Slide 1 (titre)

Good morning. My name is Etienne Dutheil

As manager of EDF's *Grand Carénage* fleet upgrade programme, I want to tell you about EDF's approach to the challenges associated with Long-Term Operation.

Grand Carénage and the LTO programme are closely interlinked: *Grand Carénage* is an industrial programme that seeks to extend the service life of EDF's nuclear fleet with continuously enhanced safety standards, whilst seeking alignment with the "energy transition" decreed by the French public authorities.

Slide 2 (the French nuclear fleet)

I will begin with an overview of EDF's French nuclear fleet. The fleet comprises 58 operating reactors and one reactor nearing the end of construction. I am of course referring to the Flamanville EPR.

The EDF nuclear fleet is highly standardised as it is entirely composed of second-generation PWR, split into only three design models.

The fleet is relatively young as the average reactor age is approximately 30 years. The units were commissioned over the period of 1978 to 1998, a relatively short time span.

Slide 3 (ten-yearly outage)

French nuclear regulations do not set time limits for the service life of nuclear power plants.

However, the French regulator authorizes operation for only ten years at a time, after which period a plant must undergo a ten-yearly outage. Ten-yearly outages are therefore a key milestone in the life cycle of our nuclear power plants.

The double purpose of this outage is to verify plant compliance with applicable standards, and to implement nuclear safety improvements. In order to achieve these goals, a ten-yearly outage comprises two main types of activity: a complete inspection of the plant and a periodic safety review.

Slide 4 (Complete plant inspection)

The complete inspection comprises a very large number of tests including a hydrostatic testing of the primary circuit. This test is performed in the presence of the regulatory authority's inspectors, who approve the results. The complete requalification process also comprises numerous non-destructive tests. This photo shows an in-service inspection machine inside the reactor vessel at Saint Laurent B1 during its third ten-yearly outage in 2014. This machine is a robot that performs non-destructive tests on the reactor vessel's metal parts and welds.

The scope of a complete inspection also includes a containment leak-rate test where containment pressure is taken up to 3 bars in order to verify containment leak-tightness.

Retour slide 3 (Ten-yearly outage)

The second purpose of a ten-yearly outage is an in-depth periodic safety review that starts around ten years before the actual ten-yearly outage.

With these periodic safety reviews, we want to ensure that the plant is capable of operating safely for another decade until the next ten-yearly outage, as well as to raise its level of safety by implementing modifications to improve the design.

All activities included in the periodic safety review are proposed by EDF and must be approved by the French nuclear regulator. Once the regulator has approved the content of a periodic safety review for a given reactor series, the activities are carried out on each reactor.

The periodic safety review itself includes two aspects which are a compliance review and a safety review.

The purpose of compliance review is to check that the reactor completely fulfils the requirements that are applicable at the time of the ten-yearly outage, and that it will uphold this capacity over the next 10 years.

To do this, EDF uses routine test results, supplemented with additional checks carried out during the compliance review, especially on parts of the plant not covered by systematic maintenance programmes.

For plants more than 30 years old, compliance review is supplemented by the ageing management process. This process set up by EDF is linked to the AIEA baseline.

It is based on research and development actions whose purpose is to identify the ageing mechanisms likely to affect the equipment. The goal is to check that these mechanisms are properly factored into the maintenance programs. If this is not the case, the programs shall be adapted, or the equipment shall be modified or replaced.

Slide 5 Ageing management

Two components are especially sensitive according to this approach: the reactor vessel and the containment dome, since they cannot be replaced. EDF has initiated extensive R & D actions in this field, which are illustrated there with photos of the “Vercors” mock-up, installed

on an EDF R&D site in the Paris area. This is a 1/3 scale model of a containment vessel , which undergoes an accelerated ageing programme for us to be able to understand the future behaviour of nuclear power plant containments and deduce the appropriate measures to guarantee sustained performance.

Concerning reactor vessels, during the fourth ten-yearly outages on the 900 MWe units EDF is planning to introduce Hafnium control rods so as to reduce neutron flux to the reactor vessels, which slows the ageing process.

For the plants that are going to pass the 40-year mark, the ageing management process also includes qualification upkeep. Some pieces of equipment that are required in the event case of an accident are qualified to guarantee operability in specific conditions. Such equipments were qualified for 40 years at the time of plant construction. There is no actual physical limit, but a design hypothesis for lifetime had to be selected for initial qualification.

In order to exceed this length of time, new testing is needed to ensure the equipment is qualified for another 10 or 20 years. If qualification is not possible, the equipment should be replaced; sometimes new equipment needs to be qualified. In certain cases, replacement is directly chosen, for example, in case of foreseen equipment obsolescence.

For the fourth ten-yearly outage at the 900 MWe units, a sample of 600 items of equipment is currently undergoing qualification testing. At the same time, without waiting for the test results, the list of equipment that needs to be replaced has been complied to securize the strategy.

Return to slide 3 (ten-yearly outage)

The purpose of the periodic safety review is to improve plant safety level, by updating risk assessment, by integrating fleet and international OE, changes in knowledge and in rules applicable to the facility.

This review results in compiling of the modification programme to be applied as | from the ten-yearly outage.

Slide 6 (the safety aims corresponding to the 4th periodic safety review of the 900 MWe reactors)

The 900 MWe NPPs in the EDF fleet are the first to hit the 40-year mark in France. The safety review conducted on these reactors therefore has highly specific aims, all the more so as it is being conducted after the Fukushima accident and in parallel with the start-up of the first French third generation reactor, the Flamanville EPR.

The Nuclear Safety Authority has therefore set a highly ambitious target for this safety review of the 900 MWe reactors, with safety goals similar to those for the third generation reactors.

