Plant Life Extension Recent Developments in EDF's Nuclear Fleet

Noel CAMARCAT
Special Advisor for Nuclear R&D and International Issues, EDF Generation

EDF NUCLEAR POWER PLANTS FLEET

58 reactors in operation

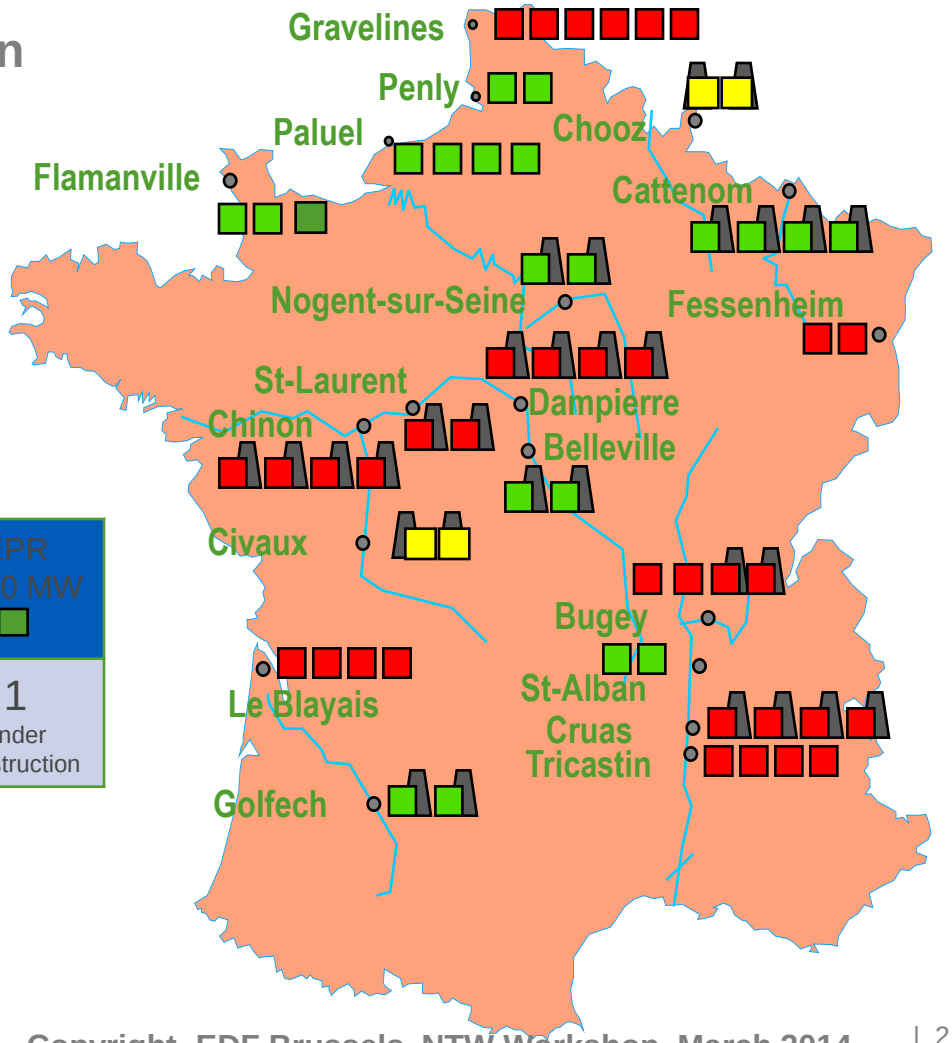
1 reactor (EPR) under construction

Technology : PWR

Spread out over 19 sites

- Nuclear generation = 80 % Total Electricity Generation

NPP	PWR 900 MW	PWR 1300 MW	PWR N4 1450 MW	EPR 1630 MW
Nb Unit	34	20	4	1 under construction



