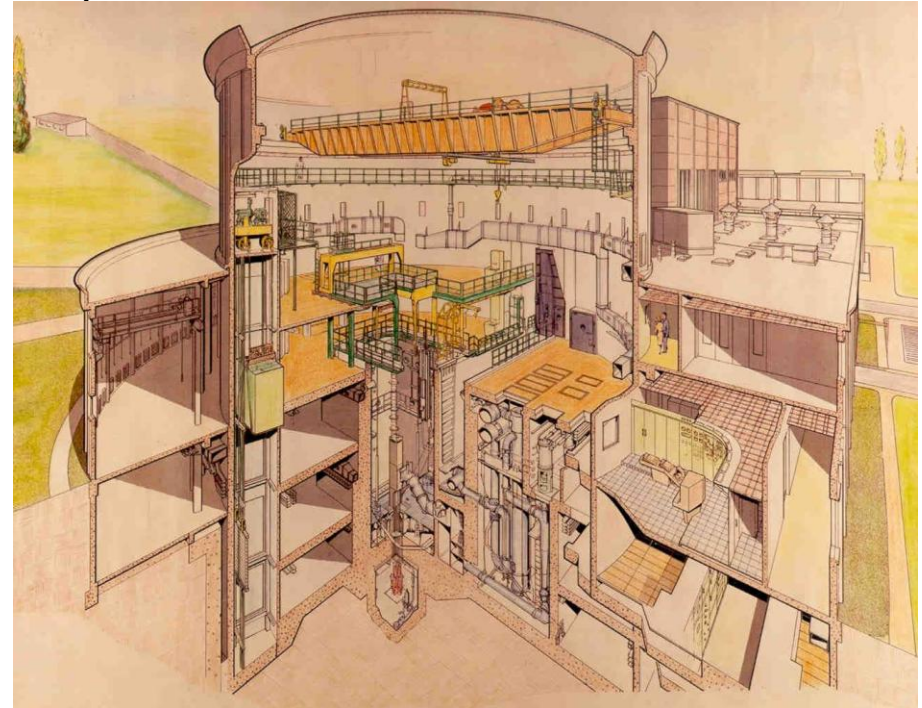
# Design Basis (1/2)

- ISIS and OSIRIS : open core pool type reactors linked by a water channel : about 1800 m<sup>3</sup> of water in pools and channels

- Osiris primary core circuit gets natural convection valves, which allow exchanges with the pool

- In current conditions, OSIRIS pool is connected to the channel

- Rooms housing parts of the core or pool refrigeration circuits are all in the « water-block »