In order to achieve these goals, 4 guidelines have been defined :

1. Minimise the radiological consequences of design basis accidents to avoid sheltering of the local population.
2. Prevent long-term contamination of the territories in the case of accident with core meltdown.
3. Enhanced consideration of external hazards (earthquakes, flooding, heat waves, tornadoes, etc.).
4. Enhance safety of the spent fuel storage buildings.

The stipulations of the French regulator and these 4 guidelines are completely consistent with the European Council Directive 2014/87 /Euratom.

This fourth safety review covers the safety improvement actions that have been taken since the start of the 900 MWe units, with 3 ten-yearly outages during which safety reviews have already been conducted, and the recent implementation of modifications stemming from Fukushima feedback. The starting point of the 4th safety review is not that of the reactors as they were when they were commissioned 40 years ago, but plants on which extensive modifications have been implemented to improve safety.

Slide 7 (the main modifications implemented on the 900 MWe units during the 4th ten-yearly outages)

In order to achieve these highly ambitious goals, an extremely high volume of activity is required. For example, the cost of the modifications implemented for the 3rd periodic safety review of the EDF 900 MWe reactors was 30M€ per reactor, while for the 4th periodic safety review it will be 225 M€ per reactor.

The main modifications include:

1. Addition of a long-term reactor cooling system preventing opening filtered containment venting system in the event of accident with core meltdown. This system is part of the “hard core plant”, defined after the Fukushima accident in application of the requirements laid down by the French regulator. The photo shows the pump prototype for this system which is currently undergoing testing at a factory in France.
2. Installation of the hard core steam generator feed water system, designed to prevent severe accident.

3. Installation of the hard core spent fuel pool cooling system.
4. Reinforcement of basemat in case of the reactor vessel piercing after core meltdown
5. Renovation of the I & C system; which serves the double purpose of supporting the addition of new systems and facilitating ageing management.

Slide 8 (major renovation industrial programme)

To coordinate all these activities, EDF senior management has set up the major renovation programme "Grand Carénage". This programme includes 3 categories of activity totaling 22 projects:

1. One-off maintenance operations, mainly replacement and renovation of large components, such as the steam generators and transformers
2. Modifications, and especially those stemming from periodic safety reviews.
3. Sustaining qualification. These activities must be planned far in advance of the actual ten-yearly outages. They have already begun for the 4th periodic safety review of the 1300 MWe reactors, whereas those reactors' 3rd ten-yearly outages have just been started and the 4th ten-yearly outages will only be started in 2026.

Part of these activities already existed before setting up of the major renovation programme. However, the current period tends to be busier than in the past, due to higher volumes of one-off maintenance, implementation of the activities stemming from Fukushima feedback or the fact that the current ten-yearly outages are denser than previous ones because of more extensive goals set

by the Nuclear Safety Authority. All this leads to a 25% increase in the volume of activity compared to the normal investment scheme.

Slide 9 (main ongoing activities for the major renovation programme)

In concrete terms, the main ongoing activities for the major renovation programme are as follows:

- The third ten yearly outages for the 900 MWe reactors are being finished off. There are only 4 left out of an original 34.
- The third ten-yearly outages for the 1300 MWe reactors have been started and 2 out of 20 have been completed. Another two will be finished by the end of this year. The main work here is extensive renovation of the I & C system.
- The modifications stemming from Fukushima feedback are currently implemented. This activity is very extensive with ongoing construction of 54 emergency diesel generators of 3 MWe at the same time and construction of additional feed water backup systems. This emergency diesel and feed water backup system are part of the "hard core plant" designed after the Fukushima accident.
- Preparation is under way for the 4th ten-yearly outages for the 900 MWe reactors, with the first one scheduled for 2019, as well as for the second ten-yearly outage for the 1450 MWe reactors, with the first one of those also set for 2019.

These examples show that the major renovation portfolio is made up of projects that are at different stages of the life cycle: certain projects are being finished off while others are being designed. This characteristic means that the major renovation programme can be

adapted according to policy guidelines set for France's future energy mix - that is, the amount of nuclear generation - since investment decisions are taken independently for every project, and even for every reactor.

Slide 10 (Schedule and budget – conclusion)

The *Grand Carénage* programme resulted from a decision taken by the EDF Chairman in 2015. It comprises two constituent parts: a technical component that I have just described, and a managerial component that seeks to change the way the licensee, the engineering staff and industry contractors interact. The idea is to foster collaborative initiatives between all *Grand Carénage* stakeholders focusing on LTO objectives, generation and safety targets, and on the financial control of projects.

In concrete terms, we are encouraging these stakeholders to work as a team from a much earlier stage. The modifications planned for the fourth set of 10-yearly outages on the 900-MWe reactor fleet have been designed for implementation in accordance with a standardised outage schedule jointly prepared by the engineering staff and the licensee. Their design takes into account challenges encountered in implementation during the outages, whereas in the past, the schedule had to be adjusted to accommodate the modifications. Industrial partners also get involved at a much earlier stage. Their teams are already working on the detailed design phase for the 4th ten-yearly outage at Tricastin NPP, the first scheduled on the 900-MWe reactor fleet, in 2019.

This collaborative effort is essential if all stations are to successfully complete all this work.

In conclusion, I would like to draw your attention to the following 3 points:

1. Preparatory work for LTO-related items is undertaken by EDF far in advance of other work. The company has a schedule and budget for this process.
2. The fourth periodic safety review of the 900-MWe reactor fleet seeks to align the safety objectives as closely as possible with those of generation-3 reactors.
3. These activities are incorporated into an industrial programme, *Grand Carénage*, which seeks to ensure that they are properly implemented on the stations.

Thank you for your attention.