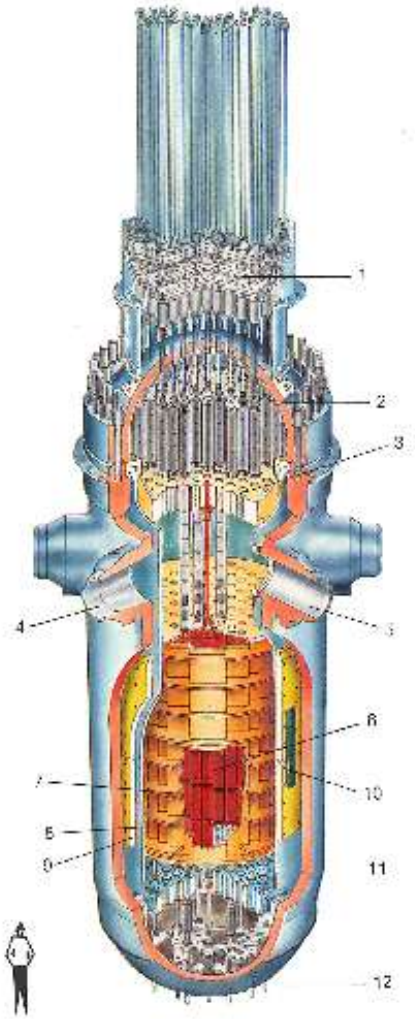
Status of the french NPP's

	1st 10 ys Visit 10 yrs	2nd 10 ys Visit 20 yrs	3rd 10 ys Visit 30 yrs	4th 10 ys Visit 40 yrs
900MW (34)	completed	completed	**2009 à 2020 (18 completed)**	**2019 à 2030**
1300MW (20)	completed	Completed end of 2014	**2015 à 2024**	**2025 à2034**
1500MW (4)	completed	**2019 à 2022**	**2029 à 2032**	**2039 à 2042**

- End of 2013, 5 Units (900 MW series) formally authorized for 10 years beyond 30 years with special requirements to be performed (exemple basemat thickening at Fessenheim)
- In the US, 73 units out of 100 reactors in operations have been granted **a license extension up to 60 years.**

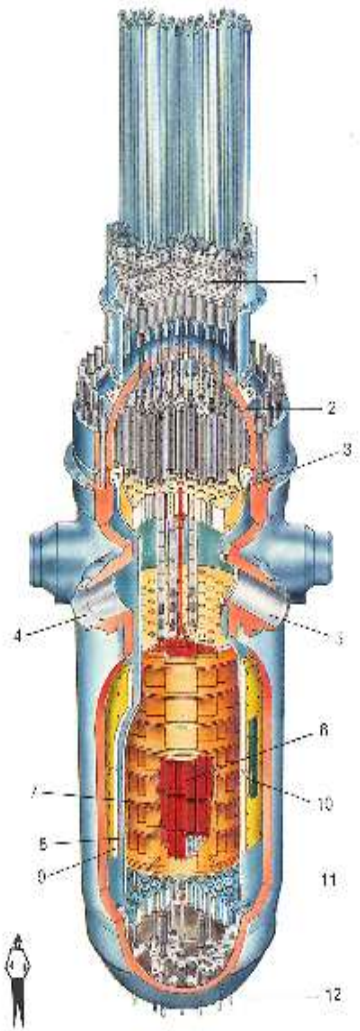
A NON-REPLACEABLE MECHANICAL COMPONENT : REACTOR VESSEL (1/1)

- **Status for lifetime up to 40 years**
  - **900 MW Units**. Vessel Safety Case accepted by the regulator (ASN) in june 2010 for all units with the provision of in service inspection and controls during the 3rd 10 years outage.
  - Satisfactory inspections and controls for the 18 first units including TRICASTIN 1 which is inspected every 5 years.
  - **1300 MW Units**. Safety Analysis file sent to regulator (ASN) in march 2013. Regulator's Position expected in 2015 for beyond 30 years.
- **Favorable features of French Reactor Vessels**
  - Steels chosen for their capability against irradiation induced embrittlement, extensive fabrication controls, in service inspection and controls every 10 years since the beginning.
  - Low "transition temperatures" for 900 MW units at 40 years : 60 to 90°C with respect to US Units at same age (130°C)