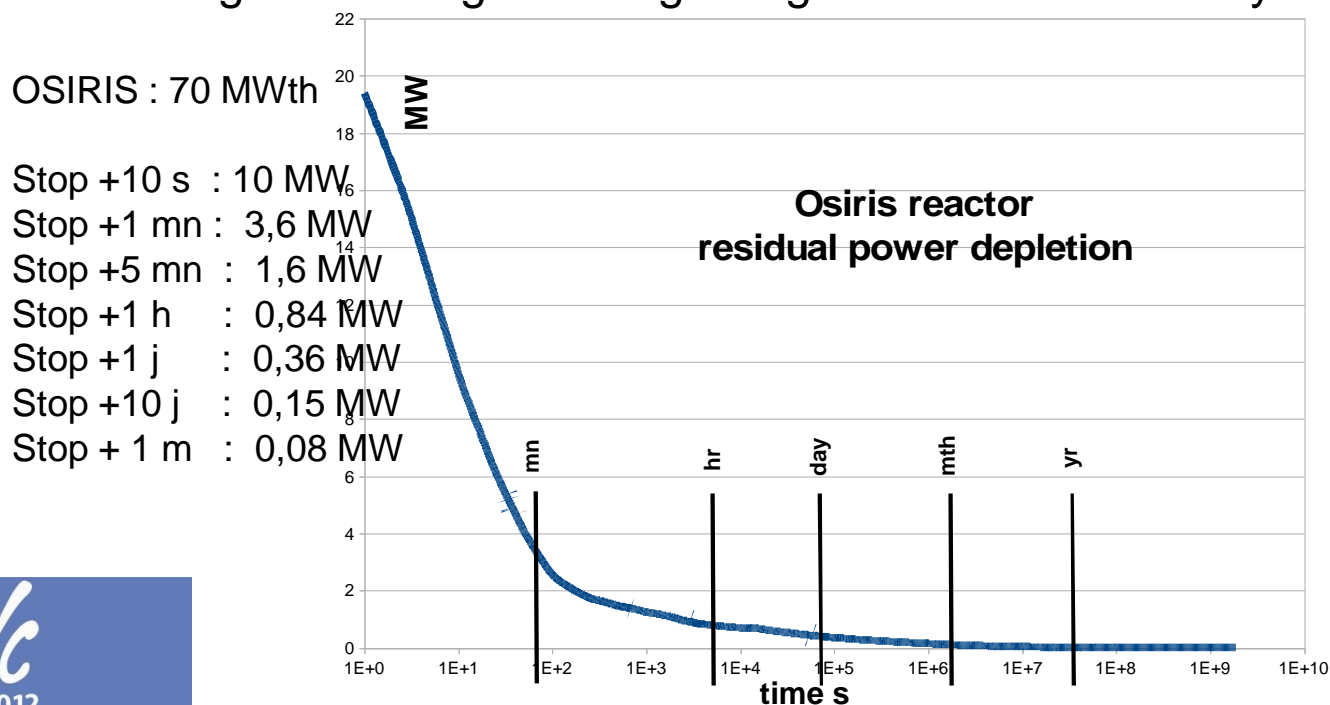
- Residual heat of ISIS is lower than the exchange ability from core tank to the pool
- ISIS core level is 1.2 m below the lowest floor

➡ No cliff edge effect risk for ISIS

## Design basis (2/2)

- After 6 months' cooling, each irradiated fuel element has a residual power inferior to 400 W, and can be withdrawn from the water without any fusion risk.
- Fuel elements can't be transferred to the n°1 channel before 40 days' cooling in the pool of OSIRIS.

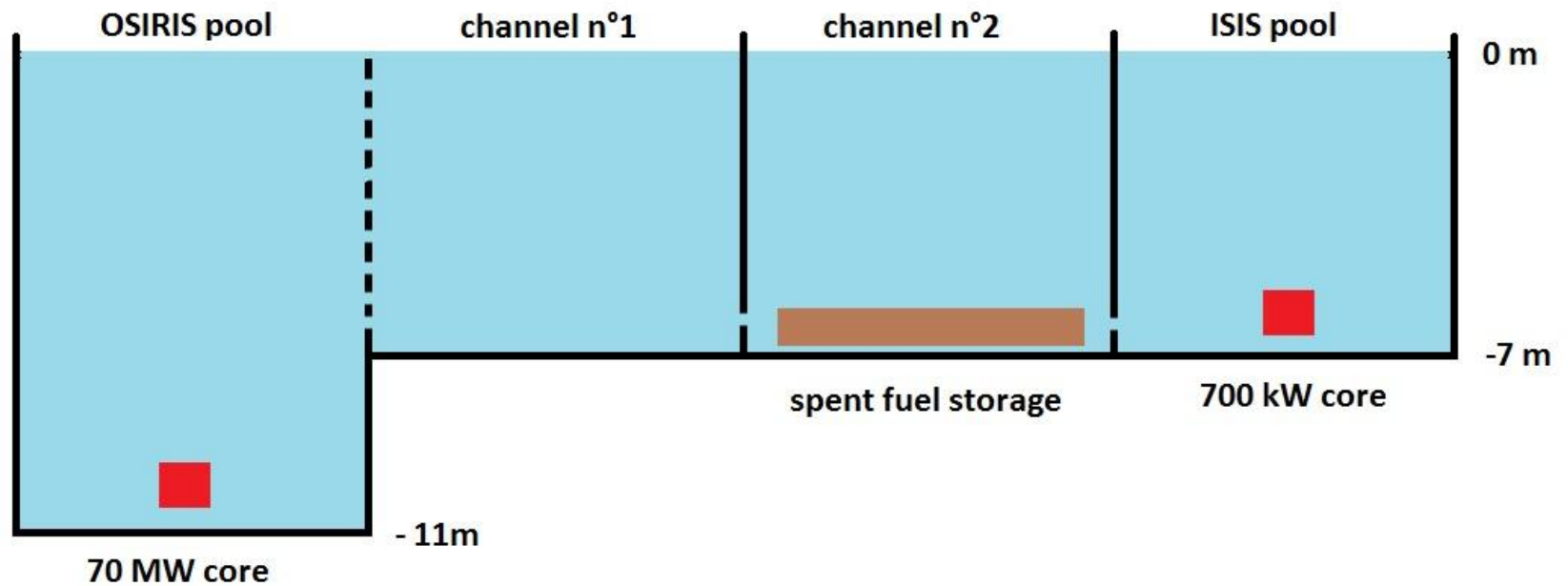
➡ No risk of cliff edge effect on the fuel if the delay between irradiation ending and emergence beginning is more than 180 days.



PWR : 4000 MWth

Stop +10 s : 195 MW<sub>6</sub>  
 Stop +1 mn : 144 MW<sub>14</sub>  
 Stop +5 mn : 105 MW<sub>8</sub>  
 Stop +1 h : 55 MW<sub>1</sub>  
 Stop +1 j : 22 MW<sub>1</sub>  
 Stop +15 j : 8 MW<sub>1</sub>  
 Stop + 1 m : 6 MW<sub>1</sub>

# Water capacities

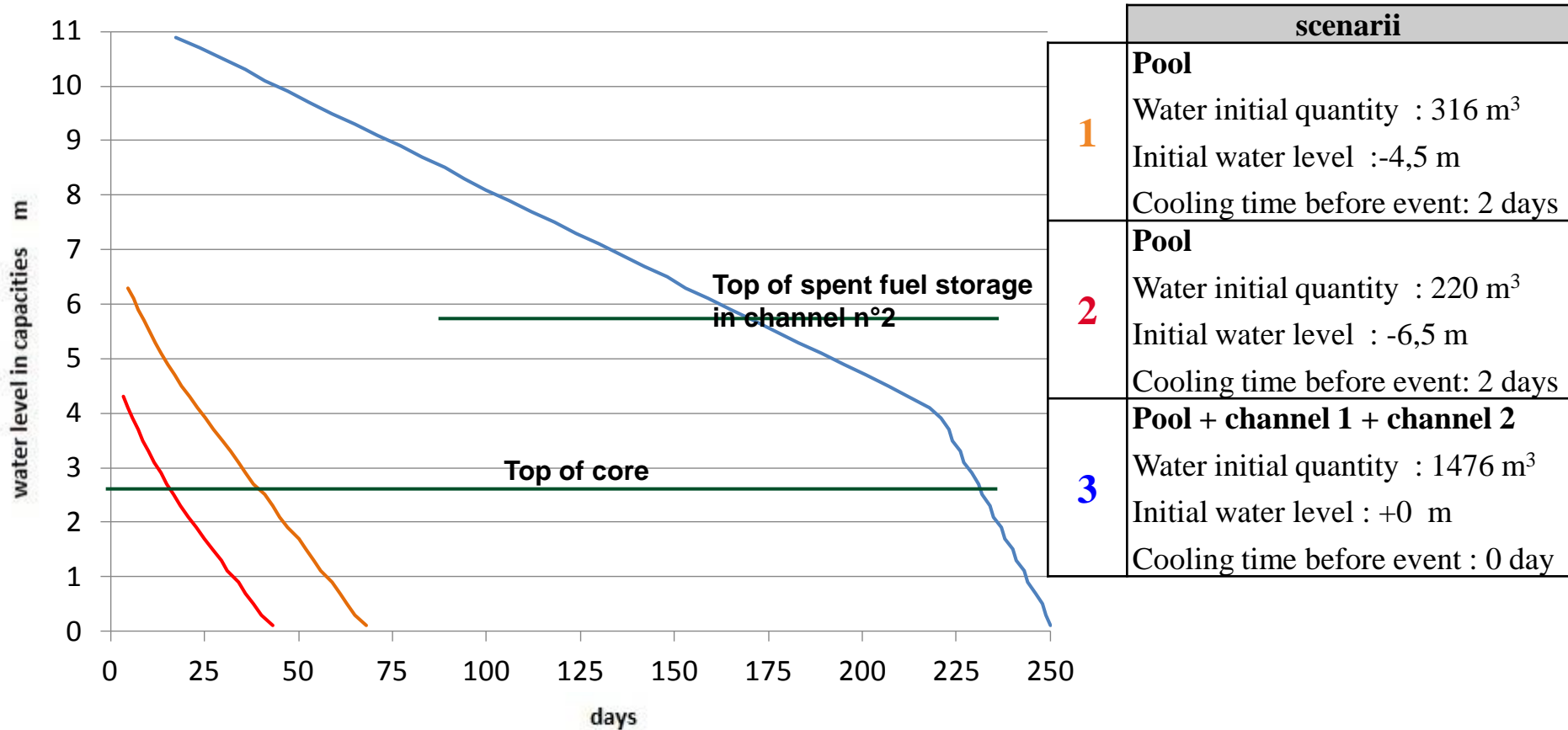




# OSIRIS cliff edge effect : core fuel emergence



Search of emergence delay for some scenarii



# Results in case of utilities loss

External and internal first rescue electrical sources loss :

If the pool is initially full

→ no cliff edge effect risk

If the pool is initially at its low level (-4 m)

→ Core fuel emergence within 43 days

Channel fuel storage emergence occurs after more than 6 months



Loss of cooling :

Internal or external available volumes of water  
give a delay before OSIRIS core and fuel storage  
Emergence largely greater than 6 months



Proposals : Secure electrical power supply to water pumps, to cranes (to be able to move coffer dams) and to one rescue ventilation fan

## Earthquake hazard considered in Saclay

Building respected classical building rules featuring the resistance to an about 0.05 g acceleration, corresponding to the intensity of a VI MSK earthquake : small cracks in plasters, fall of little debris of plaster in ordinary buildings