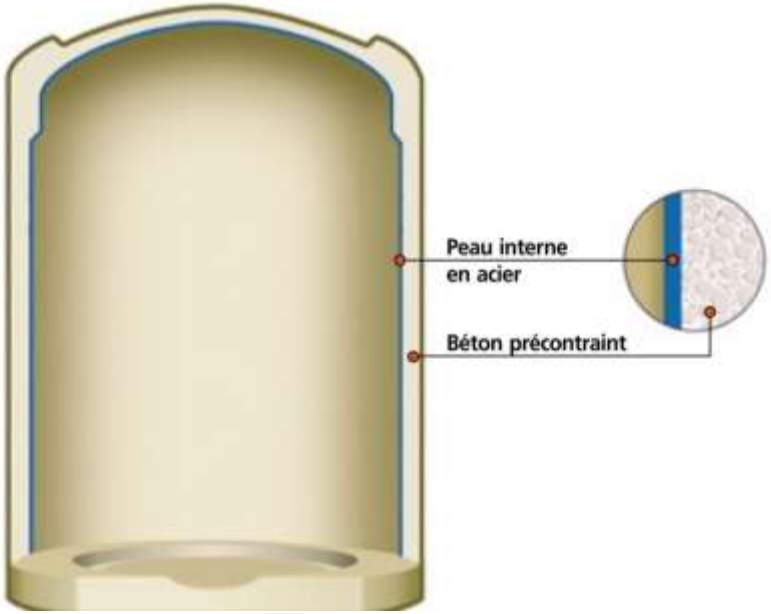
A NON-REPLACEABLE MECHANICAL COMPONENT : REACTOR VESSEL (2/2)

- **The two major ageing mechanisms :**
  - Irradiation embrittlement of the core shells
  - Thermal ageing of the nozzles
- **EDF Prognosis : Expected End Of Life 60 years**
  - Good quality of design and manufacturing
  - Detailed ten year controls, from the beginning
  - Good experience feedback.
  - Regulator's first generic position beyond 40 years expected for 900 MW Units in 2015
- **Long term operation strategy**
  - EOL prognosis based on a deterministic conservative approach
  - State-of-the-art methodologies (mechanics & thermal-hydraulics)
  - Mitigation and surveillance actions
    - Low leak core management
    - Irradiation surveillance program on-site (capsules)
  - Optional : if necessary beyond 40 years , increase of safety injection temperature

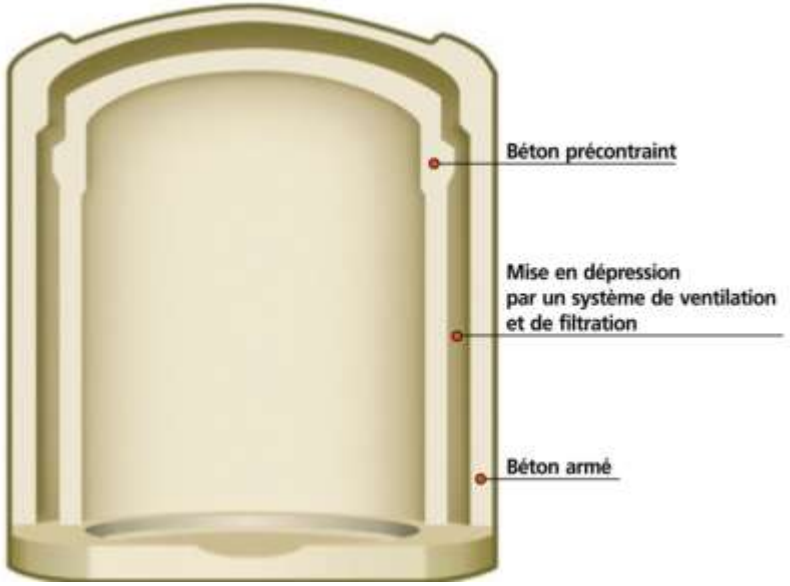


A NON – REPLACEABLE CIVIL WORK COMPONENT : CONTAINMENT

900 MWe series
Simple wall + liner



1300 MWe and N4 series
Double wall



- Ageing phenomena studies
- Periodic pressure test (every 10 years) at design pressure
- Technological solution under developpement