The maximum likely historical earthquake (MLHE) corresponds to a V MSK earthquake : badly shut doors bang open and close, floor vibrations seems similar to those of a heavy object fall

The Fundamental Safety rule 2001-01 specifies a response curve based on an horizontal ground acceleration of 0.1 g for infinite frequencies (fixed earthquake, including the MLHE). Such an earthquake can be related to the Pointe à Pitre earthquake on March 16<sup>th</sup> 1985 (6 lightly injured persons)

In 2004, a study of the seismic hazard based the safety increased earthquake (SIE) at 0,08.g, beyond the level of the fixed earthquake (FE)

# Earthquake : margins evaluation

consequences



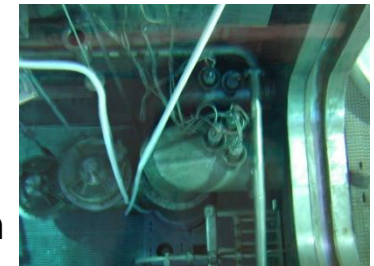
channel n°1 seal



Superstructures

Ventilation chimney

Secondary Circuit



Natural  
convection  
valve

Infrastructures

level

0,04.g 0,08.g 0,1.g 0,13.g 0,2.g  
MLHE SIE FE 2.FE

« Low level » in Osiris pool +  
mechanisms room leakage  
(earthquake > 2 FE → core  
fuel emergence within 19 days



- The Saclay environment doesn't include any river, dam or dike
- Ground water lies at a depth of 40 m
- Pluviometry on Saclay is about 680 mm/year
- The century rain leads to 40 mm of water during 1/2 hour, to be compared to the rain event of april 29<sup>th</sup> 2007 : 90 mm in 6 hours

OSIRIS is located in the highest part of the CEA Saclay site.