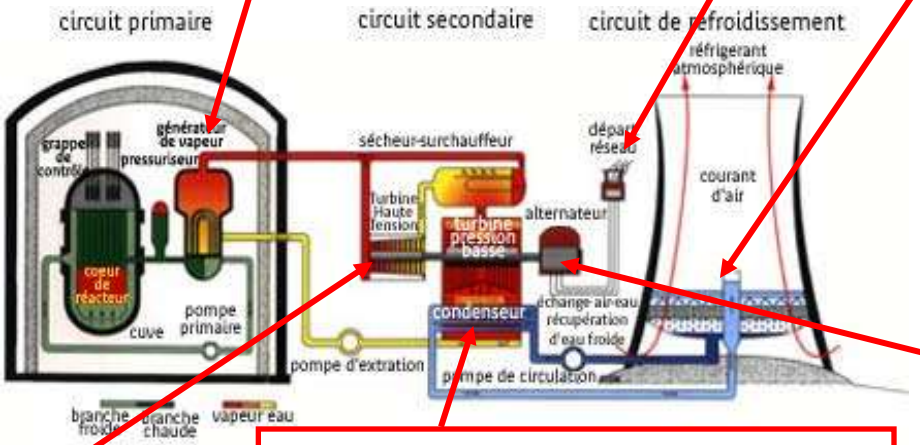
REPLACEABLE COMPONENTS

SG Replacement

Replacement of Unit Transformers and Metal-clad Substations

I&C Modernization

Replacement of Cooling Tower Packing



Main Generator
1. Rotor Renovation
2. Stator Replacement

Renovation of Main Turbine LP Cylinders

Condenser : Renovation of
1. Tube Bundles of some units
2. Cleaning System

The French 2006 law (TSN) and the regulatory context

General policy : continuous improvement of nuclear safety, with regard to the state-of-the art of scientific knowledge, to the worldwide operation feedback, and to the safety improvements of new reactors

Periodic safety review (PSR) every ten years for each unit

No limited licensing life time but advice by the French Nuclear Safety Authority, on a case by case analysis for each unit, to operate for another ten year period. Generic approval for 900 MW units given in 2009 for operation beyond 30 years.

Numerous modifications already implemented on the plants (after TMI, Tchernobyl, Blayais site storm in 1999, summer heat wave in 2003, ...). Among them : sand filters on containment (1986), Hydrogen recombiners , new concept of emergency procedures, man-machine interface (N4 series), etc...

EDF safety goals for long term operation

As far as reasonably practicable

For design basis accidents, mitigitating its consequences and avoiding radioactive releases that would require off site emergency measures (iodine ingestion, evacuation)

Continuing to reduce the risk of core melt, already divided by ten since the commissioning of the plants in case of internal events

Significantly enhancing plant resistance to hazards

Minimizing time and space-related countermeasures in the event of a severe accident, making use of the important modifications required by the regulator (ASN) as part of the post Fukushima EDF action plan

Taking into account Fukushima's event

Following the Complementary Safety Assessments performed by EDF, the French Safety Authority (ASN) issued the following statement (January 2012) :

- **"the ASN considers that the plants show a level of safety sufficient that enables her not to ask the immediate shutdown of any of them.**
- **At the same time, the ASN considers that it is necessary to increase, in a time as short as possible, beyond the safety margins already in place, the robustness of the plants to cope with extreme situations."**

A three step post-Fukushima EDF action plan submitted inside the French action plan to the European Peer Review Exercice of 2012

STEP 1: 2012-2015

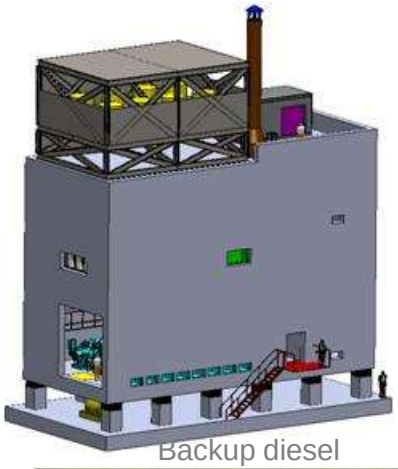
- **Coping with situations of water and electricity losses more severe than today (several units of a site, long duration)**