A century rain may induce an overflow of 221 m<sup>3</sup> coming from the southern storm drain. → A water sheet of less than 50 cm high could go in the ring-shaped void, whose capacity is 560 m<sup>3</sup> before water could go in the reactor hall.

**→ no cliff edge effect risk**

# Cumulated earthquake and flooding

Possible hazards are:

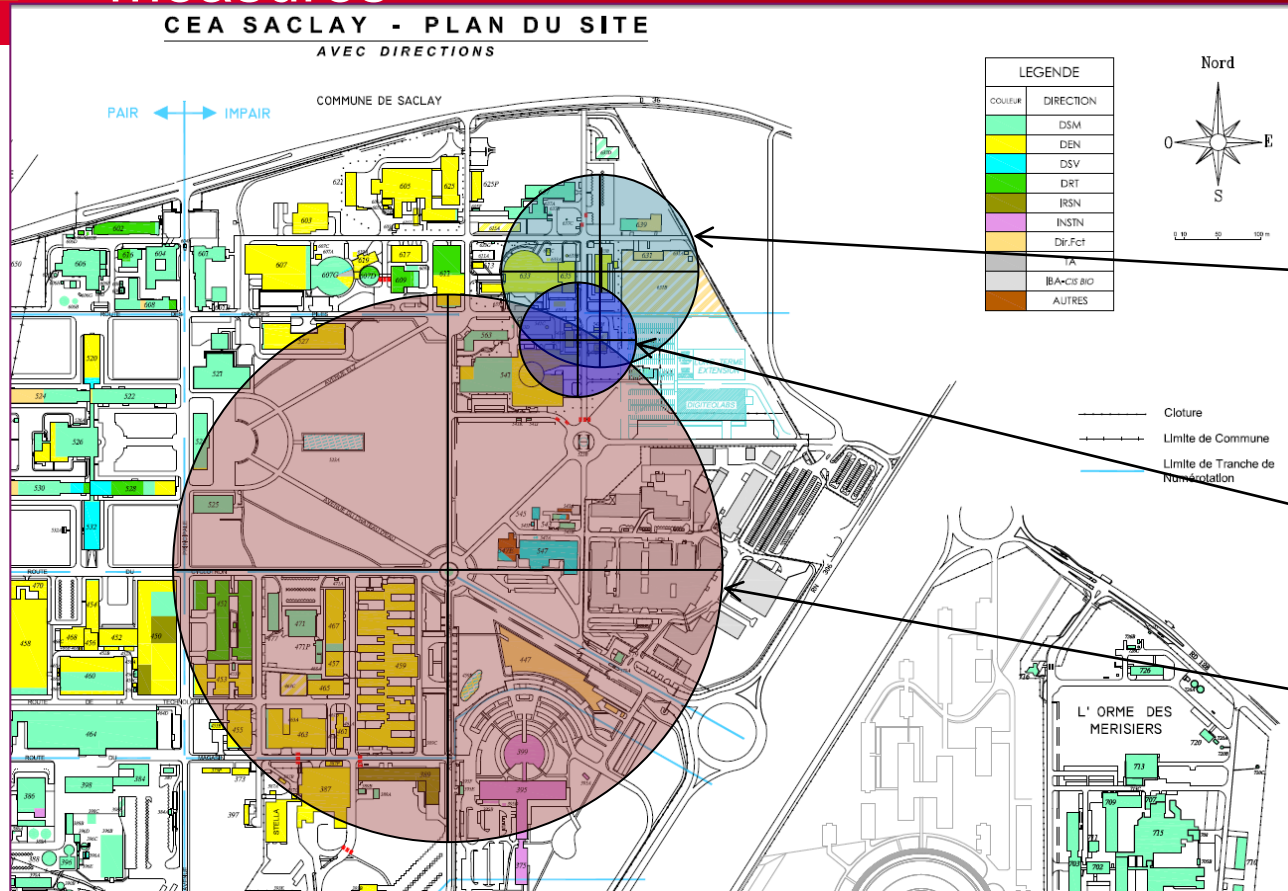
- The water tower's collapse ( $800 \text{ m}^3$ ) : water sheet level would be 1 cm high
- The simultaneous failure of refrigeration basins of OSIRIS ( $1000 \text{ m}^3$  over the ground) and of ORPHEE reactor ( $475 \text{ m}^3$ )
- A technical gallery links -4 m level to the refrigeration towers (secondary pipes course) : possible water entry therein
- Internal flooding due to a pipe failure :
  - Secondary pipe at -4 m level
  - Secondary pipe in the reactor hall
  - Drinkable or recycled water pipes at -4 m level