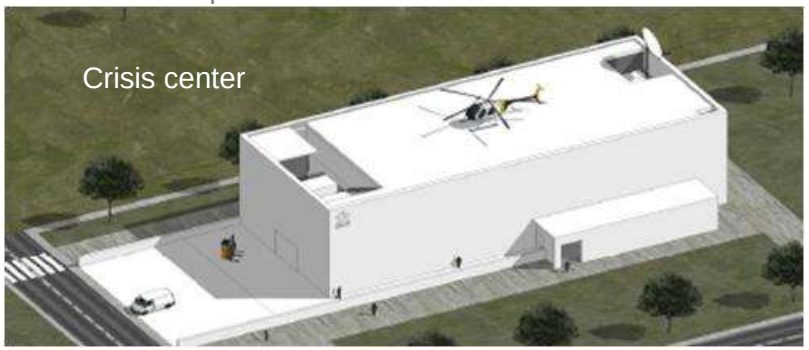
- **By the use of crisis means and provisory modifications**
  - Mobile devices (pumps, pipes, generators…)
  - Provisory modifications (diesels generator on the roof of the electrical buildings, nozzles …)
  - Upgrade of the crisis organisation
  - Automatic reactor shutdown in case of earthquake
  - Earthquake and Flood protection reinforcement (SMS and CMM)

STEP 2 : 2015 – 2019

- **Coping with situations of water and electricity losses more severe than today by design changes, anticipated vs. initially planned for life time extension programme**
  - Construction of the DUS (ultimate back-up diesel generator)
  - Implementation of ultimate water supply
  - Protection against extreme flooding
  - Construction of new Local Crisis Centres (CCL)*
  - Filtration system reinforcement against earthquakes
  - Passive tight seals for primary main cooling pumps (if qualified)
  - Reinforcement of shift teams on the NPPs (ability to manage a Fukushima situation by their own)

*first : in 2016 (Flamanville). For the following : planning under study (end after 2019)


Backup diesel



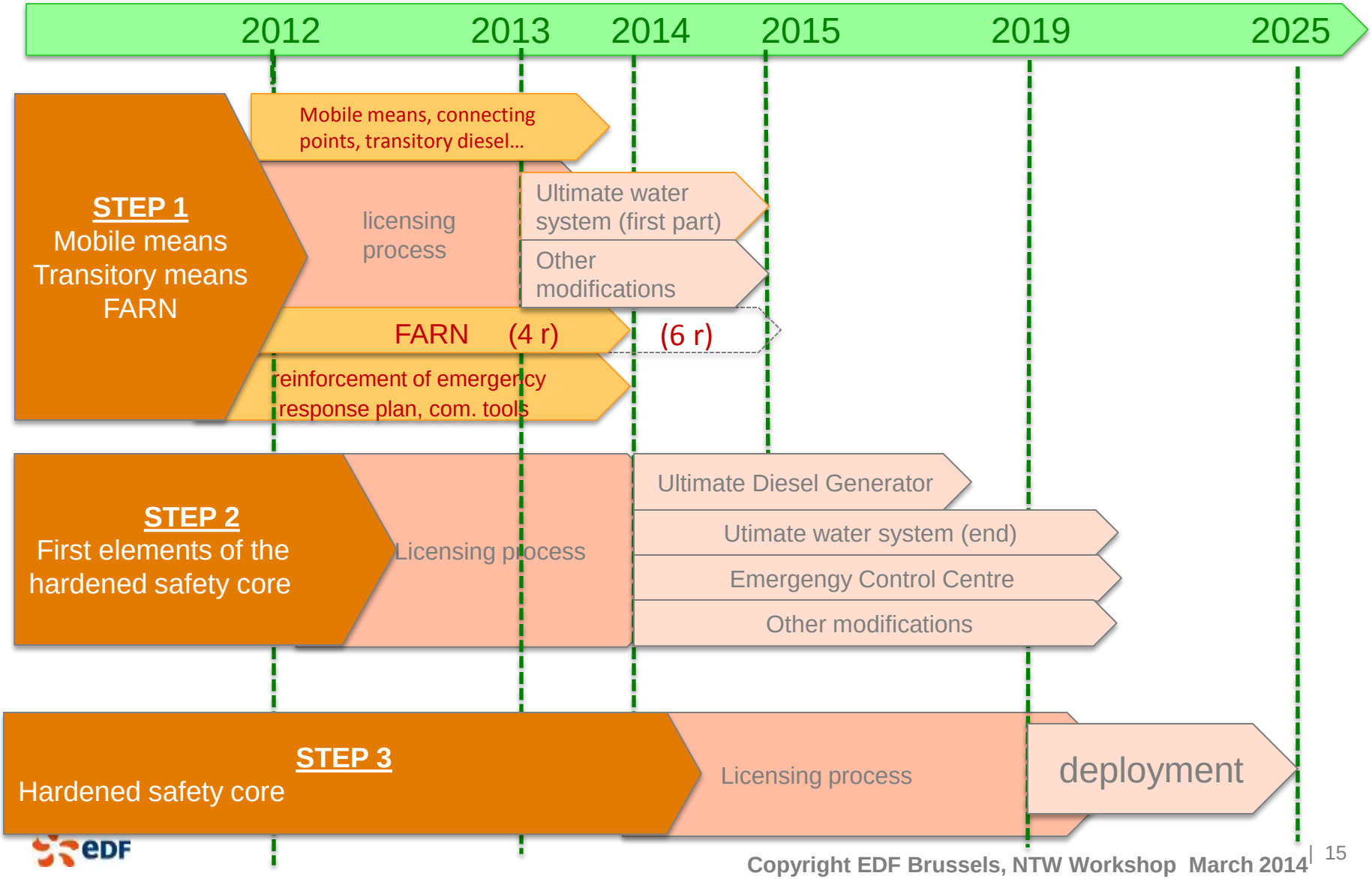
STEP 3 : FROM 2019 (AS PART OF THE FLEET LIFE EXTENSION)

Completion of the hardened safety core

- Implementation of the step 3 from 2019 onwards :
  - SG residual heat removal (dedicated feed water pump, dedicated SG tank, ultimate water supply)
  - Ultimate primary injection pump
  - Containment residual heat removal
  - Extreme earthquake and flood requirements
- The implementation of the three steps of the post-Fukushima action plan makes it possible to reach on the existing fleet in operation a **safety level as close as reasonably practicable to the safety level of Generation 3 reactors**. This is a requirement of the French Safety Regulator (ASN) to extend the operating life of the plants beyond 40 years.
- **Ongoing discussion with ASN since 2008; letter of june 2013, important work programme between now and 2019 : 4th 10 years outage of Tricastin 1 Unit**

THANK YOU

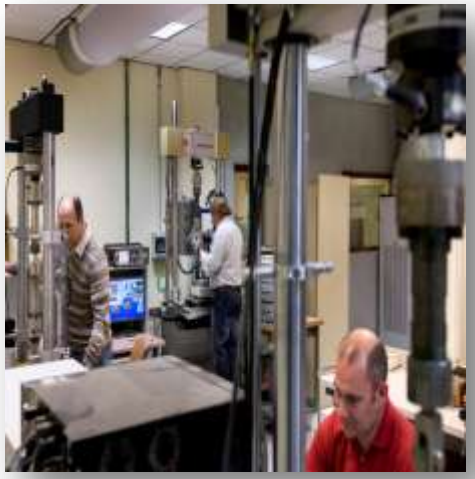
3 STEPS TO IMPLEMENT MODIFICATIONS



The Materials Ageing Institute for R&D relative to plant life extension

- **Need for Predictive Capability for**
  - **- Inspections**
  - **- Mitigations**
  - **- Replacement**
- **Through Mechanistic understanding of ageing processes**

Materials Ageing Institute



- **80 Researchers and technicians involved**
- **20 universities / institutes associated**
- **11 M€ annual budget in 2013**
- **11 Members representing 66% NPPs**
- **35 M€ total EDF's Investment (2008-2016)**
- **250 participants yearly in the E&T program**