**Only if the initial water in the pool is at « low level » :**

➡ **core fuel emergence occurs within 19 days if earthquake > 2 FE and floodings volume >  $5000 \text{ m}^3$  (60 cm of water in floor -4 m)**

# Cumulated earthquake and flooding : conceivable measures



Flooded area from  
refrigeration towers  
basins of OSIRIS

Flooded area from  
refrigeration towers  
basins of ORPHEE

Flooded area from the  
water tower(1 cm)

Proposals : Get a secured electrical alimentation to a safety fan located at a 2 m height and to draining pumps in the ring-shaped void

Make technical galleries watertight



## Criticality

- No criticality risk for used fuel storage, even during water evaporation period.
- No criticality risk for fresh fuel storage, which keeps its geometry.

## Hydrogene risk

- Realistic calculations, taking into account the decreasing of residual heat, leads to an hydrogen equilibrium concentration equal to  $1/20^{\text{th}}$  the blowing out inferior limit, reached the following days after reactor scram. One month later, this concentration equals  $1/60^{\text{th}}$  the blowing out inferior limit.
- These calculation results are highly superior to the results given by an experimental approach (50 samples taken out from varied configurations of the ventilation), for calculations don't take into account the recombinations of the radiolysis different products.
- Pressure doesn't grow in the reactor hall.



Robustness of buildings and headquarters used during crisis management will be evaluated in the center evaluation file of june 2013

# Hardened safety core definition as post stress-test works

In June 30, 2012, CEA presented to French Nuclear Safety Authority ASN a **hardened safety core** of robust physical and organizational provisions for extreme situations studied in further safety assessments (ECS), in order to:

- a) prevent a serious accident or to limit the progression,
- b) limit the massive rejections,
- c) Permit to operator the tasks mandated in crisis management.

This hard core is made of Structures & Systems Components (SSC)

- Pool water level measurement,

- Pool water T° measurement,

- Availability and operability of the mobile pumps and flexible pipes  
(Supplement in water)

- Diagnosis Panel

- Lines of ultimate water supplement

- Valves of natural convection (core)

- Position information of natural convection valves

- Means of communication inside/outside

- Mobile detectors of radioprotection

- ❑ The robustness of underground structures of OSIRIS allow the reactor to resist to an earthquake superior to twice the fixed earthquake (FE), which contains high margins in comparison with the maximum likely historical earthquake.
- ❑ Superstructures stability is proved facing an earthquake up to 1.3 the FE level.
- ❑ Available volumes in OSIRIS allow facing an unlikely flooding.
- ❑ The risk of emergence of OSIRIS core within 19 days appears only with the occurrence of an earthquake bigger than twice the FE, accompanied or not by an extreme flooding, during a very rare initial condition of low level of water in the pool.

- ❑ Electrical power sources redundancy and water reserves allow dismissing any cliff edge effect except when the initial condition is the very rare initial condition of low level of water in the pool. In this case, complete loss of external and internal first level electrical sources may lead to OSIRIS core emergence within 43 days.
- ❑ Fuel elements stored in channel n°2 might emerge only after an earthquake bigger than twice the FE. Other hazards do not lead to the emergence of fuel elements within a delay leading to the fusion of the fuel.